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TELEVISION TUNERS

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VIDEO I-F AMPLIFIERS AND DEMODULATORS

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VIDEO AMPLIFIERS

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TELEVISION TUNERS

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STUDY SCHEDULE

> For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

TV TUNERS

The first group of lessons of this television series introduced you to the idea of producing a monochrome picture by means of a television system. You have been introduced to the basic circuits and have made a study of the television picture tube. The second group of lessons pointed out a method of producing color pictures by television, using a system that is compatible with the existing black-and-white system. You have been introduced to the basic color TV circuits and you have studied color picture tubes. This lesson begins a detailed study of the circuits of a TV receiver. First we will cover those sections and stages of a TV receiver that are found both in black-and-white and in color receivers and then we will study stages found only in color receivers. You will be studying a complete television system--a color system. Monochrome TV can be considered as a simplified system in which no provisions are made to handle color signals. We will begin our detailed study of TV receivers with the section called the "input tuner" or simply the "tuner."

Basically, this section corresponds to the pre-selector-converter section of the sound receiver. However, instead of being an integral part of the receiver, the tuner is usually made on a separate sub-chassis, which is aligned, and then the completed unit is mounted on the main chassis. As a matter of fact, few television manufacturers build their own tuners-- most of them buy the tuner already assembled from one of the companies specializing in tuner manufacture.

You may wonder why the tuner is built on a separate chassis and treated by the receiver manufacturer as though it were a separate part of the TV receiver. Let us consider what the tuner must do and look at some of the problems that must be overcome, and you will see why the tuner is indeed a "special" part of the television receiver.

Functions.

The tuner, like the preselector-converter in a sound

receiver, must initially select the desired signals, and, by the heterodyne process, produce from it the desired i-f signals. You already know that the television channel is 6 mc wide. An ideal tuner would amplify all signals in the television channel equally, and reject all signals falling outside the channel. Of course, it is impossible to design a tuner that will do this; therefore, tuner design is somewhat of a compromise between bandpass and gain characteristics.

The preselector must pass the full 6-mc band occupied by each television channel. A 6-mc bandwidth can easily be obtained at the frequencies used by the TV stations. The tuners used in early TV receivers did not have too much gain and they had rather poor selectivity. Thus, they were often subject to various types of interference. However, through the years, tuner design has improved so that the modern TV tuner has considerable gain and is usually able to reject most interference falling outside the TV channel.

The TV Channels.

The present television channels are listed in Fig. 1. Channels 2 through 6 are the low-band VHF channels. Channels 7 through 13 are the high-band VHF channels. Channels 14 through 83 are the UHF channels. Each of these channels is 6 mc wide and contains one complete video signal and the accompanying sound signal.

The VHF channels were assigned first, and originally there were thirteen of them. Channel No. 1 was 44 to 50 mc; this is now assigned to other services, but since many receivers had already been manufactured with the channel selectors marked for Channel 1, it was simply dropped and the numbers on the other channels were not changed.

Most of the television receivers manufactured before 1964 were designed to receive the twelve VHF channels only. While there were a few all-channel sets made, most often the UHF channels could be received only by the use of an external UHF converter. How-

CH.	FREQ. (MC)	CH.	FREQ. (MC)	CH.	FREQ. (MC)
	VHF	28	554-560	56	722-728
—	——	29	560-566	57	728-734
2	54-60	30	566-572	58	734-740
3	60-66	31	572-578	59	740-746
4	66-72	32	578-584	60	746-752
5	76-82	33	584-590	61	752-758
6	82-88	34	590-596	62	758-764
7	174-180	35	596-602	63	764-770
8	180-186	36	602-608	64	770-776
9	186-192	37	608-614	65	776-782
10	192-198	38	614-620	66	782-788
11	198-204	39	620-626	67	788-794
12	204-210	40	626-632	68	794-800
13	210-216	41	632-638	69	800-806
		42	638-644	70	806-812
	UHF	43	644-650	71	812-818
—	——	44	650-656	72	818-824
14	470-476	45	656-662	73	824-830
15	476-482	46	662-668	74	830-836
16	482-488	47	668-674	75	836-842
17	488-494	48	674-680	76	842-848
18	494-500	49	680-686	77	848-854
19	500-506	50	686-692	78	854-860
20	506-512	51	692-698	79	860-866
21	512-518	52	698-704	80	866-872
22	518-524	53	704-710	81	872-878
23	524-530	54	710-716	82	878-884
24	530-536	55	716-722	83	884-890
25	536-542				
26	542-548				
27	548-554				

Fig. 1. Table of channel numbers and corresponding frequencies.

ever, manufacturers were forced by law to build all-channel receivers after a cut-off date in 1964. Sets made since that time cover both VHF and UHF channels.

In the early all-channel receivers and in the VHF receivers with external converters, UHF reception was obtained by a UHF tuner converting the UHF signal to a VHF signal. The VHF signal was then converted by the separate VHF tuner to an i-f signal and then processed by the receiver the same as a signal from a VHF station. In modern all-channel receivers, two separate tuners, a UHF tuner and a VHF tuner, are still used. However, in the UHF position, the VHF tuner is tuned to the i-f frequency and the oscillator in the VHF tuner is made inoperative. The UHF signal is then converted directly to an i-f signal and then fed to the VHF tuner which simply amplifies it without changing its frequency. We'll go into both these arrangements in detail in this lesson.

INTERFERENCE PROBLEMS

Interference is far more annoying in the picture of a television receiver than in the sound of a radio, because the eye is far more critical than the ear. Consequently, television receivers are designed to eliminate interference as much as possible. Let's see what can be expected of the input tuner in this respect.

Man-Made Interference.

Interference resulting from the operation of elec-

trical apparatus can best be eliminated at the source. About all that can be expected of a tuner in eliminating such noise is that it should be able to reject noise whose frequency is more than 6 mc on either side of the channel frequency. Fortunately, interference in the form of noise is not nearly as prevalent in the VHF range as it is in the frequency range used for the Standard Broadcast band and it is practically non-existent in the UHF range.

FM Interference.

Both the low-band VHF channels and the high-band VHF channels are subject to interference from nearby stations in the FM broadcast band (88 to 108 mc). The low-band VHF channels, particularly Channels 5 and 6, are so close to the FM broadcast band that a strong nearby FM station operating near the low end of the band may be able to get right through the tuner and cause considerable interference. This type of interference can often be eliminated or greatly reduced by means of a trap tuned to the frequency of the offending station.

The second harmonics of the FM broadcast band range from 176 to 216 mc and can cause interference in the high VHF band. Interference of this type, however, is usually confined to locations close to the FM transmitter. There is no way this type of interference can be eliminated at the receiver.

Adjacent-Channel Interference.

Most tuners pass not only the entire 6-mc channel to which they are tuned, but also a good portion of the channels immediately below and immediately above it. The sound and video carrier frequencies for Channels 2, 3, and 4 are shown in Fig. 2. If the set is tuned to Channel 3, the bandwidth may be such that the Channel 2 sound signal, which is at the high end of the channel, and the Channel 4 picture signal, which is at the low end of the channel, may get through the tuner. This is called adjacent-channel interference. The interference from Channel 2 will be adjacent-channel sound interference, and the interference from Channel 4 will be adjacent-channel picture interference. Notice that you get sound interference from the channel below and picture interference from the channel above. Traps are inserted in the video i-f amplifier to prevent adjacent-channel sound and/or adjacent-channel picture interference. You will seldom
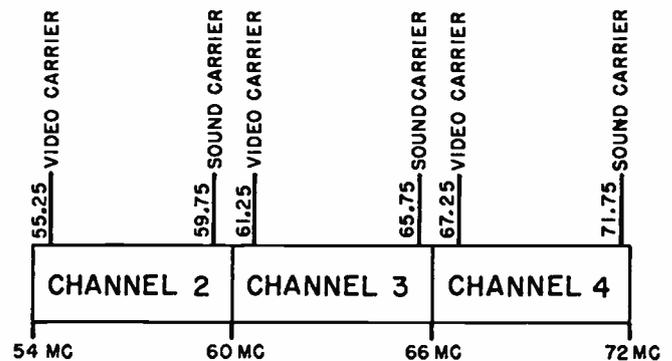
Fig. 2. The sound and video carrier frequencies of channels 2, 3, and 4.

BULLETIN

What's New In Color TV?

Color Television has been around for over a decade. During this time it has had its ups and downs. Slow public acceptance resulted from many factors. Too few color shows led the list. Customers were reluctant to pay the higher price for the color set just to watch a few color shows. Along with the higher initial price they could expect to pay more for repair service.

At the same time the black and white pictures on the color receiver were not quite as good as on a monochrome set. A larger offering of color programs waited for a bigger color audience. Advertisers were reluctant to pay for higher priced color shows, particularly when so few viewers had color sets. This unhappy deadlock lasted for a long time. But over a period of years a sizable number of color receivers were put into the homes of the viewing public.

Lack of consumer interest in color TV made it difficult for set manufacturers to successfully market a line of color receivers. After color TV was first authorized, nearly all of the major TV manufacturers produced color receivers. All except RCA eventually dropped their color line. At various times in the mid 50's, several of the manufacturers made bids for the color market. Each time they failed. They could not corner enough of the small market to justify a full-scale production line. From 1959 to 1963 many major manufacturers entered the color market using sets licensed by RCA. In most cases these sets used the RCA chassis, parts, and circuitry. A notable exception was the successful 21-inch Zenith. Later Motorola brought out a new chassis design for the rectangular 23-inch CRT.

Since 1963 many receivers have used basic RCA circuitry with the manufacturer's own variation. Each manufacturer performs independent development to give his receiver special sales features. This will eventually lead to completely new designs.

The volume of color set sales has now reached a point that assures the continued growth of color. It is estimated that one set in seven of all the sets sold in 1964 was color. This adds up to an impressive total. This important factor has led to increased color programming by the networks. Most metropolitan areas now have enough color programs to definitely justify the consumer purchase of a color receiver.

The growth of color sales in 1964 was sparked by a mid-year drop in prices. This was the first noticeable price cut in five years. It appears the price cut was initiated by the manufacturers in the hope of increased volume. It also seems unlikely that there will be any large price reduction in the near future. However, with the new rectangular tube and more models to choose from, a greater price spread is developing between the bottom-of-the-line and the top-of-the-line models.

Customer satisfaction with color sets has been a factor in promoting sales. People who have had a color set for 4, 5, or even 7 years report reliable performance. When asked, they usually report that the service calls have not been any more frequent than for a black and white receiver. As expected, the individual repair bill runs higher than on black and white. Color set owners usually demand better quality pictures than they would for a black and white receiver. Perhaps they become more critical of picture quality from watching color. Then too, some defects, such as snow, ghosts, etc., are much more noticeable when viewing a color program. When answering a color service call, the service technician should be prepared to bring the set up to top-notch operating condition.

WHERE ARE THE CHANGES?

When you examine the color TV receivers that have been produced over the past several years, the changes have been small. The basic principle of color reception has not changed at all. Even so, the improvement in the quality of the color picture is remarkable. The entire color TV industry is characterized by improved technology. Improvement in color cameras, studio and broadcast equipment is producing better off-the-air color signals. Likewise in the color receivers, while no major changes are apparent, small improvements throughout result in a greatly improved picture.

The most noticeable change in new receiver designs is the introduction of the rectangular 90° deflection picture tube. This tube enables the designer to produce a slimmer cabinet. The rectangular screen is capable of showing the entire transmitted picture. From experience with the black and white receivers, the customer seems to prefer the rectangular face plate. Even so, the bulk of the color receivers produced in 1965 will probably still have the round 70° deflection tube which is practically a standard in the industry. The rectangular picture tubes are limited to the high price top-of-the-line models.

The new high efficiency phosphors produced by Sylvania offer a color picture tube with greatly improved brightness, saturation, and purity. The new red phosphor, made from the rare-earth element europium, replaces the red sulphide phosphor. Also

the phosphors are deposited by a new dusting process instead of the present slurry process. The results are a picture tube with a 43% increase in light output. These tubes are currently appearing in some sets, but again, they are limited to the higher priced models.

The above-mentioned new developments add to consumer enjoyment of color TV, but they have little bearing on servicing the receiver. The subtle changes in the circuitry are more apt to give the service technician trouble if he hasn't encountered them before. Let's examine the circuit changes that are taking place in the various sections of the color receivers. In many cases we will cover circuitry that is not new at all. This is done when we feel that a sure understanding of the circuitry is necessary in order to appreciate the circuit changes.

Tuners

The tuners used in Color TV receivers have undergone only small changes over the years. All color receivers use high quality tuners with wide bandpass response curves to assure the reception of the color signal. Usually you will find a tube-type VHF tuner and a two or three transistor UHF tuner. In most cases the circuits of the VHF tuner are switched in the channel 1 position (UHF) to provide additional i-f gain of the signal from the UHF tuner. Most of the changes that have taken place parallel changes in the tuners of black and white receivers. For example, the nuvistor is used as an rf amplifier in some tuners for both color and monochrome receivers. Some manufacturers use the same tuner for color and monochrome receivers.

A new fine tuning circuit appears in the tuner of the Setchell-Carlson Color Receiver chassis Model U800. The feature is called MICRO-TUNING and uses a varicap diode for fine tuning. The schematic in Fig. 1 shows a portion of the tuner, including the micro-tuning circuit. The triode section of the 6CG8A forms a conventional local oscillator circuit. The variable capacitance diode, 1N87A, is effectively across the oscillator tank circuit. The rf oscillations that appear at the plate of the oscillator are coupled through C3 to the diode. The rf is rectified by the diode, causing electrons to flow through the diode circuit in the direction indicated by the arrow. Electrons flow through the 1K resistor and the active portion of the 10K potentiometer, producing a negative voltage that back-biases the diode. The amount of negative voltage varies with the setting of the 10K ohm micro-tuning potentiometer. A change in voltage across the diode changes the capacitance of the diode which effectively changes the frequency of the local oscillator. In this way the micro-tuning potentiometer provides a smooth, small increment change to tune the receiver for best black-and-white or color reception.

This tuner has a mechanical fine tuning ring located behind the channel selector. Removing the channel selector knob exposes a knurled fine tuning ring. When the ring is pushed in, it engages the oscillator slug on the selected channel. With the micro-tuning potentiometer set in mid-position, the knurled fine tuning ring is rotated for best picture. The micro-tuning control is then used for making small tuning changes around the pre-set position. Each active station is set up in the same manner when a receiver is first installed. These pre-set adjustments normally will not have to be repeated unless the oscillator tube is replaced.


FIG. 1. A variable capacitance diode provides Micro-Tuning on the Setchell-Carlson U800 chassis.

Luminance Circuits

Almost all color receivers use a three stage i-f amplifier. While some receivers are featuring new tube types in the i-f amplifier, the circuit changes are slight. The biggest differences and changes appear after the video detector stage.

The video amplifiers in color receivers fall into main classes: those with two stages of video and those with three stages of video. The extra stages are not for gain but depend on how the circuit is matched to the delay line and the need for correct polarity of the luminance signal at the cathode of the picture tube. Let's examine the circuits for each of these classes and illustrate the new circuit changes.

Fig. 2 shows the two-stage video amplifier used in the Zenith 25MC30 chassis. While this circuit is not entirely new, it illustrates the use of a cathode follower to match the input impedance of the delay line. The video i-f signal is detected by the picture detector and filtered by C1-L1. The 4.5 mc trap removes the intercarrier sound signal. At this point a 7pf capacitor (not shown) couples the signal to the color amplifiers. The luminance video signal is peaked by L4 and coupled through C3 to the grid of the cathode follower, the triode section of the 6KT8.

FIG. 2. Simplified schematic of 2-stage luminance amplifier in Zenith 25MC30 chassis.

The low impedance of the cathode follower provides an impedance match for the delay line, which has an impedance of about 1200 ohms. The delayed video signal is then coupled through C4 to the grid of the Y amplifier stage, 12GN7. The inverted amplified video signal at the plate is coupled through the usual peaking networks directly to the cathode of the red gun. Blue and green gain controls, P5 and P6, couple adjustable amounts of video to the cathodes of the blue and green guns.

Several features of the circuit in Fig. 2 are worth noting. The contrast control, P4, in the cathode of the 12GN7 has its slider returned to ground through a large electrolytic capacitor, C10. Changing the contrast setting does not affect the bias of the stage. In effect, C10 bypasses that part of the cathode resistor between the slider and ground. The unbypassed signal appearing on P4 above the slider acts as degenerative feedback and reduces the gain of the stage.

The dc level of the detected video signal is maintained from the video detector to the cathodes of the picture tube. Notice that at the junction of L1 and L3, resistor R1 connects to the junction of R6 and C5 in the grid circuit of the 12GN7 amplifier. Any change in the dc level of the detected video signal is coupled through R1, filtered by C5, and thereby shifts the bias level of the Y amplifier. The brightness control is also in the grid circuit of the video amplifier. Its action is to set the bias level of V2 which in turn raises or lowers the dc level of the picture tube cathodes and sets the tube brightness level.

The Peak Pix control, P1, located in the cathode circuit of V1A, affects the sharpness or crispness of the luminance signal. This is a customer control that is set for personal viewing preference. It is useful for changing the texture of "snow" in fringe areas or for sharpening the signal in viewing inferior program materials such as old movies. The control acts by varying the shunting effect of C2. With the Peak Pix control fully counterclockwise (pot arm ground), C2 shunts the high frequency components of the video signal and causes slight smearing. With the control fully clockwise, the effect of C2 is minimized and slight ringing or overshoot is apparent in the picture.

Another two-stage video amplifier for handling the luminous signal is shown in Fig. 3. Variations of this circuit are used in several Motorola color chassis. The first video amplifier, 6AW8, does double duty. An amplified signal in the plate circuit provides video for the agc, sync, and color stages of the receiver. A video signal in the cathode circuit provides the video input to the delay line. At first glance, V1 may look like a cathode follower. Actually it is an amplifier with part of the load in the plate circuit (R1) and part of the load (R4) in the cathode circuit.

Notice that the video signal from the detector is applied to the tube between the control grid and the junction of R3 and R4. Resistor R3 develops the grid-to-cathode bias and it is bypassed by C2. Since R4 is not in the grid to cathode circuit, the video signal developed across it is not degenerative and some gain is realized. Capacitor C3 couples the signal changes from the top of R4 to the screen grid. This prevents degeneration that would result if the voltage between the screen grid and cathode changed with signal swing. (Degeneration would occur if the screen were bypassed to ground.) R5 provides a small amount of degeneration to stabilize the stage.

The brightness circuit in Fig. 3 is arranged to maintain direct coupling of the video signal to the grid of the second video amplifier, V2. The brightness potentiometer is in a voltage divider network between

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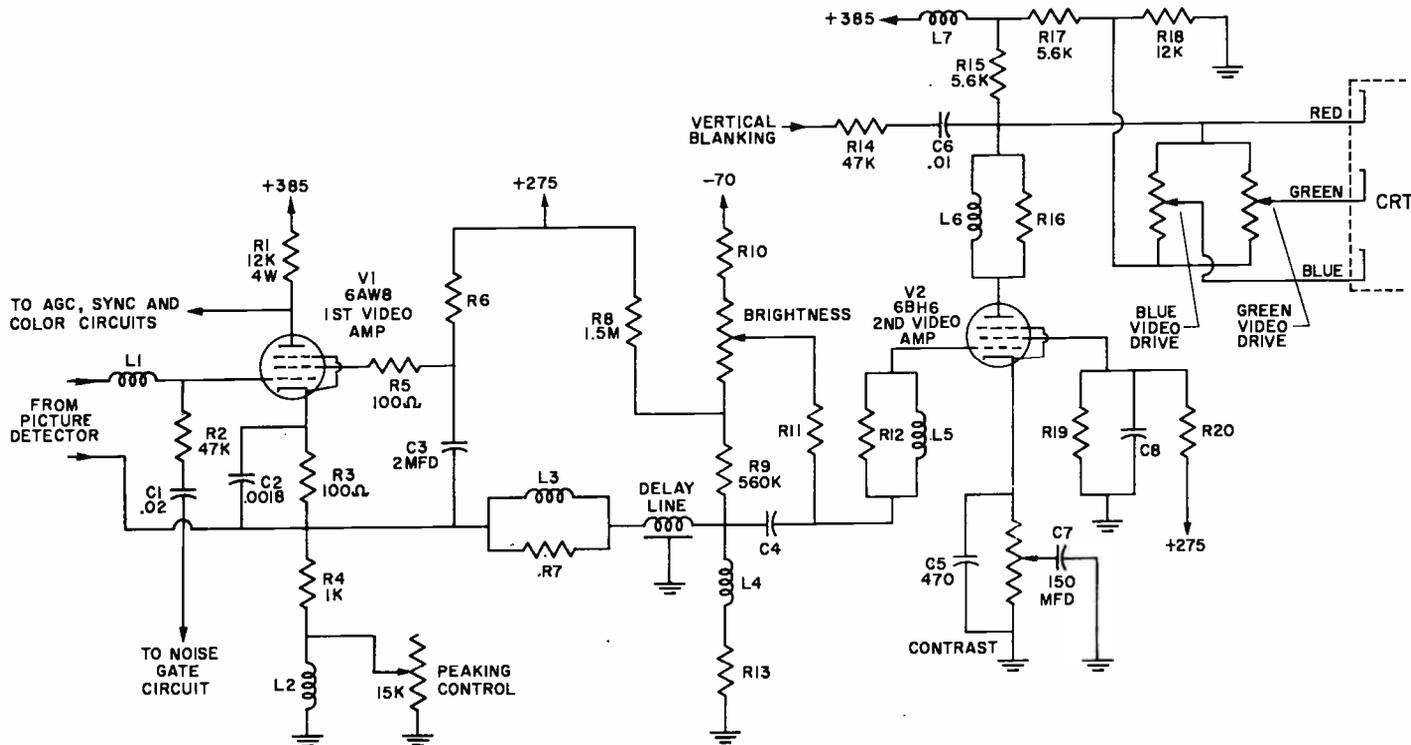
FIG. 3. Two-stage video amplifier used in Motorola color TV.

+275 volts and -70 volts. The arm of the brightness pot picks off the bias voltage for V2 to set the average brightness of the picture tube. Variations in the level of the video signal add to or subtract from the bias established by the brightness setting. In this way direct coupling is maintained from the video detector all the way to the cathodes of the picture tube.

The peaking control in Fig. 3 is a pot across peaking coil L2. The control shunts the coil and changes its effectiveness as a peaking coil. The slider of the contrast control in the cathode of V2 is connected through large electrolytic capacitors to ground. This prevents

changes in the contrast setting from upsetting the bias on this stage.

A new three-stage video section appears in the Magnavox series 45 color chassis. The principal parts of the circuit are shown in Fig. 4. The video signal is dc coupled through a 4.5 mc trap to the grid of the 6GH8A sync amplifier, V1A. Amplified signals are taken from the plate to drive the sync, agc, and color circuits. An unbypassed cathode resistor, R5, is common to both the pentode section and the triode section of the 6GH8A. In this way, the triode section is driven by a signal (not inverted) on the cathode.

V1B operates as a grounded grid amplifier with a low impedance plate load to provide an impedance match for the delay line. The signal at the output of the delay line is the same polarity as the signal at the output of the video detector. This delayed signal is coupled through C7 to the grid of the 12GN7 video amplifier stage, V2. The signal at the plate of V2 is coupled through suitable drive networks to the cathodes of the picture tube.

Direct coupling is maintained from the video detector to the grid of the output tube. The dc path is through R1, L1, a portion of the brightness control, and R15 to the grid of V2. The setting of the brightness control establishes the bias voltage on the grid of V1. Changes in the video level at the detector affect the bias of V2 and therefore the brightness at the picture tube.

A video peaking control is located in the cathode circuit of V1. Inductor L3 and capacitor C3 act as a
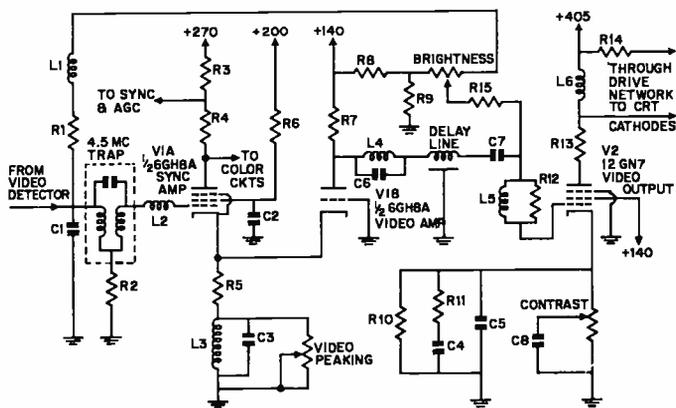
FIG. 4. Video amplifier in Magnavox series 45 color TV chassis.

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video peaking circuit for the signal appearing on the cathodes of V1. The peaking control parallels this network and controls the Q of the circuit. With the control fully counterclockwise the circuit is shorted and provides no peaking. As the control is rotated clockwise (increased resistance across the circuit) more peaking is provided to sharpen up the picture.

The three-stage video amplifier shown in Fig. 5 is used in the RCA CTC16 color TV chassis. While very similar to that used in last year's CTC15, it features a 6FL8 in place of the 6AW8. This triode-pentode has the same pin connections as the 6AW8 but the tubes are not interchangeable. The new tube has improved construction for more efficient operation as a positive grid amplifier. The video signal from the picture detector is direct-coupled to the control grid of V1A. This stage supplies an amplified video signal for the color, sync, and agc circuits. The luminance video signal is coupled through C3 to the grid of V1B. Direct coupling is maintained from the plate of V1A to the grid of V1B through R6. This biases the grid of the triode section of the 6FL8 in the positive region, but the tube is designed to take it.

The plate circuit of V1B provides an impedance match to the delay line. The output from the delay line is coupled through C4 and the peaking network to the grid of the video output stage, V2. Notice the direct

coupling between V1B and V2 through the brightness control. As explained for similar circuits, the setting of the brightness control sets the grid bias for V2, which in turn controls the plate voltage and the dc voltage at the cathodes of the CRT. Thus changes in the video level at the picture detector are felt all the way to the cathodes of the CRT and thereby maintain the correct brightness level of the picture.
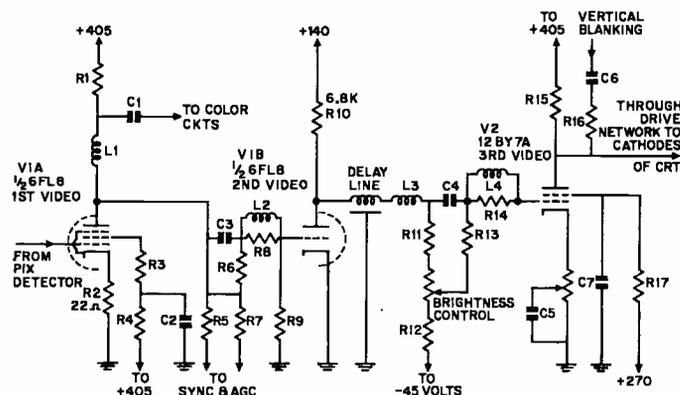

FIG. 5. Three-stage video amplifier used in the RCA CTC16 color chassis.

Chroma Bandpass Amplifiers

Few notable changes appear in the chroma bandpass amplifiers (also called color i-f) as the 1965 color receivers. The RCA CTC16 chassis uses the familiar single stage bandpass amplifier almost unchanged from the CTC15 and the CTC12 versions.

Applied to Grid . . . .

The two stage color i-f circuit shown in Fig. 6 is representative of those used in the Motorola line of color receivers. The video signal is applied through C1 to the grid of V1, the first color i-f amplifier. The plate circuit is tuned to select a band of frequencies around the 3.58 mc color carrier frequency. This signal is transformer coupled through the color intensity control to the grid of the second color i-f, V2. The amplified color signal in the plate circuit is transformer coupled to the color demodulators. The gain of the first color i-f stage is controlled by an automatic color control voltage (ACC) applied to the grid of V1. The ACC voltage originates in the color phase detector. Its amplitude varies with the amplitude of the color burst signal. In operation, the ACC voltage tends to hold the amplitude of the color signals constant when the strength of the received TV signal varies.

Signal Taken from Plate . . . .

The color burst signal is taken from the plate of the first color i-f amplifier while the color killer voltage affects only the second color i-f amplifier. The color killer voltage holds the V2 cut-off when no color is

received. The cathode of the second color i-f is returned to the cathode of the blanker tube. Thus V2 is cut off during horizontal retrace to prevent the color burst from getting on the grids of the demodulator stages and upsetting their operation.

COLOR DEMODULATORS

This year's color sync and color demodulator circuits follow the proven types. Until this year all color sets used either of two types of demodulators. By far the most numerous are the "X" and "Y" demodulators with R-Y, G-Y, and B-Y amplifiers following the demodulators. This is the type used by RCA, and with variations by most other American manufacturers. The other type is the Zenith beam-switching demodulator that delivers a high level color signal directly to the grids of the picture tube. Now a new type demodulator appears in the Sears' 16-inch color receiver imported from Japan. The circuit is shown in Fig. 7. Although the circuit appears to use high level demodulators, the 16-inch picture tube does not require large color signals. The demodulators drive the 16-inch color tube with only about one-third of the color signal required for the American 21-inch color tubes.

The circuit is designed around a new tube type, the 6R-P22. One tube is used to demodulate on each of the

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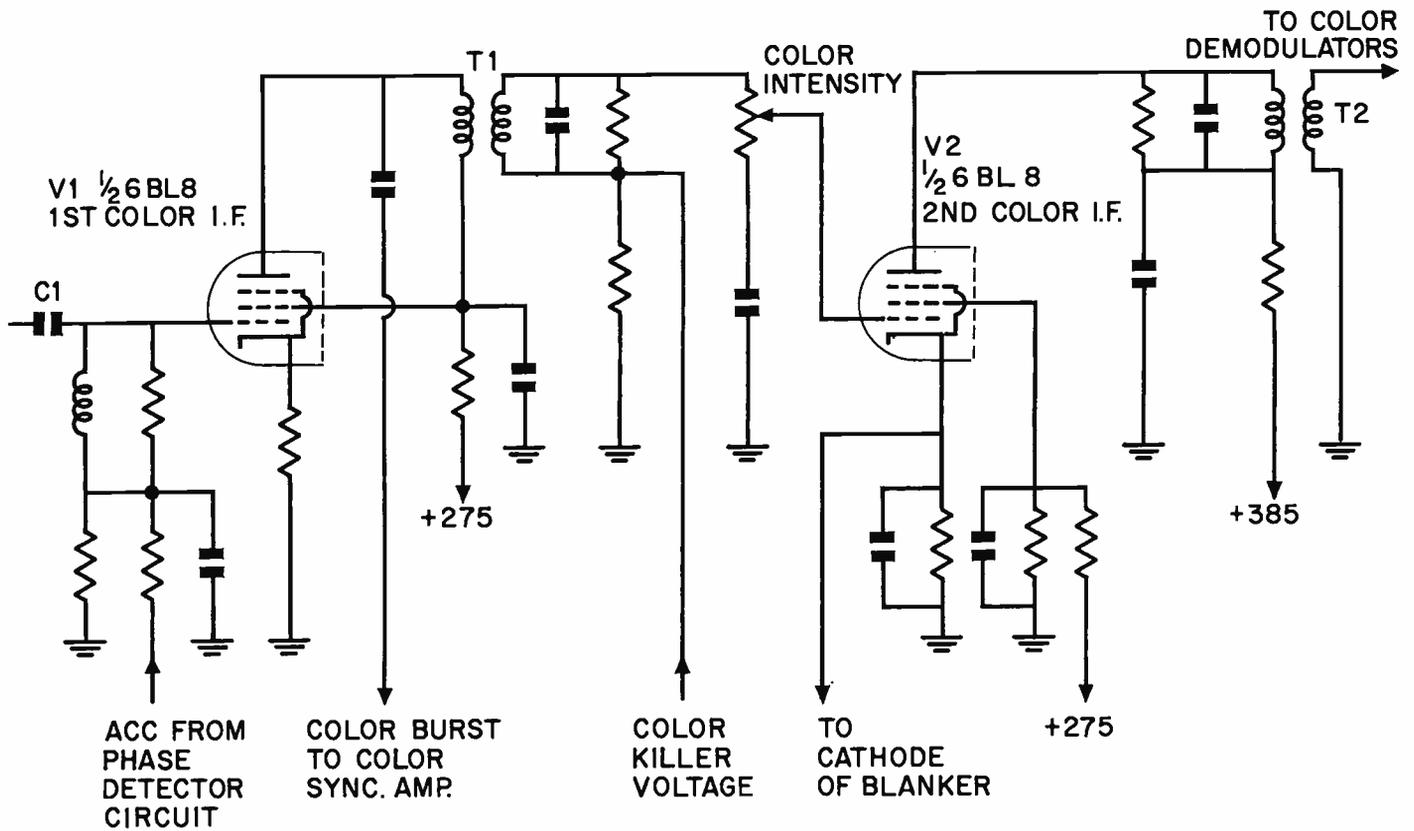
FIG. 6. Two-stage color i-f used in the Motorola color receiver.

three color axes, B-Y, R-Y, and G-Y. All three stages have a common cathode resistor, well bypassed. Likewise, the three control grids receive the same color signal from the bandpass amplifier. The amplitude of the color signal on each control grid is proportioned by resistors in the grid circuits. The transformer supplies a 3.58 mc reference signal through the phase-shift network to the suppressor grid of the three demodulator tubes. Each demodulator tube gets a 3.58 mc signal of the correct phase to demodulate in that axis.

The 6R-T22 demodulator tube appears to be a special design so that the suppressor acts as a switching grid, causing the tube current to go either to the screen or to the plate. Thus the color signal on the control grid is "sampled" at the 3.58 mc rate at a time (phase) corresponding to the demodulating axis. Adjustable slugs in the transformer and phase shift coils allow the reference signal phase to be adjusted for each demodulator.

Regulated High Voltage and Horizontal Sweep

The horizontal section of the RCA CTC16 color chassis is shown in Fig. 8. While similar to that used in the CTC16 chassis, there are some changes. The

6JE6 is again used as the horizontal output tube. The suppressor grid is returned to a low positive voltage as an aid in suppressing snivets. This is particularly
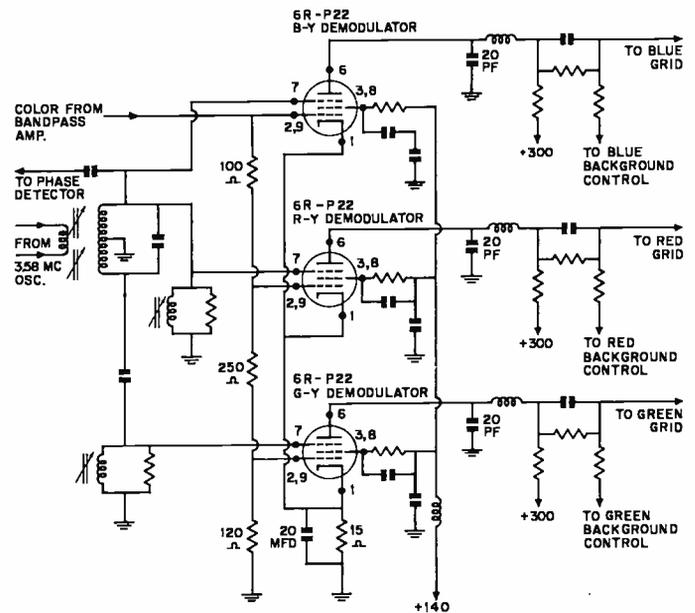

FIG. 7. Demodulator section of Sears 16-inch imported color TV.

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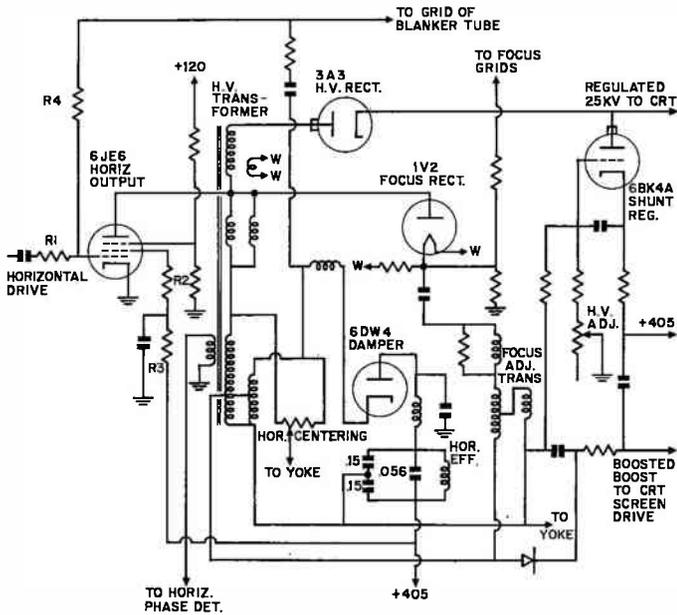
FIG. 8. Horizontal section of RCA CTC16 color chassis.

important when receiving UHF stations.

The high voltage rectifier circuit is the same but there are some small changes in the damper circuit. The capacitors across the horizontal efficiency coil have been changed to provide better horizontal linearity and increased efficiency of the output stage. The adjustments for the efficiency coil remain the same as for the CTC15 chassis. It is predicted that the circuit will give longer life for the horizontal output tube.

The most noticeable change from last year is the return of the 1V2 focus rectifier instead of the special diode. A change in the focus transformer circuit allows adjustment from 4 to 5.3 KV. This larger range is accompanied by more positive response during adjustment.

A new higher dissipation regulator tube, 6BK4A, is included in the CTC16 chassis. The circuit around the regulator stage remains the same and protection against high voltage run-away is still provided. In case the 6BK4A does fail, the high voltage would tend to rise toward 30 KV. To prevent this, a connection is provided through R4 between the control grid of the horizontal output stage and the grid of the blanker tube. As the high voltage tries to rise, the horizontal output transformer produces larger horizontal pulses that are applied to the blanker grid. This causes the blanker grid to produce a larger negative voltage that is fed through R4 to the grid of the output tube, V2. This large negative voltage limits the amplitude of the horizontal sweep and therefore the amplitude of the high voltage.

An interesting circuit for protection against loss of horizontal drive is included in the Setchell-Carlson U800 Color chassis. Details of the circuit are shown in Fig. 9. Screen grid voltage for the output stage is supplied by a diode that rectifies 250-volt positive

horizontal pulses from a winding on the flyback transformer. If horizontal drive is lost, the 250-volt pulses also disappear, effectively removing the screen voltage from the horizontal output tube. This drops the tube current to a safe value, thereby protecting the tube and output transformer.

The introduction of a rectangular picture with 90 degree beam deflection puts exacting requirements on the sweep circuit. The RCA CTC17 color chassis was designed specifically for driving the 25-inch 90° rectangular color picture tube. In most respects this chassis is the same as the CTC16. Centering controls are no longer needed because the guns are so accurately positioned in the new tube. The larger screen and larger deflection angles makes pincushioning a problem. In color receivers pincushioning magnets, such as used in black and white receivers, are not practical because each color raster would be affected differently and cause misconvergence. In the CTC17 chassis pincushioning is overcome by modifying the deflecting currents that flow in the yoke. The vertical windings are furnished a correction current from the horizontal circuit to correct for top and bottom pincushioning. The horizontal windings are furnished a correction current from the vertical circuit to correct for side pincushioning. No adjustments are required for the side pincushioning corrections. The "top/bottom pin" amplitude control and "top/bottom pin" phase control are provided for top and bottom pincushioning correction. These are easily adjusted. Simply rotate the amplitude control to maximum. Adjust the phase control for maximum effect at the top and bottom centers of the raster. Now back off on the amplitude control until a straight raster is produced at the top and bottom of the picture.

The set-up and convergence adjustments with the CTC17 chassis remain basically the same as with pre-
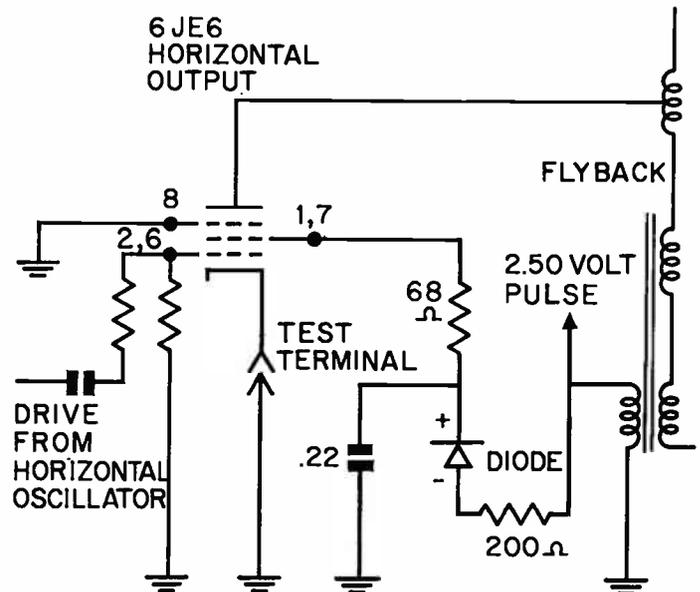
FIG. 9. Protection circuits in the Setchell-Carlson U800 chassis.

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vious color sets. These adjustments should not be made until the receiver has thoroughly warmed up for about 25 minutes. Also, center convergence should be obtained prior to adjusting for purity. A new blue lateral magnet assembly appears on the CTC17 chassis. An additional adjustment is provided for "wide blue" correction. Detailed adjustment procedures given in the manufacturer's pamphlet should be consulted before making the adjustments.

The sweep driving power for the 25" 90° rectangular tube, 25AP22, is approximately the same as needed for 70° color picture tubes. This is true because of the small diameter neck of the tube. The small neck permits the use of a high sensitivity deflection yoke.

Low Voltage Power Supply Circuits

The B+ power supplies in all late model color receivers use power transformers, silicon diodes, and full-wave doubler circuits. The RCA CTC16 chassis uses four silicon diodes in a full wave bridge circuit. Fig. 10 shows the full wave bridge circuit and the automatic degaussing circuit (ADG) used in the RCA CTC16 chassis. The ADG coils are located around the metal flange of the picture tube. The circuit operates to degauss the metal parts each time the set is turned on.

Operation of the circuit is controlled by two resistance elements---the temperature sensitive thermistor R1, and the voltage dependent resistor (VDR), R2. The cold resistance of the thermistor R1 is 120 ohms. When the set is first turned on, most of the ac in the secondary of the power transformer flows through the low resistance windings of the ADG coil and through the low resistance of the VDR, R2. This current supplies a large alternating magnetic field around the degaussing coil. As R1 heats up, its resistance drops so more current flows through R1 and less flows through the degaussing coil and R2. With less voltage applied to R2, its resistance increases. The combined action of R1 decreasing and R2 increasing causes a smooth, gradual decrease in current through the degaussing coils.

When the action is complete, the current through the degaussing coils is, for all practical purposes, zero. The degaussing operation is completed before the raster appears on the screen. The ADG circuit is not provided in every model using the CTC16 chassis. It is always used on models having wooden cabinets.

Other manufacturers are featuring similar degaussing circuits. In the Admiral color TV the feature is called AMF-Automatic magnetic-free circuitry. The Packard-Bell degaussing circuit is not automatic. The circuit is energized by pushing a spring-loaded switch and the circuit then completes the degaussing action.

CONCLUSION

For the TV technician who has shied away from color servicing, I'd like to offer some encouragement. Right now is still an excellent time to get in on the ground floor of color. The industry expects to sell two million color receivers in 1965. This upsurge in color sales will generate increased color service work three to five years hence. The effort you put into learning color now will be repaid by the increased demand for color service. Color servicing is easier to master now than it will be several years from now. The reason is that except for Zenith most sets sold now are an exact copy or a variation of a recent RCA chassis. The technician who knows the RCA chassis CT7, CT9, CT15, and/or CTC16 is in a position to service most color sets on the market. This will not be true a few years from now. From now on most manufacturers will be redesigning their own chassis and marked differences will begin to appear from set to set. By getting started in color servicing now you can easily learn the new sets as they develop.
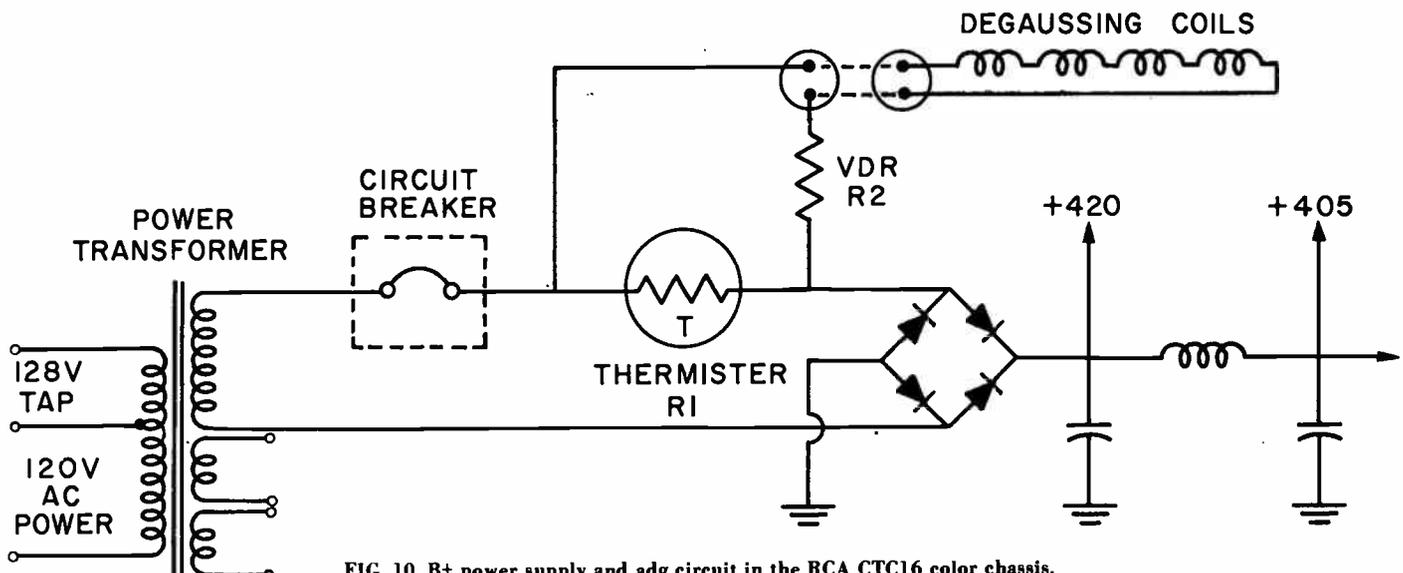

FIG. 10. B+ power supply and adg circuit in the RCA CTC16 color chassis.

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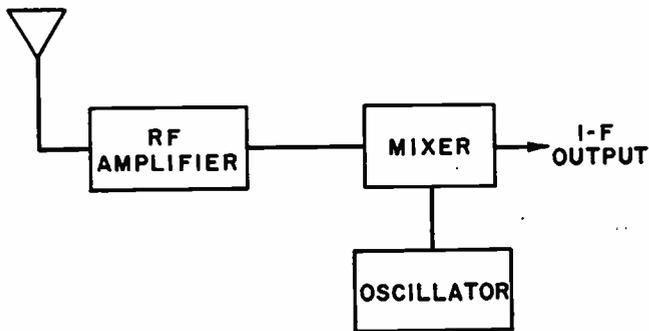
Fig. 3. Block diagram of a VHF tuner.

encounter this type of interference in large metro-politan areas having their own TV stations, but you will often find it in rural areas between two large cities.

I-F Interference.

If a TV receiver is near a strong station using a carrier frequency in the i-f region, it is quite possible for the signal to get through the tuner and cause inter-ference. The signal may also be picked up directly by unshielded leads in the i-f amplifier. Interference of this type that is getting in through the tuner can be eliminated by installing a high-pass filter in the an-tenna input lead. We will describe traps in more de-tail later. If the interfering signal is being picked up directly by the i-f amplifier, the only way to elimi-nate this problem is to shield the entire amplifier.

SUMMARY

Interference was a serious problem in early tele-vision receivers that first appeared on the market about 1947. However, a great deal of progress has been made in tuner design. Shielding has been im-proved considerably, selectivity has been improved, and new circuits have been developed.

Practically all of the early television receivers used a picture i-f frequency in the neighborhood of 25.75 mc, and a sound i-f of 21.25 mc. In later de-signs, the i-f frequencies have been changed to 45.75 mc for the video, and 41.25 mc for the sound. This change alone has helped to eliminate interference.

Improvements in tuner design have greatly simpli-fied the service technician's job. However, since there

are still many receivers in use having the early tuner designs, you should be familiar with their prob-lems. In spite of the improvements made in tuners, they still require servicing--tubes and transistors burn out, parts break down, etc.

We will now begin to study in detail some of the tuner circuits. The better you understand how these circuits operate, the easier it will be to service them quickly and professionally.

VHF AND UHF TUNERS

As we have already mentioned, because the position-ing of the parts and the shielding is so critical, the tuner is manufactured as a complete unit on its own sub-chassis; then, when it is completed and aligned, this sub-chassis is mounted on the main television receiver chassis. This greatly simplifies the problems of layout and shielding. Now let us take a brief look at the block diagram of a VHF tuner, and after we have studied it, we will look at a UHF tuner.

VHF Tuners.

A block diagram of a VHF tuner is shown in Fig. 3. Notice that the tuner consists of an rf stage, a mixer, and an oscillator.

The rf stage may use either a pentode or a triode tube. Early tuners frequently used triode tubes in a push-pull circuit. Later, improved tuners appeared, using pentode rf stages, and still later, tuner designs used a dual triode tube in a cascode circuit. Now the latest VHF tuner designs that use tubes use single triode rf amplifiers. We will study all these circuits in this lesson. We will also study transistorized VHF tuners.

Separate tubes may be used in the mixer and oscil-lator stages, but the trend in modern tuner design is to use a single dual tube, one section of the tube being used as the mixer, and the other as the oscillator. In transistor tuners, you will usually find separate transistors in the oscillator and mixer stages.

UHF Tuners.

It is not too difficult to design rf amplifiers that will work on the highest VHF channels, but problems are so great on the UHF channels that rf amplifiers are not usually used.

The block diagram of a UHF tuner is shown in Fig. 4. The actual UHF tuner consists of the UHF mixer
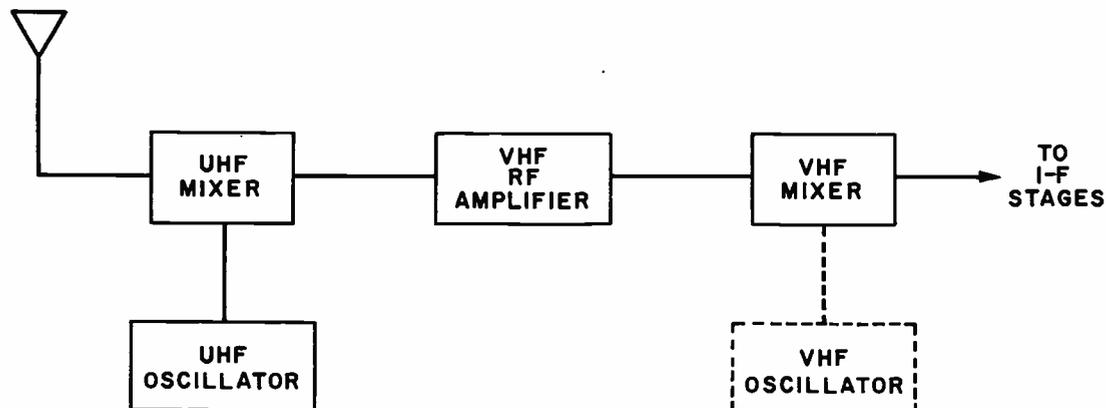

Fig. 4. Block diagram of a modern UHF tuner.
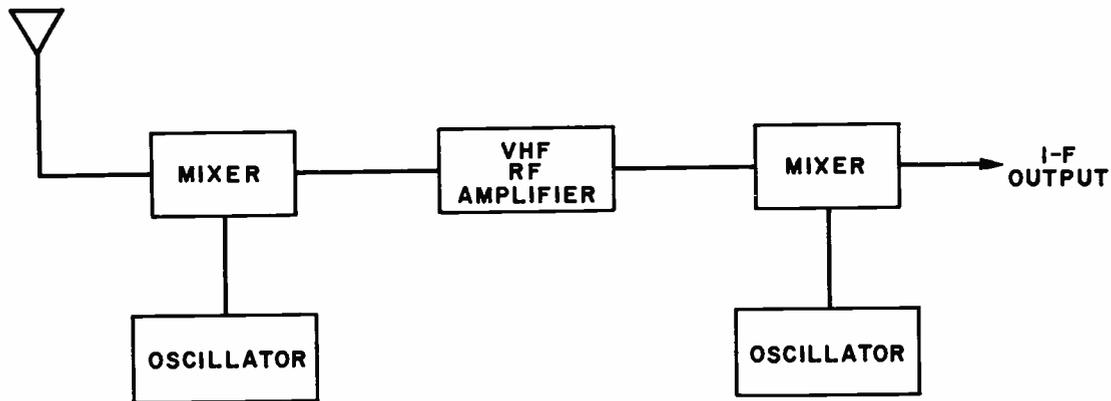
Fig. 5. Block diagram of a UHF tuner that uses double conversion.

and oscillator. The output from the UHF mixer is fed to the rf amplifier of the VHF tuner. The VHF tuner has 13 positions, twelve for the twelve VHF channels and a UHF position. When the VHF tuner is in the UHF position, the power is applied to the UHF tuner and removed from the VHF oscillator. At the same time, the rf stage and the mixer stage of the VHF tuner are tuned to the i-f frequency and they become the first two i-f stages. The UHF mixer is a crystal and the UHF oscillator in most sets a transistor, although some sets use a specially designed oscillator tube.

Older TV receivers with UHF used a somewhat different system. A block diagram is shown in Fig. 5. Notice that in effect we have simply added a converter consisting of a mixer and an oscillator in front of a typical VHF tuner. This procedure was used by most manufacturers before 1964. The UHF mixer is usually a crystal mixer, and the oscillator a specially designed UHF tube. The rf amplifier of the VHF tuner then acts like a first i-f stage and the VHF mixer becomes a second mixer.

The UHF mixer input circuit is extremely broad and usually will pass signals from several channels. Thus even though UHF tuners must be able to tune from 470 mc to 890 mc to cover all the UHF channels, mixer-oscillator tracking is not a serious problem. Also, in spite of the fact that the UHF mixer tuning is extremely broad, there is not generally too much interference encountered because of the selectivity of succeeding stages.

Now that you know what stages are likely to be found in a tuner and have seen that even when you are tuned to a UHF channel, the VHF tuner is operating, let's study VHF tuners first and then UHF tuners. We'll start studying VHF tuners by studying the first stage, the rf stage.

SELF-TEST QUESTIONS

(a) What two functions must the tuner perform?
(b) What is meant by the low band VHF channels?
(c) What channels are likely to be affected by FM harmonic interference?
(d) What type of adjacent-channel interference might you encounter from Channel 7 when the receiver is tuned to Channel 8?
(e) In a modern all-channel TV receiver, what purpose do the VHF rf amplifier and mixer serve when the receiver is tuned to a UHF channel?

The RF Stage

In order to have as much selectivity as possible, and at the same time maintain an adequate bandwidth, the rf stage of a TV receiver must be designed so that its impedance matches that of the transmission line. Most input circuits are similar to those shown in Fig. 6.

Fig. 6A shows a balanced input with two antenna terminals. The input is balanced because each terminal has the same impedance to ground. The input impedance between the two terminals is 300 ohms. Receivers with this type of input should be connected to the antenna with 300-ohm transmission line (commonly called twin lead).

A variation of this type of circuit is shown in Fig. 6B. Here the signal is inductively coupled to the grid-cathode circuit of the rf stage instead of capacitively coupled as in Fig. 6A. Circuits similar to both Fig. 6A and 6B were once widely used in TV. Most modern sets, however, use an arrangement similar to the one shown in Fig. 6C. An input circuit design to feed an unbalanced coax line into the tuner input is shown in Fig. 6D. Some of the early TV sets were designed with an unbalanced input of this type.

The input circuits shown in Figs. 6A, B and D are quite simple and should need no detailed explanation. These are simply designed to match the transmission line used to bring the signal from the antenna to the receiver and to couple the signal to the grid-cathode circuit of the rf amplifier. However, the circuit in Fig. 6C is somewhat more complex.

The input of the receiver is designed for a 300-ohm ribbon-type transmission line which is used for TV. T_1 and T_2 make up a balun which transforms the balanced 300-ohm receiver input to an unbalanced
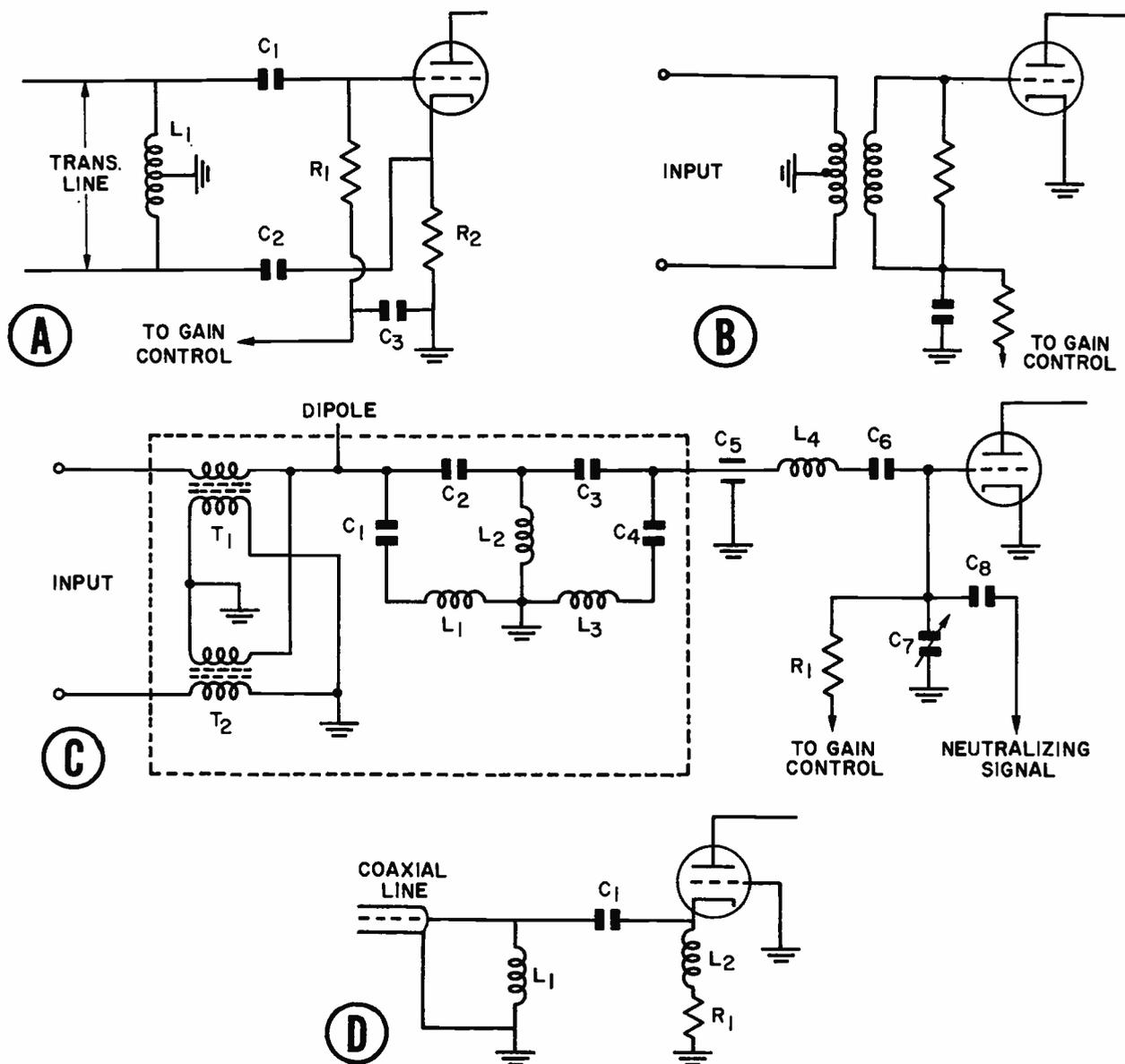
Fig. 6. VHF tuner input circuits.

75-ohm input. When the receiver uses a single dipole for reception of strong local stations, the dipole is connected to the circuit at the output of the balun as shown in Fig. 6C. The network consisting of C_1, C_2, C_3, C_4, L_1, L_2 and L_3 form a high-pass filter. This filter passes signals above 54 mc, but prevents signals below 54 mc from reaching the grid of the rf stage.

The balun and the high-pass filter are usually mounted directly on the tuner input terminals. A typical balun is shown in Fig. 7.

In the circuit shown in Fig. 6C, the resonant frequency is changed by changing the value of L_4. For Channels 2 through 6, different size coils are switched into the circuit in place of L_4. For Channels 7 through 13, coil L_4 is shorted out and a different coil for each channel connected from one side of L_4 to ground. We'll see more of this when we study complete tuners.

Gain in the rf stage improves the signal-to-noise ratio and every bit of gain ahead of the converter is important when weak signals are being received. Since considerable noise is generated in the converter stage, any rf gain that increases the signal strength before the signal reaches the converter will help the signal override the normal converter noise. However, even at best, the amount of gain obtainable in the rf stage is relatively small. The television set, like a broadcast receiver, must depend on the i-f amplifier for most of its gain.

Fig. 7. A typical balun for VHF tuner input.

TRIODE RF STAGES

You already know that one of the undesirable characteristics of a vacuum tube is that it generates a certain amount of noise. Triodes are far less noisy than pentodes, and they were used in the rf stages of many of the early TV tuners. However, the triode tube, because of the grid-to-plate feedback, either requires neutralization or must be used in a grounded-grid circuit.

Neutralization.

Two neutralized triode amplifiers are shown in Fig. 8. In Fig. 8A, the rf energy at the lower end of L_1 is 180° out-of-phase with the energy at the plate of the tube. C_4 does not bypass all the signal, so there is a small rf signal fed through C_2 back to the grid of the tube. This energy will be 180° out-of-phase with the signal reaching the grid through the plate-to-grid capacity of the tube so the two will cancel.

In the circuit shown in Fig. 8B, energy is fed from
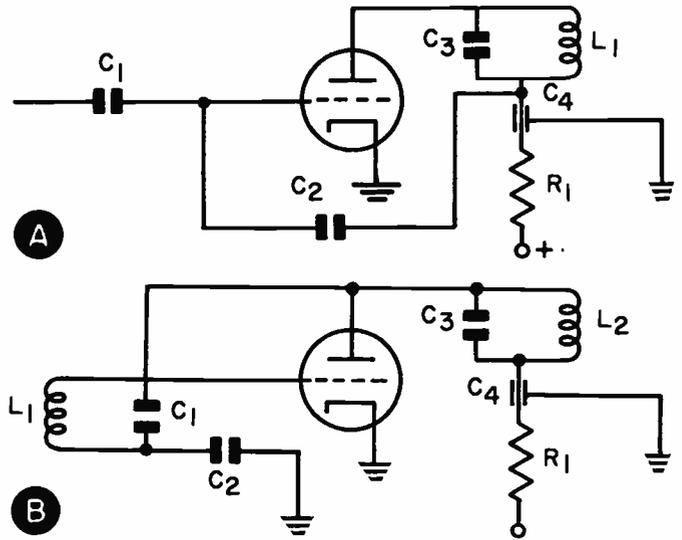
Fig. 8. Two neutralized triode circuits.

the plate of the tube through C_1 to the junction of the lower end of L_1 and C_2. C_1 and C_2 form a voltage divider and determine the amount of energy fed into the circuit at this point. The energy is reversed in phase in L_1 and thus reaches the grid of the tube 180° out-of-phase with the energy reaching the grid through the plate-to-grid capacity of the tube. If the ratio of C_1 to C_2 is correct, the signal reaching the grid through C_1 and L_1 will exactly equal the signal reaching the grid through the tube interelectrode capacities and the two will cancel.

Neutralization will work over the very wide number of channels only if the different tuning coils are carefully designed to provide the proper feedback ratio. To avoid such problems, some tuner manufacturers have used a grounded-grid amplifier instead of circuits requiring neutralization.

Grounded-Grid Circuit.

In the rf stages with which you are most familiar, the cathode is grounded and the signal source is placed between grid and ground as shown in Fig. 9A.

Fig. 9. This illustration shows the basic difference between the common grounded-cathode amplifier (A) and the grounded-grid amplifier (B).

Fig. 10. A pentode rf stage.

still have a reasonable noise level. Another advantage of a pentode rf amplifier is that it does not require neutralization. However, modern TV tuners once again are using triode rf stages. New triode tubes such as the frame grid tubes and the nuvistor, which has been specially designed to provide very high gain in rf amplifier service, make it possible to get reasonably high gain in the rf stage and at the same time have the advantage of the lower noise level that can be realized with a triode stage.

The pentode rf amplifier shown in Fig. 10 is not very different from an rf stage that might be found in a broadcast receiver. However, tubes used in an rf stage of this type are usually designed for operation in the VHF region. Low plate and screen voltages are used to keep tube noise at a reasonable level.

An rf stage of this type is kept as compact as possible. The stage is carefully shielded. Notice the decoupling resistor, R_3, used in the plate circuit lead and also the bypass capacitors C_4 and C_3 in the plate and screen circuits.

THE CASCODE AMPLIFIER

A basic cascode amplifier is shown in Fig. 11. Since this may be the first time you have seen a circuit of this type, an explanation of how it operates should be helpful to you.

The input signal across coil L_1 is applied to tube V_1, which is connected in a standard grounded-cathode circuit. The output signal from this tube is developed across coil L_2, which feeds into V_2 through capacitors C_3 and C_2. V_2 is a grounded-grid amplifier.

You might expect that V_1 would oscillate, since the circuit is a conventional grounded-cathode amplifier. However, before a tube will oscillate, there must be sufficient load-impedance in the plate circuit to develop a reasonably strong feedback signal. The tube V_2 is in effect in the plate circuit of V_1 and presents a very low impedance to V_1. The result is that the impedance in the plate circuit of V_1 is so low there is not sufficient energy developed to produce oscillation.

The coil L_4 feeds energy in the proper phase to alter the apparent input resistance of V_1 so that the noise

In the grounded-grid circuit shown in Fig. 9B, the signal is placed between the cathode and ground, and the grid is connected directly to ground. Insofar as the grid action is concerned, either position of the signal source will produce the same result, because it is the voltage between the cathode and the grid that matters. However, with the grid at ground potential, it effectively acts as a shield between the signal source and the plate. As a result, the grid-plate capacity no longer provides a feedback path, so neutralization is generally unnecessary. However, the grounded-grid circuit gives less gain than a conventional neutralized triode stage does, because the signal source is in the plate circuit and hence effectively feeds into a low resistance. The signal source is therefore heavily loaded, and if it is a tuned circuit, its Q and gain will be low.

PENTODE RF STAGES

A typical pentode rf stage is shown in Fig. 10. As we have already pointed out, a pentode is noisier than a triode; however, pentode rf stages have the advantage of increased gain over the early triode rf stages, and


Fig. 11. A basic cascode amplifier, with ac coupling.
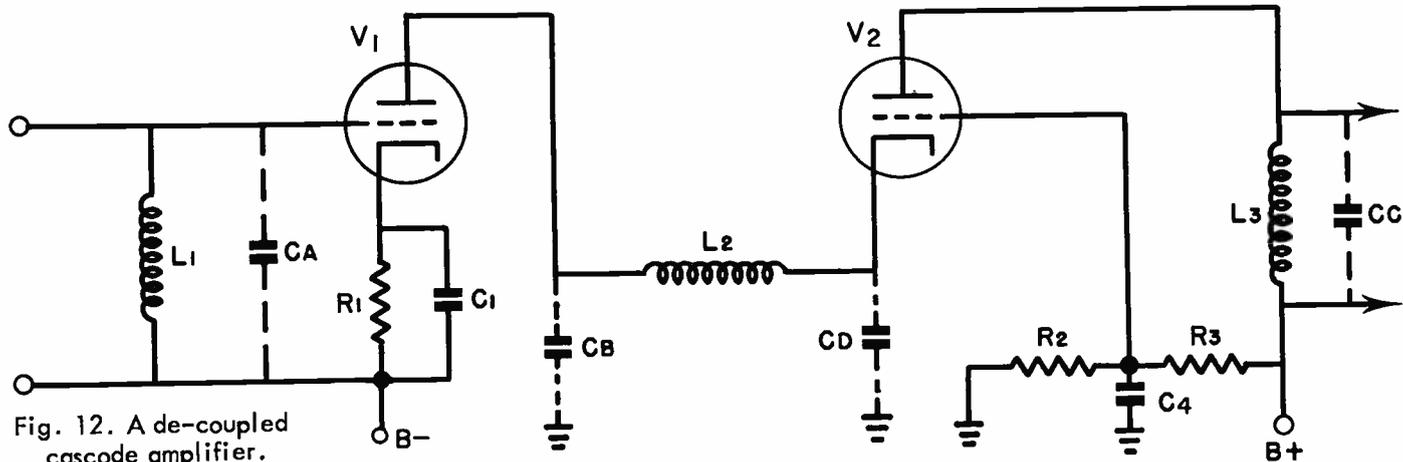
Fig. 12. A de-coupled cascode amplifier.

input will be reduced. The low noise level is the chief advantage of the cascode circuit.

In the circuit shown in Fig. 11, ac coupling is used between V_1 and V_2; the dc circuits of the two stages are isolated from each other. A practical cascode amplifier very often uses dc coupling as shown in Fig. 12. The operation of this circuit is similar to the operation of the circuit in Fig. 11. Again, V_1 is a conventional grounded-cathode amplifier and V_2 is a grounded-grid amplifier. V_1 does not oscillate, because of the low impedance in the plate circuit. The grid of V_2, although not connected directly to ground, is grounded through C_4. C_4 acts as a short circuit at signal frequencies; therefore, insofar as the signal is concerned, the grid of V_2 is effectively grounded and acts as a shield between the cathode and the plate of the tube.

The cascode amplifier was very popular a number of years ago. It replaced the pentode rf amplifier because it has a better noise figure and at the same time provided as much or more gain than a single pentode tube. However, the cascode amplifier itself was displaced by the single neutralized triode stage using very high gain tubes designed for rf amplifier service.

A TRANSISTOR RF AMPLIFIER

A typical transistor rf amplifier is shown in Fig. 13.

The transistor used in this circuit is an NPN silicon transistor.

Notice that there are two antenna input terminals. One is for a 300-ohm twin lead and the other for a 75-ohm coaxial cable. With a tapped coil such as L_1 in the input, the impedance of the coil from the center tap to either outside terminal is 75 ohms. The impedance between the two outside terminals will be four times this value, or 300 ohms. Thus the 300-ohm input can be used with twin lead in most residential installations. In commercial installations, such as motels and hotels, or in residential installations where there is excessive noise pickup on a 300-ohm twin lead, a coaxial cable can be used and connected to the 75-ohm input.

The coils L_3, L_4, and L_5 plus capacitors C_1, C_2, and C_3 form what is called a T trap. The name is because the configuration resembles the letter T. L_3 is adjustable; the trap is designed to prevent interference from any nearby strong FM stations. Transistor rf stages are particularly subject to overload and cross-modulation by strong local stations. The combinations of L_3 and C_1, and L_4 and C_2 form parallel-resonant traps, while C_3 and L_5 form a series-resonant trap. I-F interference is prevented from reaching the base of Q_1 by the i-f trap (C_6, L_6, and C_7), which has a low impedance at the video i-f frequencies.

Fig. 13. A transistor rf stage.

Fig. 14. Four forms of resonant coupling used between the rf and mixer stages.

agc line. Although the diagram does not show the agc circuit, we have what is called a delayed agc in this circuit. With delayed agc, the rf amplifier operates at maximum gain, except on very strong signals when the gain of the stage is reduced. The combination of R_2 and R_3 fixes the emitter voltage. Any increase in emitter current due to thermal runaway will increase the emitter voltage on the transistor, and thereby reduce the forward bias and protect the transistor.

GAIN CONTROL

The gain of the rf stage is usually controlled by applying agc voltage to the grid of the rf tube, or the base of the rf transistor. This will normally provide satisfactory control of the gain of the rf stage except in very strong signal locations where the receiver is close to a strong TV station. In cases of this type, resistance voltage dividers, called attenuators, are inserted in the transmission line to decrease the signal from the powerful station to a level that can be handled by the receiver.

Some of the older TV receivers did not use agc. In these receivers the gain of the rf stage was controlled by a contrast control that varied the bias on the rf and i-f stages. Practically all modern sets have agc voltage applied to the rf stage.

COUPLING TO MIXER

Several methods of coupling the rf stage to the mixer are shown in Fig. 14. The tubes shown are triodes, but the same arrangements could be used with pentodes equally well.

Fig. 14A shows the basic tuned-plate coupling. The tuning is needed to provide selectivity. However, the resistor R_1 loads the tuned circuit to broaden its response. The resonant circuit is therefore used to provide selectivity, and a low value of grid resistance is used in the following stage to broaden the response of the resonant circuit so it will not be too selective. Although we want selectivity, we must also keep in mind that the TV channel is 6 mc wide and the coupling network must be capable of handling the entire channel.

Another coupling arrangement is shown in Fig. 14B. In this circuit, the grid resistor may be made large so that the detector can be operated as a grid-leak detector. The resonant circuit is loaded by R_1, which will be a comparatively low resistance, to obtain the required bandwidth.

A third coupling arrangement is shown in Fig. 14C. In this circuit, inductive coupling is used between the coil in the plate circuit of the rf stage and the coil in the grid circuit of the mixer. The coils are over-coupled to produce a double-peak response. In addition, R_1 is usually a low enough value to load both resonant circuits. The required 6-mc bandwidth can easily be obtained in this way at the frequencies encountered in the tuner.

Another coupling circuit is shown in Fig. 14D. In this circuit, the output of the rf stage and the input of the mixer are both tuned. Coupling between the two

The input circuit of Q_1 is tuned to the various TV channels by L_1, L_8, and L_9. At Channel 13 the inductance of these coils is at a minimum. Additional inductance is added in the circuit as the tuner is tuned to the lower channels. The output is also tuned to the TV channel by varying the inductance of L_{12}. By tuning both the input and the output circuits of the transistor, adjacent channel interference is kept at a minimum. The combination of L_{11} and C_{10} provides neutralization to prevent the rf stage from oscillating.

In the UHF position, the base of the transistor is switched to C_9 and to the UHF input. The inductance in the input and output circuits of Q_1 tune these circuits to resonance at the i-f frequency, so that in the UHF position the VHF rf amplifier actually operates as the first i-f amplifier.

Forward bias for the emitter-base junction of the transistor is applied to the base through R_1 from the

circuits is through the capacitor C_3. Capacitor C_1, which tunes the coil in the output of the rf stage Q_1, is actually the output capacity of the transistor. This is why we have shown it in dotted lines on the diagram. Similarly, C_6, which forms part of the resonant circuit in the input of the mixer stage, is shown in dotted lines because it is the input capacity of the mixer transistor, Q_2. The input resonant circuit consists of C_4, C_5, C_6, and L_2.

We have already mentioned that the response of the tuner need not be flat over the entire 6-mc channel. Sometimes the response is deliberately peaked somewhat in order to make up for deficiencies in the i-f amplifier.

Fig. 15A shows the desired overall rf/i-f response curve, the result of a tuner designed with a somewhat peaked response at the frequency where the video i-f response dips. Fig. 15B shows the response curves of the i-f amplifier and tuner. Note the two peaks and a valley.

Very often you'll see a coil, having no capacitor in parallel with it, in the plate circuit or the collector circuit of an rf stage. Fig. 14D is an example of this, as is the circuit shown in 16A. These circuits are both parallel-resonant circuits.

Capacitor C_1 is a trimmer capacitor, and since it is connected in series with L_1, and the two are connected between the plate of the tube and ground, you might think that L_1 and C_1 form a series-resonant circuit. You know that a series-resonant circuit offers a very low impedance at resonance and therefore would not provide an effective load for V_1. However, at the high frequencies handled in the tuner, the plate-to-cathode capacity of V_1 and the capacity to ground of the wiring in the plate circuit actually form a comparatively large capacitor. If the circuit of Fig. 16A is redrawn as shown in Fig. 16B, you will see that the shunt capacity represented by C_3 is actually in series with C_1, and the combination of the two condensers will in effect be in parallel with L_1. The circuit made up of L_1 and the two capacities is therefore a parallel-resonant circuit and offers a high impedance at the resonant frequency.

You might think the shunt capacities in the circuit are extremely small, but at the high frequencies used
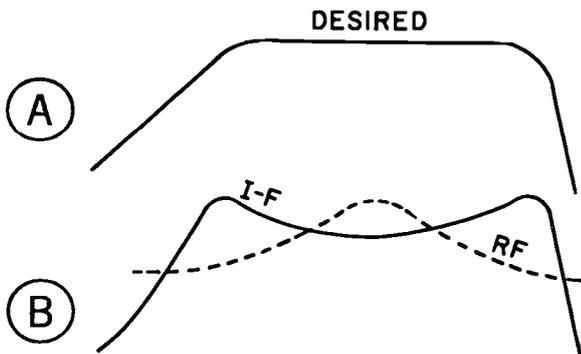
DESIRED

Fig. 15. The desired overall response of the rf and video i-f sections (A) secured by matching the responses (B).
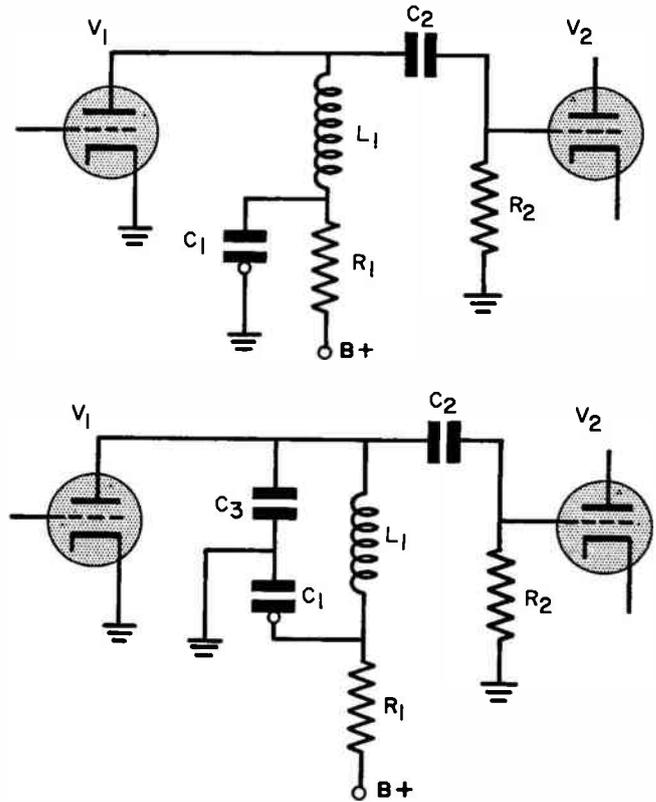
Fig. 16. A typical coupling arrangement used between the rf and mixer stages.

for television, their effect is so large that a low value of inductance must be used in the circuit on the high VHF channels. As a result, the circuit gain is low. This is one reason why C_1 is connected as it is; when capacitors are connected in series, the total capacity will be less than the capacity of the smaller of the two. Therefore with C_1 in series with C_3, the effective capacity across L_1 is reduced, and therefore a larger inductance can be used.

SELF-TEST QUESTIONS

(f) What is the balun shown in the input circuit of Fig. 6C used for?

(g) What is the purpose of the high-pass filter found in the input circuit of most modern tuners?

(h) What is the chief advantage of using a triode rf amplifier over a pentode rf amplifier?

(i) What is the main disadvantage of the triode rf amplifier?

(j) Why doesn't the first stage of a cascode amplifier oscillate?

(k) What is the chief advantage of the cascode circuit?

(l) Are cascode amplifiers used in the rf stage of late model TV receivers?

(m) Why is the coupling circuit between the rf stage and the mixer often loaded by a resistor?

(n) What kind of resonant circuit is used in the collector circuit of the rf amplifier shown in Fig. 14D?

The Converter Section

The converter section of a television receiver, like that of a radio, consists of a mixer-detector and an oscillator. In a radio, a single i-f signal is produced by beating the incoming signal with a signal from a local oscillator. In a television receiver, two i-f signals are produced, the sound i-f and the video i-f.

Although pentagrid converters are commonly used in radio receivers to perform the functions of both the mixer-detector and the local oscillator, television receivers that use tubes generally use two separate tubes, but they are usually in one envelope. The pentagrid converter is not suitable for use in TV tuners. Transistor TV receivers usually use two separate transistors, one for the mixer stage and the other for the oscillator.
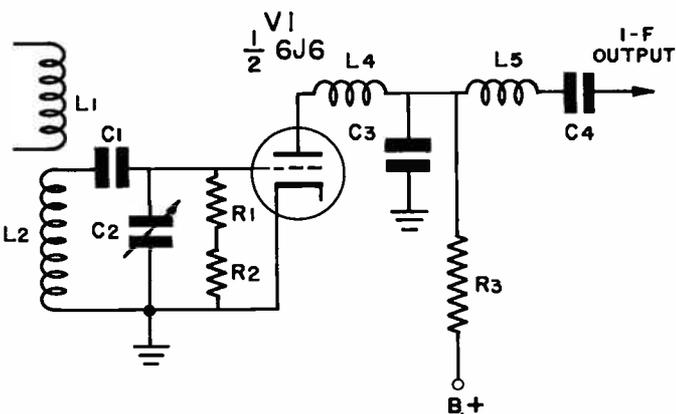
Fig. 17. A triode mixer circuit.

You already know that considerable noise is generated in a mixer stage. The noise level is high in tube-type mixers, because the strong signal from the local oscillator swings the mixer plate current close to cut-off. When the plate current is low, random noise generated by the tube will be at a maximum. When used as amplifiers, pentodes are noisier than triodes. This is also true when they are used as mixers -- a triode mixer will generate far less noise than a pentode mixer. A transistor used as a mixer is noisier than it would be if used as an amplifier. The reason once again is the strong oscillator signal; it drives the collector current close to cut-off.

In early tuners, triodes were always used because of a lower noise factor. With the development of the cascode amplifier for use in the rf stage, and the resulting improvement in the signal-to-noise ratio available at the input to the mixer, most late model tuners use a pentode mixer to take advantage of the higher gain available with a pentode tube. Pentode mixers are also used in late model tuners where high-gain single triode stages have replaced the cascode rf amplifier. The pentode tube used is designed especially for this type of service and the noise is kept as low as possible. The pentode is usually one half of a dual tube. The other half is a triode which is used as the oscillator.

Triode Mixers.

A simple triode mixer circuit is shown in Fig. 17. Grid-leak bias is used; the bias voltage is developed across resistors R_1 and R_2. Coil L_1 is in the plate circuit of the rf amplifier, and it is inductively coupled to coil L_2. The two coils are overcoupled to give the desired 6-mc bandwidth. The oscillator is also inductively coupled to L_2.

The two signals that are coupled to L_2 are applied between the grid and cathode of V_1. When the signals swing the grid of V_1 positive, grid current flows and charges C_1. During the period when the signals swing the grid negative, there is no grid current flow and C_1 discharges through R_1 and R_2 biasing the grid of V_1 negative.

The events occurring in V_1 are almost identical to those that occur in a grid-leak detector used in a radio receiver to separate the audio from the rf carrier. Because V_1 is a detector, mixing occurs in the stage, with the result that signals equal in frequency to the sum of the incoming signal plus the oscillator, and equal in frequency to the difference between the incoming signal and the oscillator, are produced. The signal we are interested in is the difference signal.

Before leaving this discussion it would be well to mention once again that the relationship between the sound and picture signals is reversed in the heterodyning or mixing process in the VHF tuner. Fig. 18 should help illustrate what happens. In the block diagram shown, the receiver is tuned to Channel 2, which is 54-60 mc. The video carrier for Channel 2 is 55.25 mc and the sound carrier 59.75 mc. As illustrated, the signals are amplified by the rf amplifier and fed to the mixer. Here they are mixed with the 101 mc signal from the local oscillator. In the mixer, two i-f signals are produced, one equal to the difference between the video carrier and the oscillator (101-55.25 =45.75 mc) and the other equal to the difference between the sound carrier and the local oscillator (101-59.75 =41.25 mc). Before mixing, the sound carrier frequency was higher than the video; after mixing, the opposite is true.

CHANNEL 2
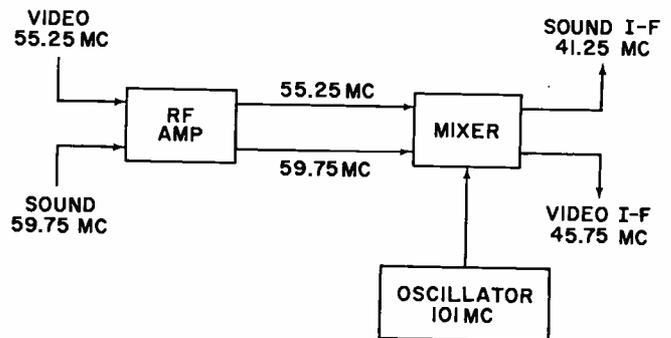
Fig. 18. Block diagram showing frequency conversion in the VHF tuner.
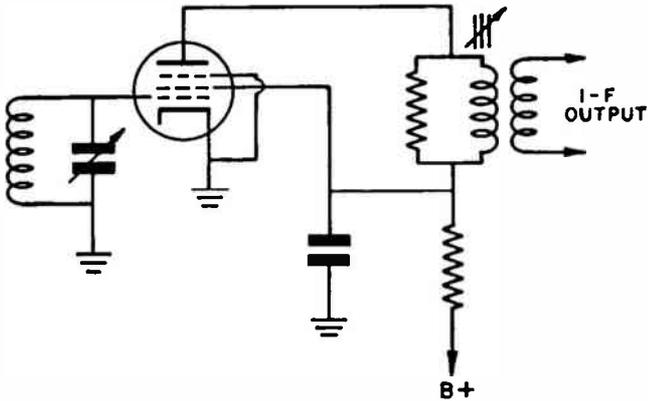
Fig. 19. Simplified schematic of a pentode mixer.

Pentode Mixers.

A simplified schematic of a pentode mixer is shown in Fig. 19. Notice that the circuit is similar to the circuit you might expect to find in a broadcast-band radio receiver. The oscillator and the rf signals are inductively coupled into the grid of the mixer stage. When a pentode mixer is used, low plate and screen voltages are used to keep tube noises at a minimum. Special tubes containing a pentode and a triode in one envelope have been developed for use in TV tuners.

A TRANSISTOR MIXER

A transistor mixer using a silicon NPN transistor is shown in Fig. 20. Notice that the circuit is not too different from the triode-tube mixer shown in Fig. 16.

In the circuit shown, L_1 is used with C_1, C_2, and the transistor input capacity to tune the input circuit to the desired VHF channel. The input signal is fed to the base of the transistor along with the signal from the local oscillator. Forward bias on the base is provided by the voltage divider consisting of R_1 and R_2. The output of the mixer stage is quite broad and tuned to the center of the i-f passband by L_2, which is adjustable. The parallel-resonant circuit in the output of the transistor consists of L_2 in parallel with the series-connected C_6 and C_7.

OSCILLATORS

The oscillators used in TV tuners using tubes are generally triodes. As we mentioned previously, a separate tube is usually used as the oscillator, although
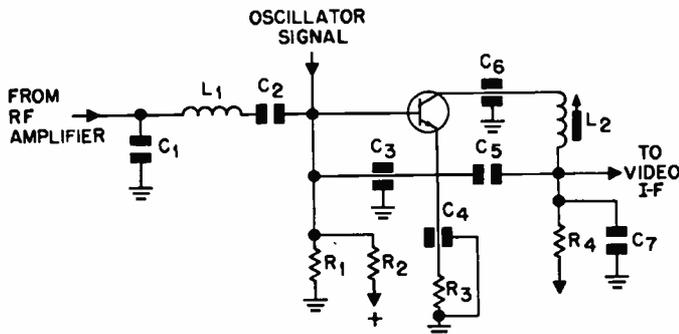
Fig. 20. A transistor mixer.

it may be in the envelope with the mixer.

A typical oscillator circuit is shown in Fig. 21. The oscillator tube is one half of a dual triode tube--the other half is the mixer. Generally, when a dual tube of this type is used, the coupling between the two sections of the tube is sufficient to inject the oscillator signal into the mixer. In some cases, additional coupling is provided.

An adjustable slug inside the oscillator coil L1 is used to adjust the oscillator to the correct frequency. Once the oscillator has been properly adjusted, any minor changes in oscillator frequency can be taken care of by adjusting the fine-tuning control.

The fine tuning requires only a very small change in capacity to produce any change in frequency that might be necessary. Most manufacturers use a capacitor consisting of two fixed plates and a movable dielectric. The dielectric is attached to a shaft mounted on the channel-selector switch and, by rotating the fine-tuning control, the position of the dielectric between the two plates of the tuning capacitor can be changed. Changing the dielectric changes the capacity of the capacitor, which in turn changes the oscillator frequency.
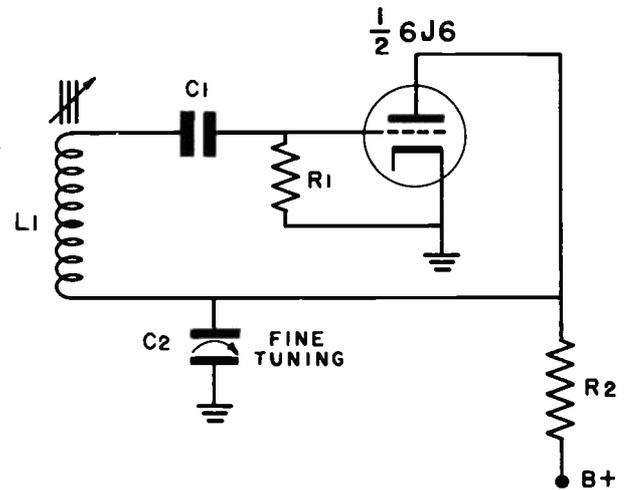
Fig. 21. Schematic of a simple triode oscillator.

In some oscillator circuits, where one side of the fine tuning capacitor is grounded, the chassis of the tuner is used as one plate of the capacitor. The other plate is a small metal plate insulated from the chassis. Instead of changing the capacity of the capacitor by changing the dielectric between the plates, sometimes the capacity is changed by changing the spacing between the insulated plate and the chassis. This produces quite large changes in capacity because the total capacity varies inversely as the square of the distance. If you cut the spacing between the plates in half, the capacity will be four times as great.

Preset Fine Tuning.

Many modern TV receivers have a feature known as "preset fine tuning". In the tuner used in this type of receiver, separate oscillator coils with adjustable slugs are used on each of the VHF channels. When
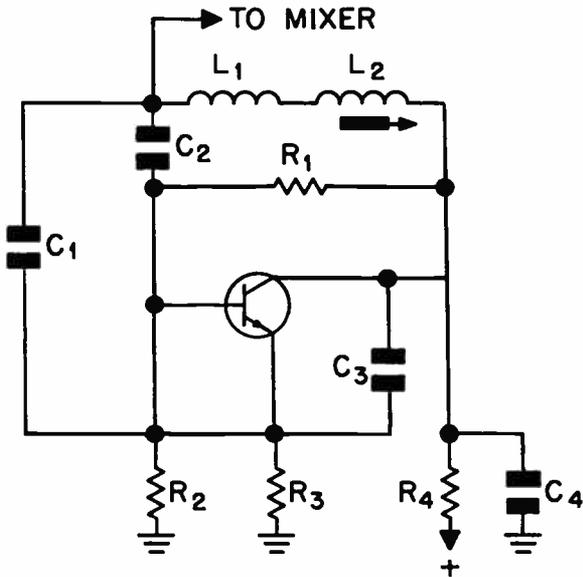
Fig. 22. A transistor oscillator.

the channel-selector switch is set to a given channel, the fine tuning is engaged to a gear or drive that permits the operator to tune the slug in the oscillator coil to the correct position.

Once the slug in the coil has been set to the correct position, the receiver can be tuned to another channel, and then the slug in the oscillator coil set. Once the slugs for the oscillator coils on the local VHF channels have been set, you can tune from channel to channel without resetting the fine tuning on each channel.

An example of a transistor oscillator using preset fine tuning is shown in Fig. 22. In this circuit an NPN transistor is used in the oscillator circuit. To tune from channel to channel, both L_1 and L_2 are changed. L_1, which is a fixed inductance, provides most of the required inductance. L_2, which is adjustable, is adjusted to add to L_1, to give the required total inductance for the channel to which the tuner is tuned.

SELF-TEST QUESTIONS

(o) What is the advantage of a triode mixer over a pentode mixer?

(p) Why are pentode mixers more widely used than triode mixers?

(q) Why is the sound i-f lower than the video i-f?

(r) Why are the plate and screen voltages on pentode mixers kept low?

(s) How is the capacity of the fine-tuning capacitor changed?

Complete VHF Tuners

Up to this point we have studied separately the rf amplifier, the mixer, and the oscillator circuits used in VHF tuners. Now, we will see how these circuits are put together in complete tuners and also how the task of switching from one channel to another is handled. There are a number of different types of tuners using different tuning systems. We will cover the more popular systems in detail.

You already know that the frequency of a resonant circuit can be changed by changing the inductance and/or the capacitance in the resonant circuit. Therefore we can change the frequency of a resonant circuit by keeping the capacity in the circuit constant and changing the inductance. We could, on the other hand, keep the inductance constant and change the capacity. We could also change both the capacitance and the inductance in the circuit. All three arrangements have been used in commercially manufactured tuners. However, in the majority of tuners, the capacitance in each circuit is held essentially constant, and the frequency of the resonant circuits changed by changing the inductances.

TURRET TUNERS

More television receivers have been manufactured using turret tuners than any other type. The tuner is called a turret tuner because the coils required for the various TV channels are mounted on a turret or drum, as shown in Fig. 23. The individual coils used
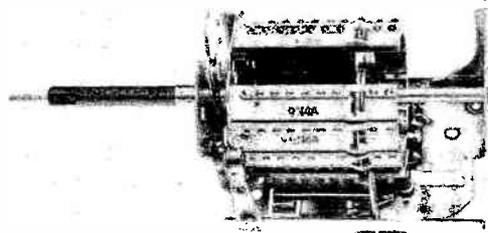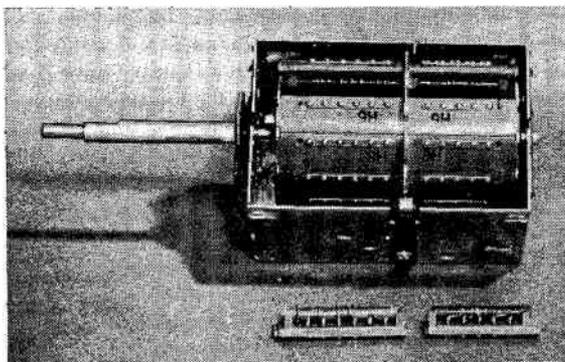
Fig. 23. Two turret-type tuners.

in a tuner of this type are mounted on strips. In the tuner shown in Fig. 23A, the rf and oscillator coils are mounted on one strip, and the antenna coil is mounted on another strip. In the tuner shown in Fig. 23B, all three coils for each channel are mounted on one strip. The strips from one channel are shown beside each tuner.

The drum is mounted inside the tuner, as shown in Fig. 23, so that the contacts from one set of coils will connect the coils to the external circuits through the fixed contacts inside the tuner (Fig. 24). To change from one channel to another, the drum is rotated until the coils for the desired channel are in contact with the stationary contacts.

The complete schematic of the tuner, shown in Fig. 23A, is shown in Fig. 25. Coils L_{101} and L_{102} are mounted on the strips located to the rear of the drum. Oscillator coil L_{105}, and coils L_{103} and L_{104} are mounted on the front of the drum. A slug inside the oscillator coil is accessible through a small hole in the front of the tuner case. It may be necessary to "touch up" this adjustment when the tuner is first put into service, and from time to time as the tubes and parts age. Let us take a closer look at this tuner to study some of the circuits it uses. It is typical of the type of tuner you may find in some of the older sets you will have to service.

The transmission line from the antenna is connected to the terminals marked A. The primary of the input transformer, L_{101}, is center-tapped, providing a balanced input. L_{102} is inductively coupled to L_{101}, and applies the signal induced in it to the grid of a pentode rf amplifier. The plate coil, L_{103}, and the mixer-grid coil, L_{104}, are overcoupled to provide the desired 6 mc bandwidth. The oscillator signal is fed into the mixer by the coupling between coils L_{104} and L_{105}.

This circuit is used to cover all twelve VHF channels. The tuner is switched from one channel to another simply by rotating the drum, which in turn inserts a new set of coils in the circuit.

The schematic diagram of the tuner shown in Fig. 23B is shown in Fig. 26. This is a later model tuner and comparison of Figs. 25 and 26 will permit you to see how tuners were improved over a span of several years. Notice in Fig. 26, the input is fed to a balun and then to a parallel resonant trap (C_{101} and L_{101}) to prevent i-f interference. The rf tube is a high gain triode tube designed for use as a VHF rf amplifier. The tube elements are quite small to keep interelectrode capacities at a minimum. The dc plate current through the tube is kept low to keep tube-generated noises as low as possible.

The coupling from the plate of the rf tube to the mixer is by means of inductive coupling between L_{104} and L_{105}. The pentode section of a 6CG8 tube is used as the mixer, the triode section of the same tube as the oscillator. Oscillator injection is by means of inductive coupling between L_{105} and L_{106} and by coupling through the tube.
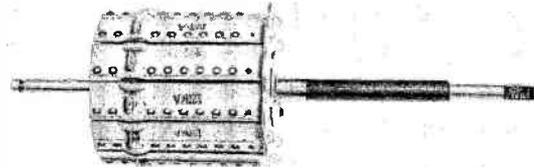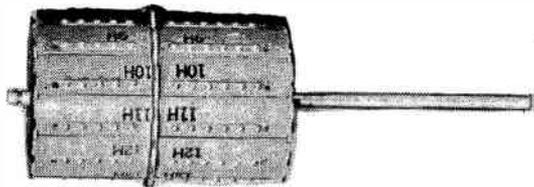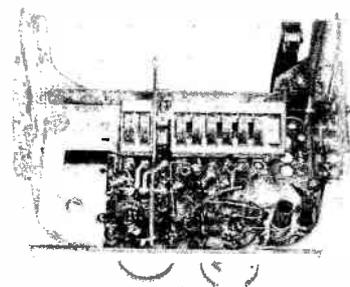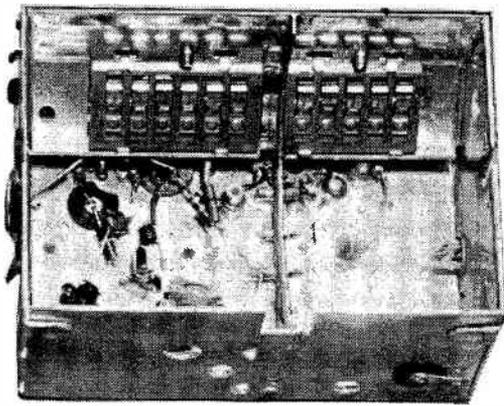
Fig. 24. Photos of the two types of turret tuners showing the drums removed and the inside of the tuner showing the stationary contacts.

The tuner shown in Fig. 23A was made for a sound i-f of 21.25 mc and a video i-f of 25.75 mc. These i-f frequencies were used in almost all receivers manufactured for a number of years after World War II. Later tuners with almost identical circuitry were made with a sound i-f of 41.25 mc and a video i-f of 45.75 mc. These frequencies are more or less standard and are used in all modern sets except a few imported receivers. The tuner shown in Fig. 23B was manufactured after the change in i-f, so all tuners of this type were made for the higher i-f frequencies.

Fig. 25. Schematic of VHF tuner with preset fine tuning.

ALL CAPACITANCE
VALUES STATED IN MMF

21.25 MC SOUND
25.75 MC VIDEO
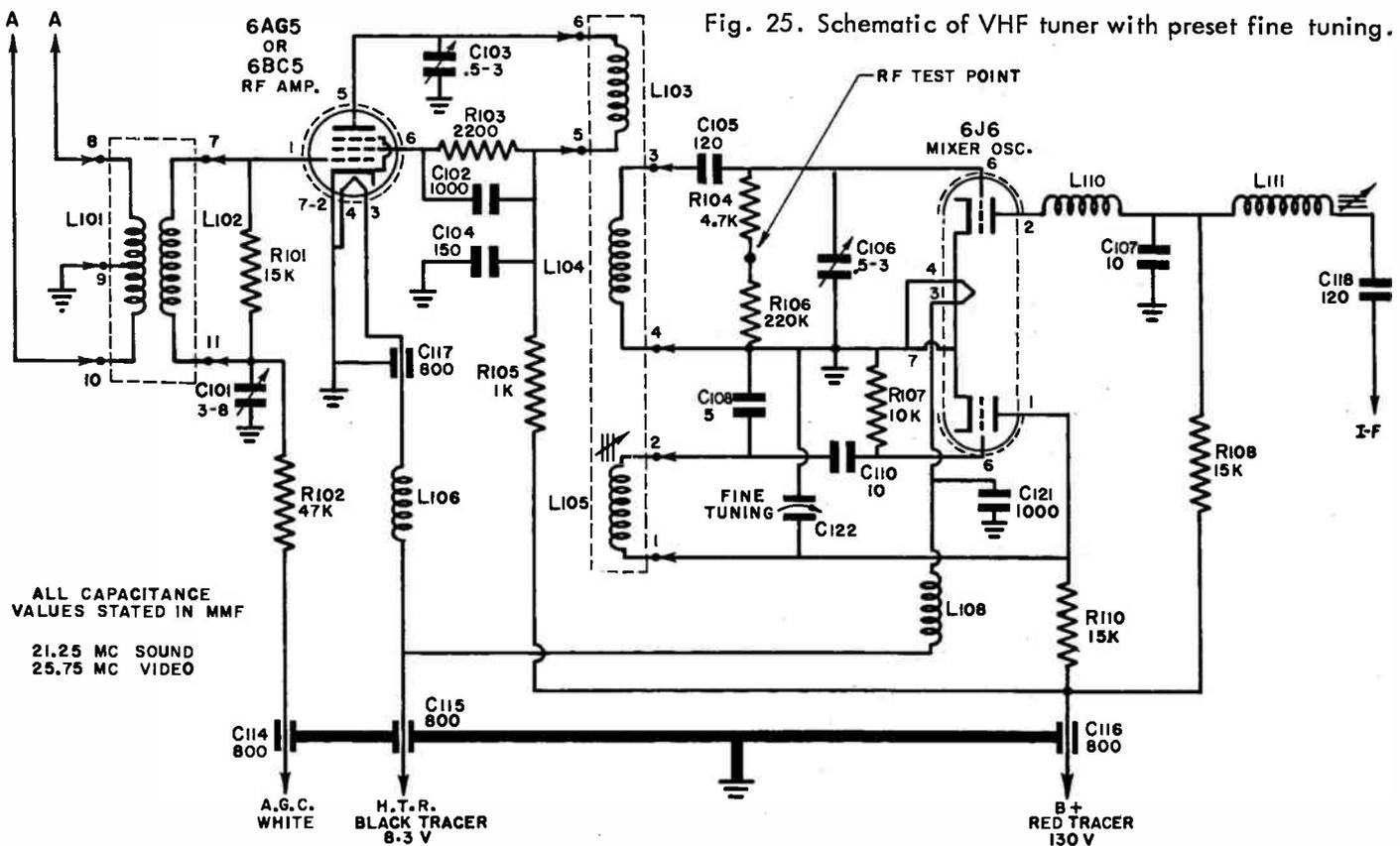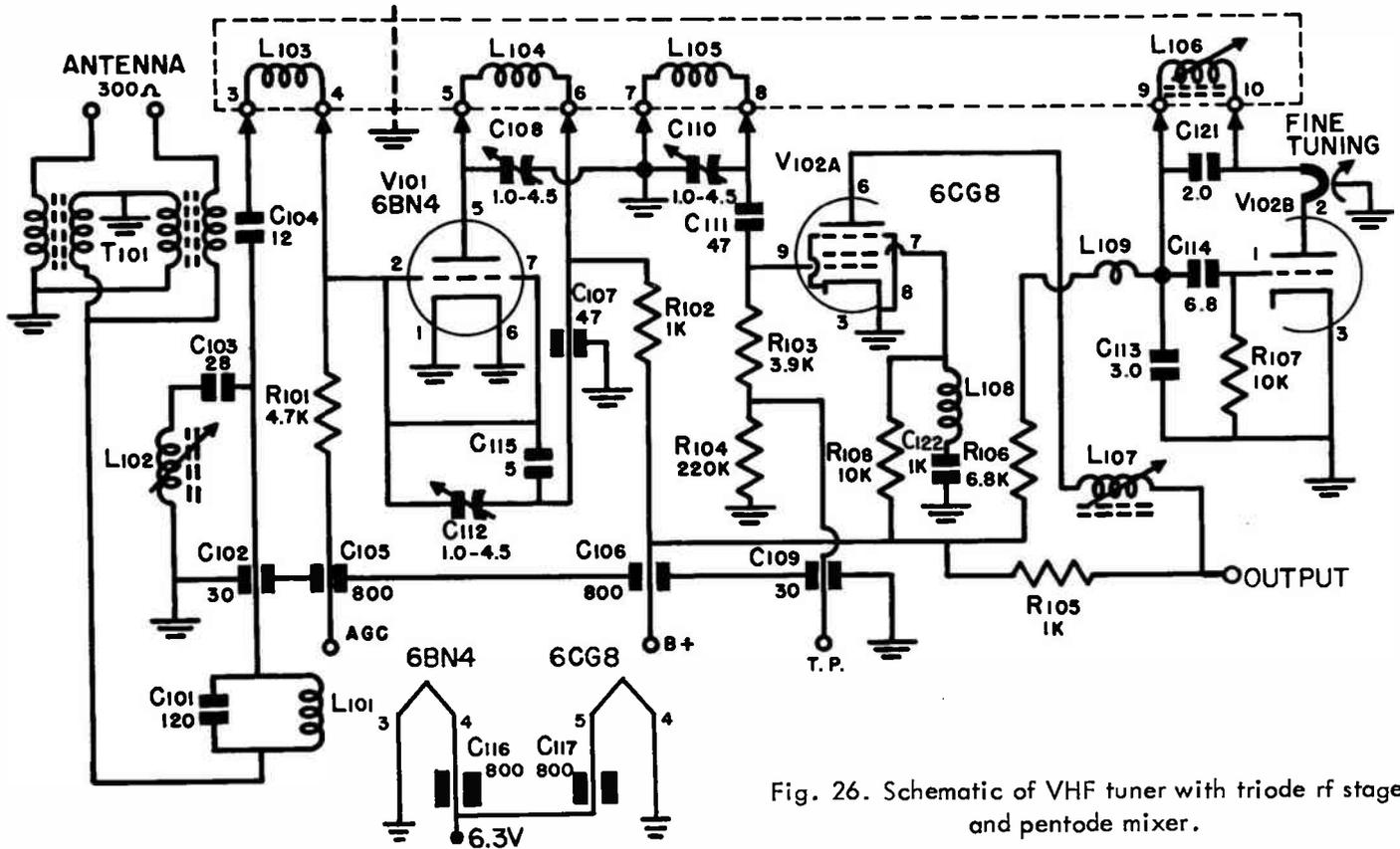
Fig. 26. Schematic of VHF tuner with triode rf stage and pentode mixer.

Another example of a turret-type tuner is shown in Fig. 27. In this tuner, all the coils are permanently mounted on the drum so that the coils for an individual channel cannot be removed. The only way you can remove a coil is to remove the entire drum assembly from the tuner.

The schematic diagram of this tuner is shown in Fig. 28. While the circuit is not too different from the one shown in Fig. 23, there are some variations. The input circuit in this tuner is not a balun, but a high-pass filter which prevents signals below 54 mc from reaching the rf amplifier. Also notice that the neu-

Fig. 27. Photo of turret tuner in which coils are permanently mounted on drum assembly.

tralizing signal is fed through C3 and through the antenna coil to the grid of the rf tube. In Fig. 26, the signal is fed from the rf plate coil through C_{112} and C_{115} to the grid of the tube.

Perhaps the most interesting difference in the tuner shown in Fig. 28 is in the oscillator fine tuning. This tuner uses preset fine tuning (a feature we briefly described earlier) in the oscillator circuit. Fine tuning is accomplished by varying the setting of a slug in the oscillator coil. There is one slug for each coil, so the setting does not affect the oscillator on any other channel. Fine tuning is accomplished by means of a gear drive, which engages a small gear attached to the oscillator slug when the fine tuning is rotated.

As soon as the fine-tuning control is released, a spring disengages the gear drive. Once the oscillator slug is set for a channel, it shouldn't move, so you should find that once the coils have been set you'll be able to tune from channel to channel without touching the fine-tuning control. The photo in Fig. 29 shows the fine-tuning gears and the oscillator slug gears.

The most common cause of trouble in tuners is dirty contacts. When the tuner contacts are dirty, you may find the receiver noisy on some or all channels. You may have to wiggle the channel selector back and forth when you change channels to make a good contact before the station will come in. Sometimes when you are watching a program the picture simply disappears and you have to wiggle or rotate the channel selector back and forth to get the picture back. On other occasions when watching a color program, the sound and picture may remain, but the color may disappear. These are all symptoms of dirty tuner contacts.

The big advantage of the turret tuner is that the drum can easily be removed from the tuner assembly. Once the drum has been removed, the contacts on the drum can be cleaned as well as the stationary contacts inside the tuner. After the contacts have been cleaned you should lubricate them before reassembling the tuner. Suitable tuner contact cleaners and lubricants can be obtained from any radio-TV wholesaler.

STEP-TYPE TUNERS

In this section we will discuss a tuner using rotary switches, as shown in Fig. 30. In this type of tuner, the inductances are mounted right on the rotary switch. Tuning to a lower channel simply adds inductance to the circuit. When you start off at Channel 13, you have a relatively low inductance in the circuit. If you switch the tuner to Channel 12, you leave the original inductance in the circuit and add an additional inductance. Each time you switch the tuner to a lower channel, inductance is added, until you have tuned to Channel 2, when all the inductance will be in the circuit.

With this type of tuner, a defect in any coil upsets the performance of all channels below it. For example, a defect in the coil connected between the Channel 5 and Channel 6 contacts on the switch may upset the performance of a number of channels. Channels 6 through 13 inclusive would work satisfactorily, but Channels 2, 3, 4, and 5 might be affected by the defect.

The schematic diagram of a cascode tuner using
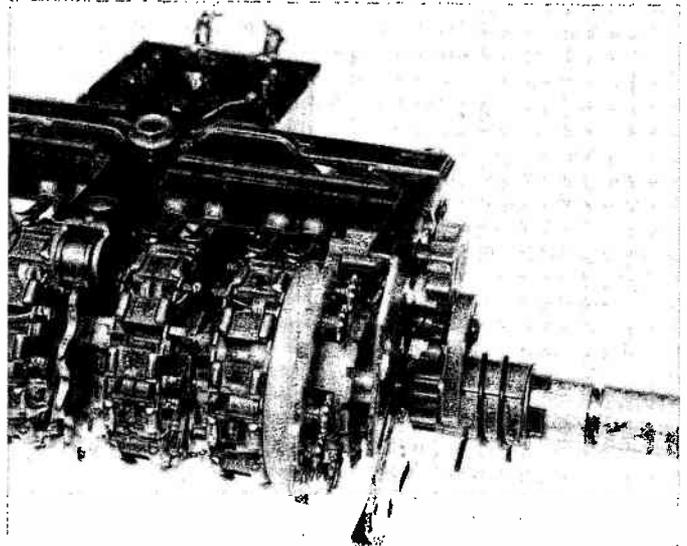
Fig. 29. Photo of tuner showing fine-tuning gears and gears on oscillator slugs.

rotary switches is shown in Fig. 31. Inductance is added to the circuit as you tune from the higher channels to the lower ones by adding coils in series.

In the input of the tuner there are a number of traps. Two i-f traps are used to eliminate interference that may be caused by nearby transmitters operating in the i-f passband. An FM trap is also incorporated and

Fig. 28. Schematic of VHF tuner with preset fine-tuning.
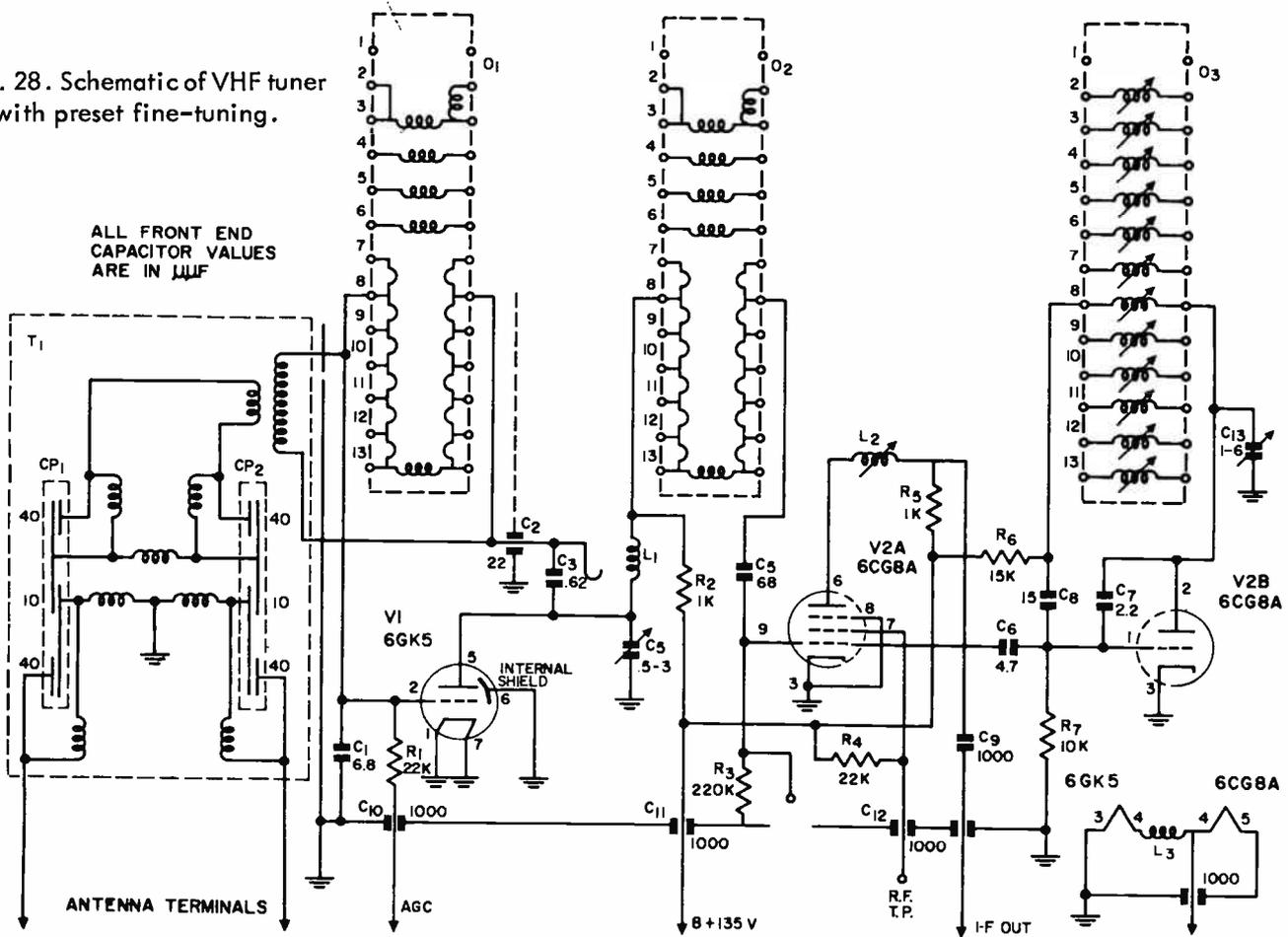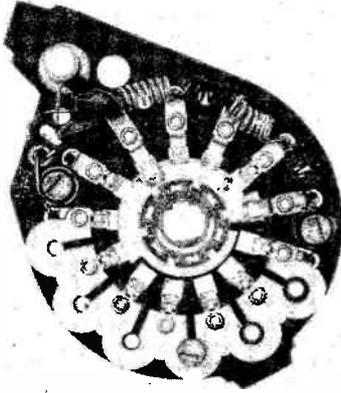
Fig. 30. One of the switch decks used in a step-type tuner. The inductance for the high band is provided by the semicircular loop of metal at the bottom of the deck.

can be tuned to eliminate FM interference that might be caused by a nearby FM station.

The rf amplifier is the dc type of cascode rf circuit, which we discussed previously. The rf tube is specially designed for use in this type of circuit.

A specially designed tube is also used in the mixer-oscillator stage. The pentode section is the mixer, the triode section is the oscillator. The oscillator signal is injected into the mixer grid through capacitor C_{22}. C_{27} is the oscillator fine tuning.

A schematic of this tuner may appear rather formidable and you might think that it would be an extremely difficult job to trace out all the circuits in the tuner. As a matter of fact, it would be difficult to try to trace out all of the circuits, but as a serviceman, you will have no occasion to try to do this. The important things for you to recognize are the types of circuits used and how the tuning is accomplished, so that when you have to service a tuner of this type, you will know what type of defect may be expected to cause the trouble you have encountered.

Insofar as the actual circuits themselves are concerned, as we mentioned previously, the rf amplifier is essentially a conventional dc-coupled cascode amplifier. The mixer and oscillator circuits are standard. Tuning is accomplished by varying the amount of inductance in the circuit. The switches marked S1-E tune the input to the rf amplifier, switches S1-C are used to tune the output circuit of the rf amplifier, switches S1-B tune the input of the mixer, and switch S1-A tunes the oscillator circuit. That is about all you have to know about the tuner to start to service it. When you have isolated the trouble to one circuit, you can then trace out that one circuit if necessary.

A schematic diagram of a more modern VHF tuner using rotary switches is shown in Fig. 32. You'll notice immediately that the diagram looks far less complicated than the one shown in Fig. 31. Of course, the triode rf stage is simpler than the cascode stage, but much of the simplification is due to the way the

diagram is drawn. The coils are drawn in a straight line rather than in a circle as they are arranged around the switch section. However, since the purpose of a schematic diagram is to show the electrical connections, not the physical arrangement of the parts, there is no reason why the circuit diagram cannot be simplified in this way.

For the most part, the circuit is similar to the turret-type tuners described previously. However, this tuner is designed for use in an ac-dc receiver using a series heater string. The heater of the mixer oscillator tube is connected to the chassis and B-, therefore the tuner must be placed at the B- end of the string. In order to provide good rf grounds and proper shielding, the tuner chassis must be connected to B-. Since B- will be connected to one side of the power line and this could be a shock hazard, the tuner chassis in a receiver of this type should be insulated from the main receiver chassis. Also the channel selector shaft and the fine-tuning shaft must be insulated from the chassis.

Notice also that the antenna terminals are isolated from B- and the tuner chassis. Isolation is by means of the 470-mmf capacitors and the 1.5-meg resistors. This is to eliminate the shock hazard that could exist if B- is connected to the hot side of the power line and the antenna or antenna transmission line is grounded. The service technician must always be careful in servicing this type of set to avoid touching B- and any grounded object.

Another VHF step-type tuner is shown in Fig. 33. Notice this tuner has 13 positions, one for each of the twelve VHF channels and a thirteenth position for UHF reception.

In the twelve VHF positions, the signal is fed into the 300-ohm input, through the balun and high-pass filter in the input section, to the rotor of the switch section. This rotor is marked S4R and it is electrically connected to the rotor marked S4F. Thus the VHF signal goes through the switch and coil assembly to the grid of the triode rf tube. The remainder of the tuner is similar to the other VHF tuners we have described.

In the UHF position, which is marked Channel 1, the signal is fed from a separate UHF tuner through the coil assembly to the grid of the rf stage. The signal from the UHF tuner is an i-f signal with a 41.25-mc sound frequency and a 45.75-mc picture frequency. Coil L_{20} is switched into the plate circuit of the rf tube and L_{21} into the grid circuit of the mixer which now acts as an i-f amplifier. There is no plate voltage applied to the oscillator tube, so it does not oscillate. One section of the channel selector switch completes a circuit which applies voltage to the UHF converter.

Since the law requiring manufacturers to build sets to receive all UHF channels as well as the VHF channels went into effect, all manufacturers have used an arrangement of this type. It is easier and more economical to use two separate tuners, one for VHF and one for UHF, than to try to design and build a single tuner that will cover both the VHF and UHF channels.
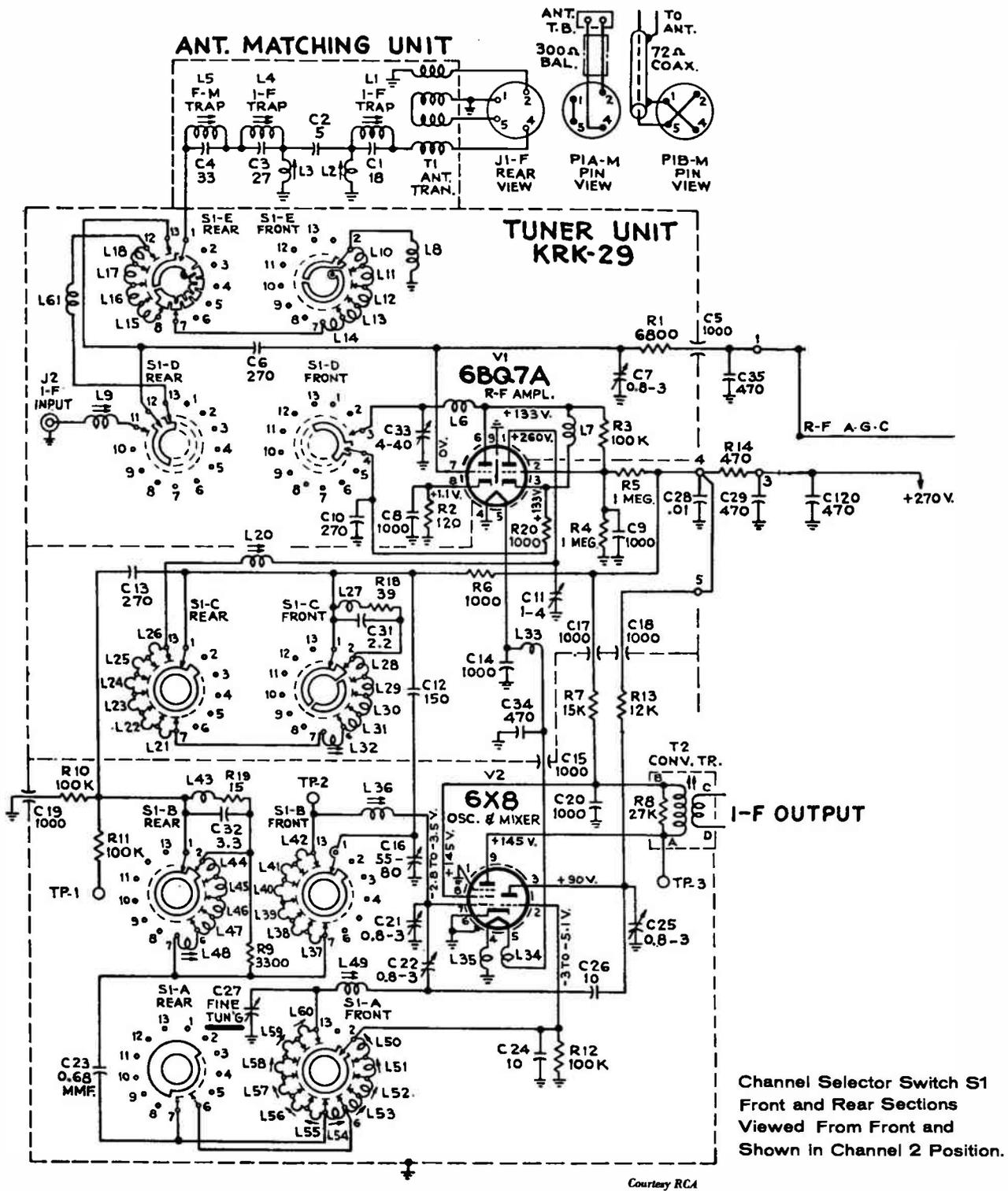
Fig. 31. A cascode tuner using rotary switches.

SELF-TEST QUESTIONS

(t) How is the resonant frequency of the tuned circuits changed in most VHF tuners?

(u) What type of tuner has been most widely used for VHF?

(v) What is the most common cause of trouble in tuners?

(w) What is T_{101} in Fig. 26 called?

(x) Why are the resistors and capacitors used in the antenna input of the tuner shown in Fig. 32?

(y) What is the network consisting of C_1, L_2, L_3, C_2, L_4 in the input circuit of Fig. 33?

(z) What is the purpose of L_{20} and L_{21} in Fig. 33?
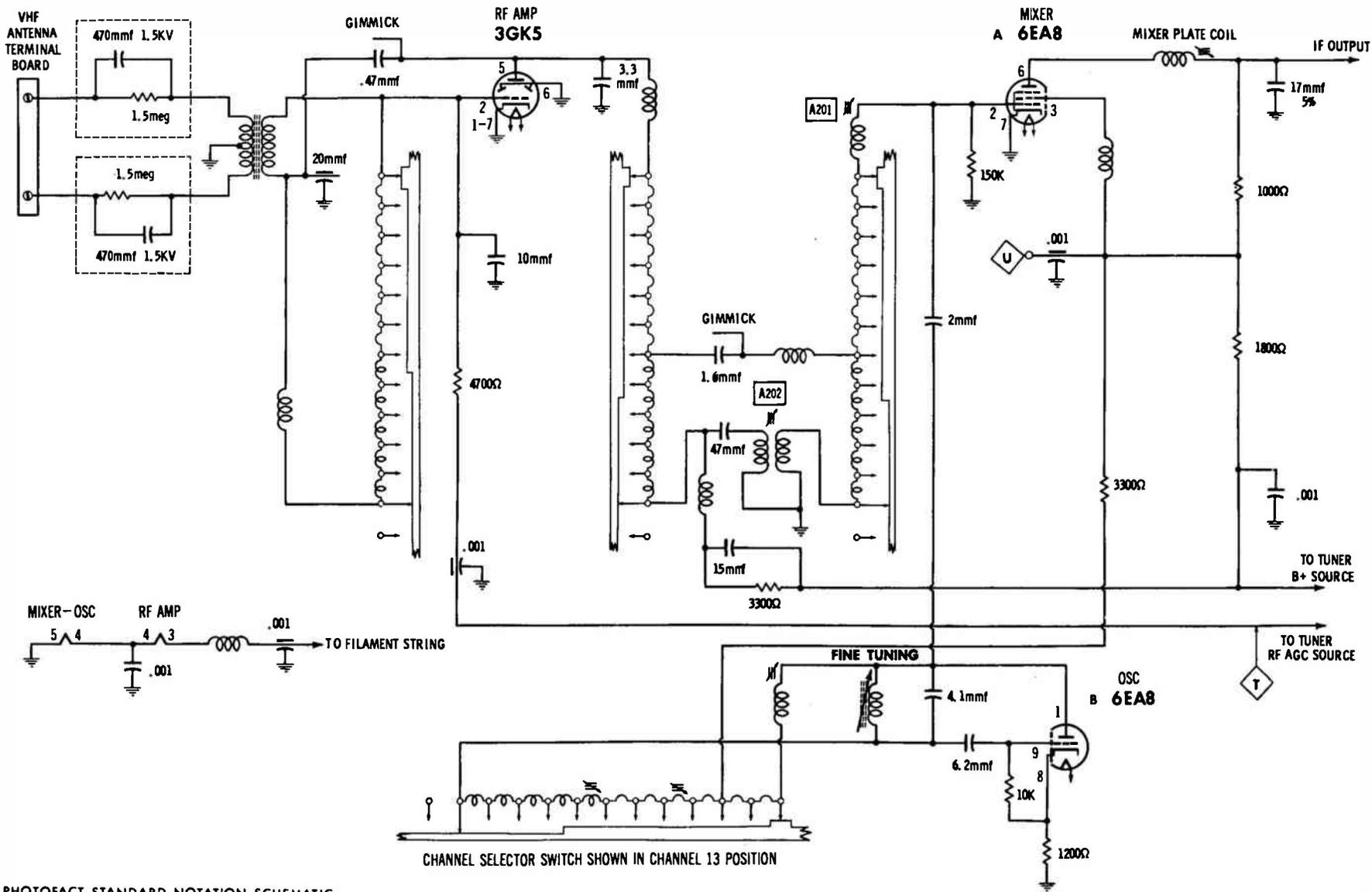
Fig. 32. A modern step-type tuner.

B507 – 20
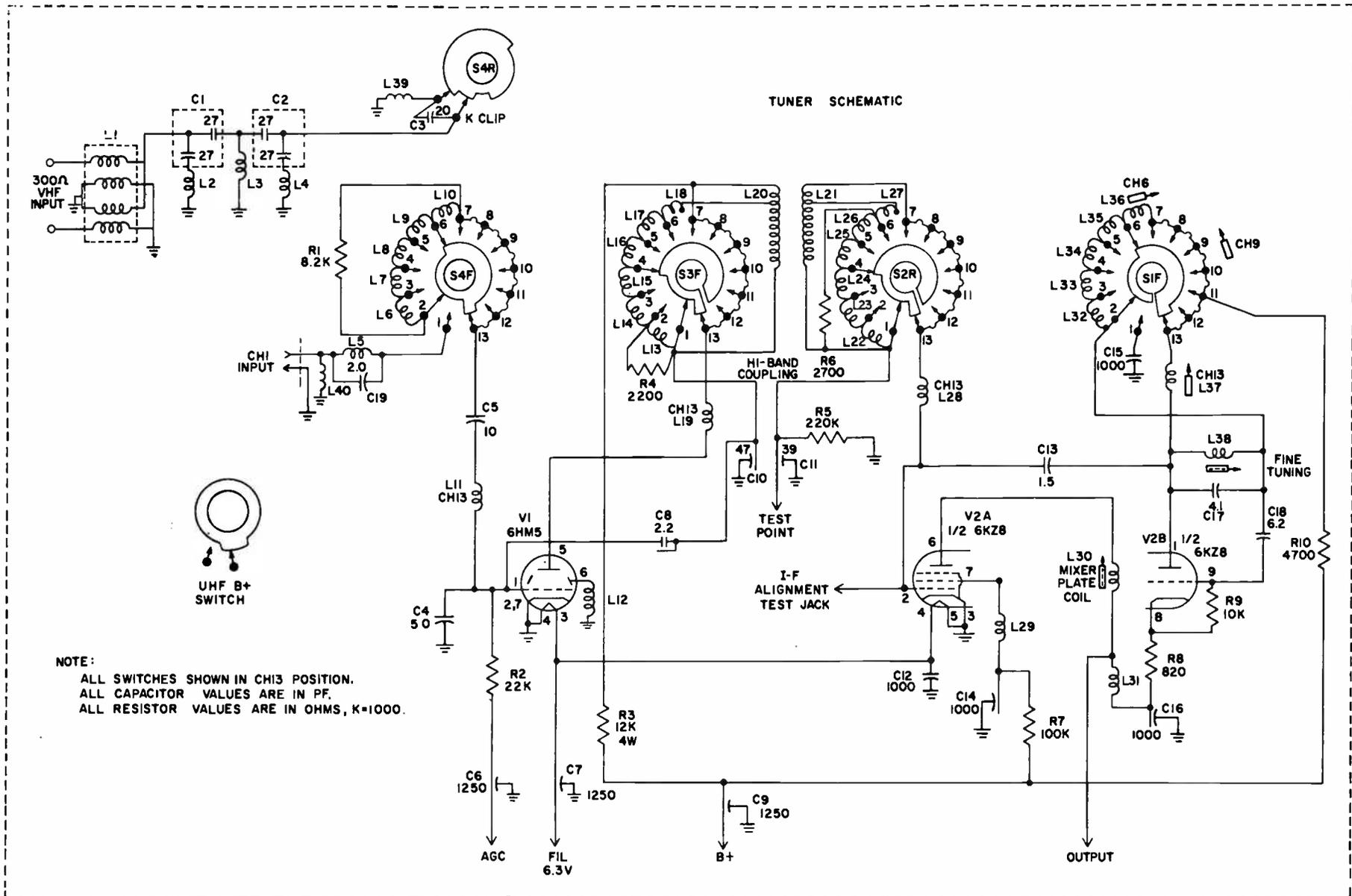
Fig. 33. A VHF step-type tuner with a UHF position.

UHF Tuners

Although UHF tuners must operate at a much higher frequency than VHF tuners and their design is quite exacting, the tuners themselves are very simple. As a matter of fact, your first look inside a UHF tuner will immediately make you ask the question, "what is in it?" Actually, there is usually a fairly large amount of circuitry, but the parts are so small and look so simple that at first glance you may not realize exactly how many circuits there are in the tuner.

There are two basic types of UHF tuners. The first type converts the UHF signal to a VHF signal and then the signal is converted to an i-f signal in the VHF tuner. This is a double conversion process and was used in early VHF-UHF sets and used in UHF converters that were sold separately for use with VHF only receivers.

The second type of UHF converter converts the signal directly to an i-f signal. This is a single conversion process and is used in the modern UHF converters used in late model all-channel receivers.

SINGLE CONVERSION TYPE

An example of a modern UHF converter is shown in Fig. 34. The schematic of the tuner is shown in Fig. 35. This tuner is used with the VHF tuner shown in Fig. 33 to provide all-channel TV reception.

The UHF tuner is energized when the VHF channel selector switch is tuned to the UHF (Channel 1) position. Then voltage is supplied through a switch on the VHF tuner and through a suitable dropping resistor to the UHF oscillator.

In the UHF tuner, the 300-ohm line is transformed by T_1 to match the input of the tuned circuit. The tuned circuit consists of C_1, C_2, L_1 and L_2. At 470 mc, the low end of the UHF band, the circuit looks like Fig. 36A. At 890 mc, the high end of the band, it
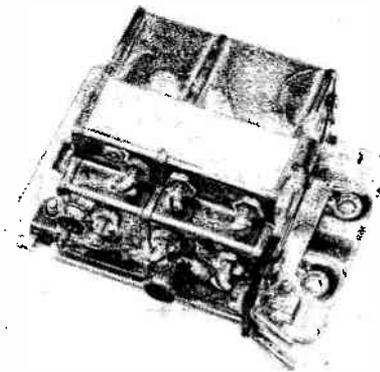
Fig. 34. Photo of modern UHF tuner.

looks like Fig. 36B. Capacitor C_2 serves as the 470-mc adjustment and C_1 as the 890-mc adjustment. Notice that at 890 mc, as the value of the inductance decreases, C_2 is almost shorted out of the circuit. Thus with both the inductances and capacitances decreasing, a wide tuning range can be obtained and at the same time a fairly constant L/C ratio maintained.

The second tuned circuit, consisting of C_3, C_4, L_3 and L_4, is essentially the same type of circuit. Coupling between the two circuits is magnetic. There is a shield between the two circuits, but the shield has small openings in it called windows through which the magnetic field is able to link the two circuits.

The transformer T_2 matches the tuned circuit to the diode detector. A crystal diode is used to get the best possible signal-to-noise ratio. Other types of mixers are unsatisfactory in the UHF region because of the very high noise they generate.
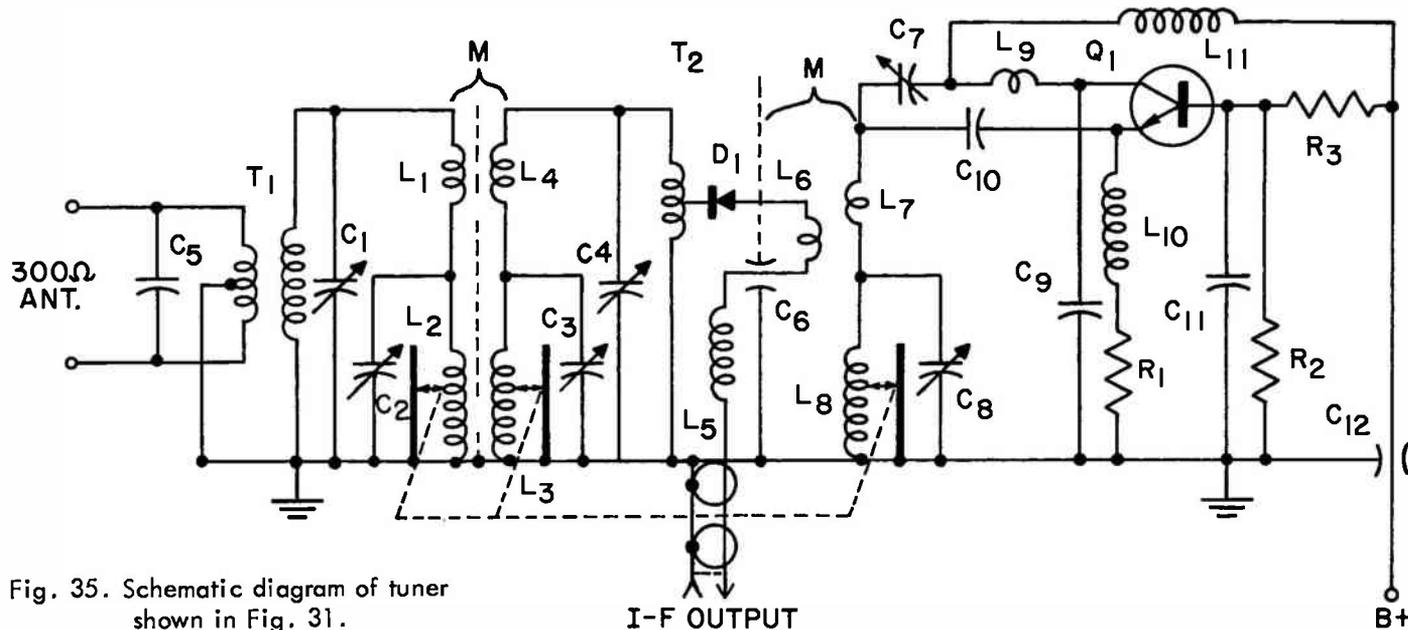
Fig. 35. Schematic diagram of tuner shown in Fig. 31.

I-F OUTPUT

While UHF tuners using vacuum tubes have been made, most modern tuners use transistor oscillators. There were a few tuners made using tubes that were almost identical to the one shown in Fig. 34, but this tuner was discontinued in favor of the transistor model.

The transistor used in the Fig. 35 oscillator circuit is a silicon planar epitaxial type. It is used in a common base circuit. A simplified schematic of the oscillator tuned circuit at 470 mc is shown in Fig. 37. As the oscillator is tuned towards 890 mc, C_8 is shunted by a continuously smaller value of inductance and thus the shorting effect increases as in the rf circuit to keep the effective L/C ratio constant and to provide the required wide tuning range. C_{10} is the feedback capacitor; C is emitter-to-base and stray shunt capacities.
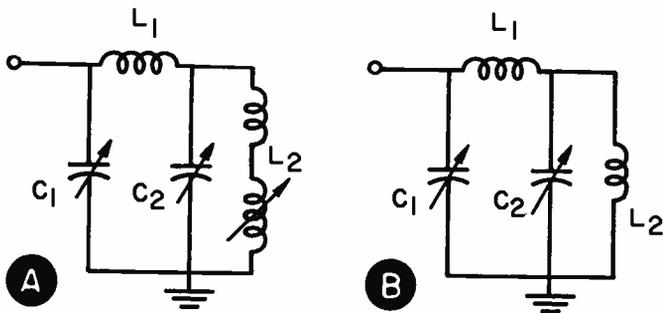
Fig. 36. Schematic of basic tuned circuit.

The signal from the oscillator is coupled from L_7 through a window to L_6. The i-f signal produced in the mixer is fed through the broadband filter consisting of L_5 and C_6 to the i-f input of the VHF tuner.
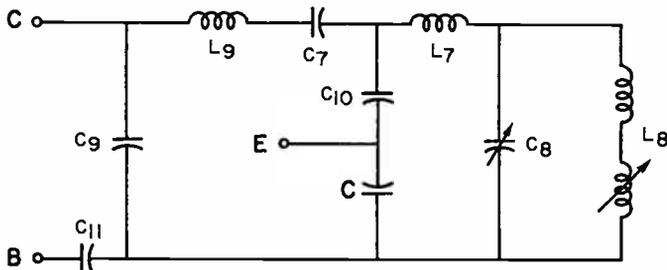
Fig. 37. Schematic of an oscillator tuned circuit.

The inductances L_2, L_3, and L_8 form the heart of this tuner. They are made in the shape of a ring, as shown in Fig. 38. These rings are made to a very exact shape and size to provide the exact inductances required. The inductance is varied by means of moving contacts that slide over the surface of the inductances, as shown in Fig. 39. The inductance rings are carefully plated with silver to a very precise thickness to keep the skin resistance of the inductances as low as possible. A flashing of gold is added over the silver to prevent corrosion.

In a UHF tuner such as this where the UHF signal must be converted directly to the same i-f as used with the VHF tuner, the oscillator must operate above the channel frequency. It must be 41.25 mc above the sound frequency and 45.75 mc above the video fre-
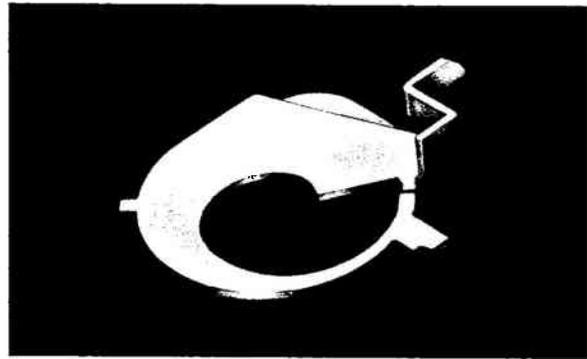
Fig. 38. A UHF Inductance Ring.

quency to produce the correct i-f. We'll see later that with double conversion tuners, the opposite is true; the oscillator must be operated below the frequency of the incoming signal.

COMBINATION UHF-VHF TUNERS

Since the number of UHF channels likely to be assigned any one locality is limited, there is really no need to be able to tune all the channels. Before the law was passed requiring all-channel reception some manufacturers built sets designed to cover a number of VHF channels plus a number of UHF channels. An example of this type of tuner is shown in Fig. 40. It can be set up for any 16 TV channels. Usually the tuner is set up to cover the 12 VHF channels and four of the UHF channels. The tuner is a turret-type, and the strips for any unused channel can be removed and strips for another channel inserted.

A crossover network is used in the antenna input circuit. The lead-in from a VHF antenna can be connected to one set of terminals and the lead-in from a UHF antenna to the other set. The signals are fed through a network to the stationary contacts marked 1 and 2 on the diagram.

When the tuner is used on any of the VHF channels, a 6BQ7A cascode rf amplifier is used. The output from this amplifier is fed to a crystal mixer where the rf
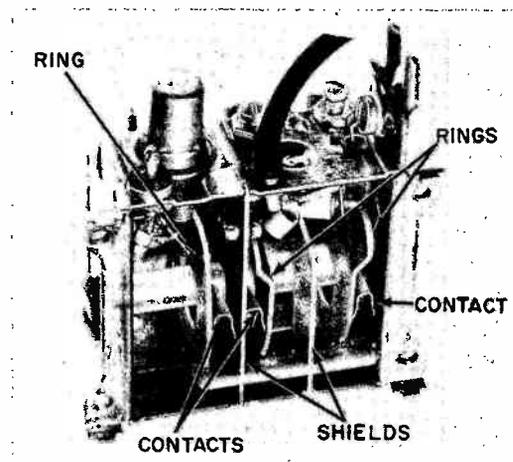
Fig. 39. UHF tuner showing moving contacts on Inductance Rings.
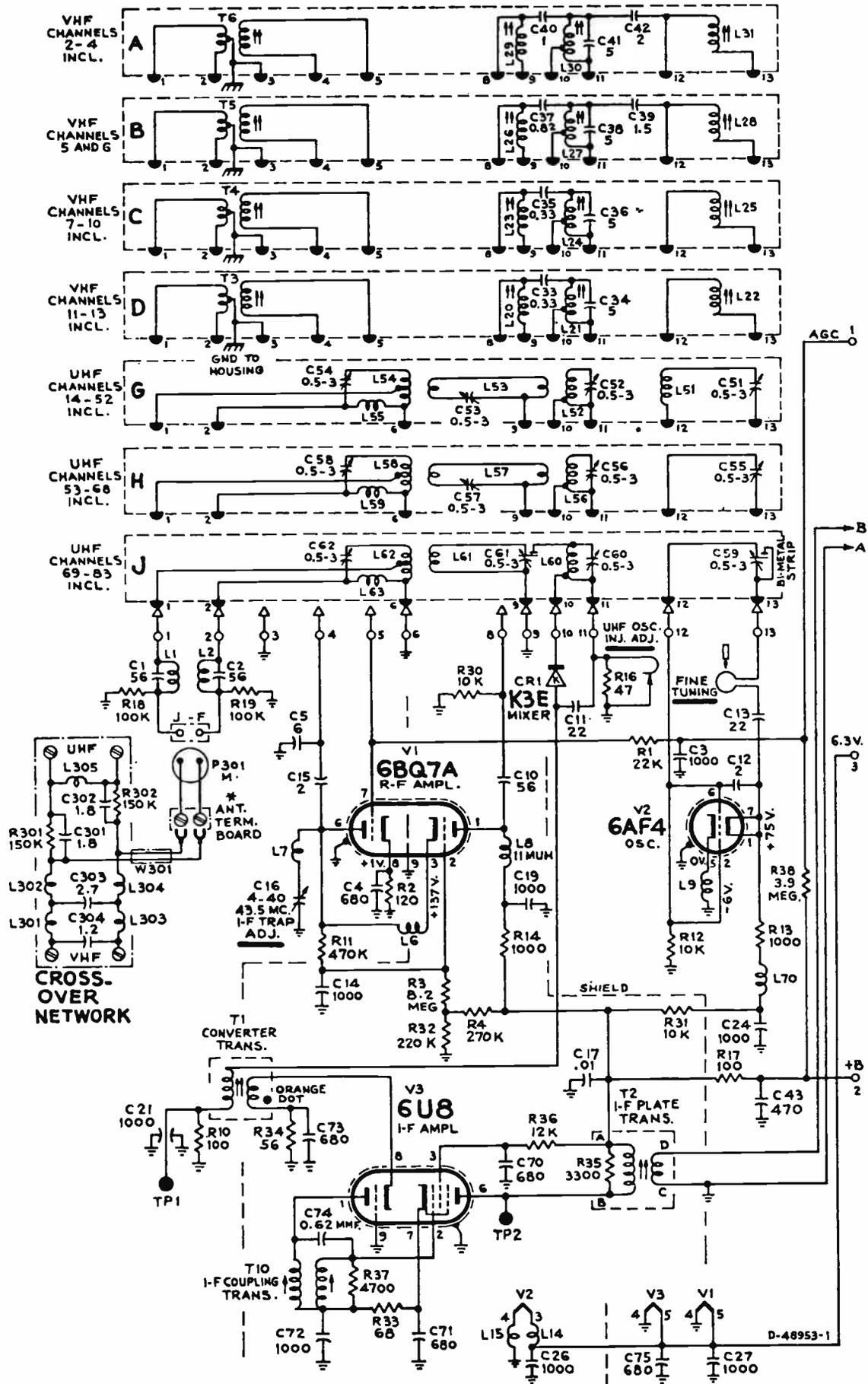
Fig. 40. A VHF-UHF tuner used in an RCA color TV receiver.
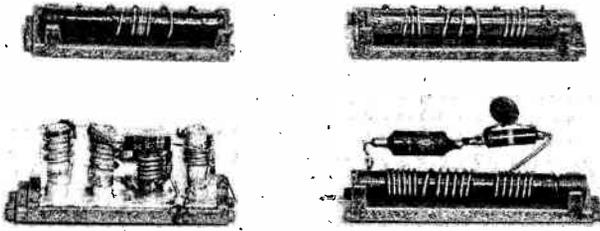
Fig. 41. UHF (below) and VHF strips from a turret-type tuner.

signal is beat with the signal from the local oscillator. The output of the mixer is fed to an i-f amplifier. Let us examine the tuner in more detail and see what happens when the tuner is tuned to Channel 2.

In the Channel 2 position, the coil strip on the top of the diagram, marked A, will be connected to the stationary contacts. In this position the signal from the antenna is fed to the primary of T_6, and the secondary of T_6 applies the signal to the rf amplifier input. The signal is amplified by the 6BQ7A used in a dc-coupled cascode amplifier, and the output from this stage is fed to the stationary contact marked 8. Coil L_{29} provides a tuned load in the output of the rf amplifier, and the signal is coupled to coil L_{30} which is connected to the mixer input. Coil L_{31} is the oscillator coil; on this channel, the signal is coupled through C_{42} to the mixer coil. The incoming signal and the signal from the local oscillator are fed into the crystal mixer.

The output signal from the mixer is fed to the converter transformer T_1. The secondary of the converter transformer is connected to the cathode of the triode section of the 6U8 i-f amplifier. This tube is used in a grounded-grid circuit. The output signal from the triode section is coupled through i-f coupling transformer T_{10} to the grid of the pentode section of the i-f amplifier, and the output from this stage is fed to the following video i-f stages.

When the tuner is used on the UHF channels, the rf amplifier is not used. Let's examine the tuner circuit when the UHF strips marked G are in place. The signal from the antenna again is fed through the stationary contacts of terminals 1 and 2 to L_{54}. L_{54} is inductively coupled to L_{52} through the link of L_{53}. The coil L_{52} connects to the mixer. The oscillator signal is mixed with the incoming signal, and the output fed directly to the triode section of the 6U8 i-f amplifier.

Notice the difference in the circuit of the tuner when it is used on UHF channels compared to the circuit on VHF channels. When it is tuned to a VHF channel, the rf stage is used before the mixer. However, when it is tuned to a UHF channel, the signal is fed directly to the crystal mixer—there is no rf amplifier. As we have pointed out previously, this is more or less standard practice, because it is extremely difficult to design an rf amplifier that will function efficiently at the high frequencies of the UHF channels. On the other hand, if the signal can be converted to a lower frequency immediately, then it can be handled with comparative ease.

Note that this tuner does not utilize the VHF rf amplifier as an i-f amplifier on UHF channels. The mixer output is at the receiver i-f frequency, and the VHF rf amplifier is completely out of the circuit when a UHF channel is being received.

While modern TV receivers do not use this type of
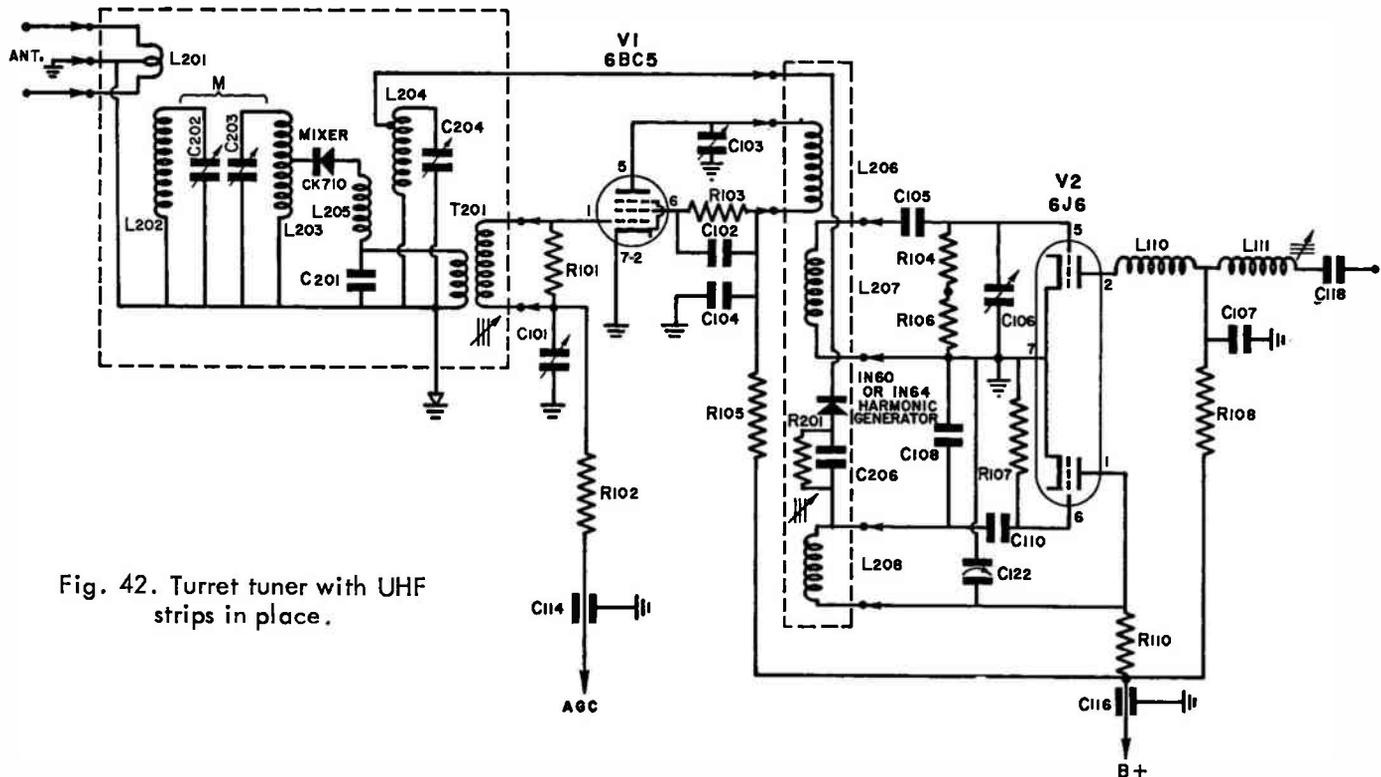
Fig. 42. Turret tuner with UHF strips in place.

UHF-VHF tuner, there were many sets made that did use them, so you should know how they work. Then you'll be able to service any you might encounter.

DOUBLE CONVERSION TYPE

When the UHF channels were first authorized by the FCC, there were relatively few all-channel receivers manufactured. Most large cities were adequately served by VHF stations. There were only a few UHF stations on the air in the early years of UHF TV and reception from them was not (and still is not) as satisfactory in most cases as from VHF stations. There simply was no market for an all-channel TV receiver.

However, in some areas, where there was one UHF station operating, UHF reception could be obtained with receivers that used turret tuners with removable strips by removing one of the unused VHF strips and inserting a UHF strip designed for the channel in its place. The VHF strips from the tuner shown in Fig. 25 are shown on the top in Fig. 41, and a set of UHF strips that replaced them are shown on the bottom.

The schematic diagram of the tuner with the UHF strips in place is shown in Fig. 42. Notice how the circuit is changed by the insertion of the UHF strips. The incoming signal is selected by the resonant circuits consisting of L_{202}-C_{202} and L_{203}-C_{203}. The signal is then fed directly to a crystal mixer where it is mixed with a locally generated signal. This signal is obtained by feeding a signal from the local oscillator to a crystal harmonic generator. The incoming UHF signal is mixed with a harmonic of the oscillator and converted to a signal in the VHF region. The VHF signal is fed to the original rf amplifier by T_{201}. The signal is amplified by this stage, which is now acting as an i-f amplifier, and then fed to the 6J6 mixer. In the 6J6, the signal is mixed with the fundamental of the oscillator to produce the required sound and video i-f signals.

There are several noteworthy things about the way in which the tuner is used on the UHF channels. There is no rf stage ahead of the UHF mixer. A crystal mixer, which is mounted on one of the strips, is used to convert the UHF signal. Double conversion is used to reduce the signal to the sound and video i-f signals, and the 6BC5 tube that was used as the rf tube at VHF, now serves as a VHF i-f tube between the UHF and VHF mixers. By using this tube as an i-f amplifier, excellent image rejection can be obtained because the first i-f stage operates at VHF. In addition, it is possible to take advantage of the extra gain that can be obtained from this stage.

It is interesting to note that in a double conversion arrangement, the UHF oscillator signal must be below the frequency of the incoming UHF signal. This is necessary because the VHF signal produced in the UHF mixer must be like the VHF signal transmitted by the VHF stations. The sound carrier must be 4.5 mc higher than the video carrier. If the UHF oscillator operates above the incoming signal, the oscillator frequency minus the sound frequency will be less than the oscillator frequency minus video frequency. If the oscillator operates below the incoming signal, the
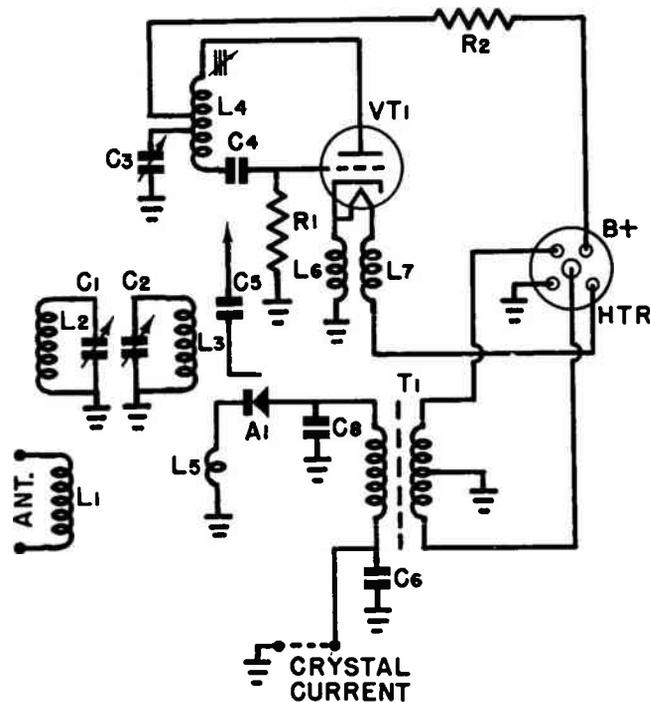
Fig. 43. A single-channel UHF converter.

sound difference signal will be higher in frequency than the video difference signal.

Although the results from this type of UHF tuner arrangement may not be as good as those obtained from a tuner designed primarily for UHF reception, generally speaking, the performance is entirely satisfactory. In addition, the convenience of having only one tuner is superior in many ways to having two tuners as we do in modern receivers.

Some of the older TV receivers had a socket on the back to which a single channel UHF converter could be connected. The converter obtained its operating voltage from the TV receiver. For UHF reception, the receiver was tuned to one of the unused low band VHF channels and then the converter turned on. A schematic of this type of converter is shown in Fig. 43. Again since double conversion is used, the UHF oscillator operates below the frequency of the incoming UHF signal. These converters were widely used in areas where one or more VHF stations plus one UHF station operated.

There were many different brands of all-channel UHF converters introduced before the advent of the all-channel receivers. However, except in a few areas the sales of these converters were very limited. For the most part the public was satisfied with VHF TV and didn't want to spend the extra money to get UHF. These converters used a crystal mixer and vacuum tube oscillator to convert the signal to a VHF channel, usually either Channel 5 or 6. Some of the more elaborate converters had an i-f stage which amplified the output signal from the mixer before feeding it to the VHF receiver. If you should run into one of these converters for servicing, you'll probably find it easy enough to find the trouble, but if the defect is in any of the parts in the tuned circuits, the chances are

you will be unable to get replacement parts.

SELF-TEST QUESTIONS

(aa) Why are diode mixers used in preference to tubes at UHF?

(ab) In the UHF tuner shown in Fig. 35, what are two advantages of changing both L and C across the tuning range?

(ac) What type of circuit is used in the oscillator in Fig. 35?

(ad) Why are the inductance rings in the UHF tuner in Fig. 35 silver-plated?

(ae) On what channels is the cascode i-f amplifier used in the tuner in Fig. 40?

(af) In a double conversion type UHF converter, does the oscillator operate above or below the incoming signal frequency?

Transistorized Tuners

We have already pointed out that even in modern tube receivers the UHF tuner uses a transistor oscillator. With the crystal mixer, the entire unit uses semiconductor devices. You will also have to service TV receivers that use all semiconductor devices, or sets that are hybrids, where some stages use semiconductors and others use tubes. Many of these receivers use transistors in the VHF tuners as well as in the UHF tuners. You have already studied VHF rf, mixer, and oscillator stages using transistors. In this section of the lesson you will study the VHF and UHF tuners of a modern portable TV receiver.

THE VHF TUNER

A schematic diagram of the VHF tuner is shown in Fig. 44. The tuner is a thirteen-position tuner, one position for each of the VHF channels and a UHF position. The various coils for each channel are mounted on a drum which is similar to the drum used in tube-type turret tuners.

The input signal is fed to a balun which changes the 300-ohm balanced input to a 75-ohm unbalanced circuit. A single built-in dipole is connected to the 75-ohm line for reception on strong local stations. The 75-ohm input is fed to L_{51} and C_{52} which form a parallel resonant circuit at 41 mc. L_{52} and C_{53} are connected in series and form a series circuit resonant at 45 mc. These two traps are to reduce i-f interference.

The signal is fed from the traps through CT_{51} and L_1 through C_{55} to the base of the rf amplifier Q_1. Q_1 is used in a common emitter circuit. L_{54} and CT_{52} provide a feedback path for neutralization.

The VHF i-f signal is amplified by the rf amplifier Q_1 and fed to L_2. L_3 is inductively coupled to L_2, so the amplified rf signal is induced in it and fed through CT_{54} to the emitter of Q_2. Q_2 is used in a common base circuit.

The oscillator Q_3 is used in a common emitter circuit. L_4 is the oscillator coil and a separate slug is used in each coil to set the oscillator to the correct frequency. Fine tuning is accomplished by varying the inductance of L_{55}, which is in parallel with the oscillator coil.

The oscillator signal is induced in L_3 because it is inductively coupled to L_4. The signal is fed to the emitter of Q_2. Mixing occurs in Q_2 and the resulting i-f signals are fed from the collector of Q_2 through L_{56} to the i-f output terminal on the tuner.

In the UHF position, B+ voltage is supplied to the UHF tuner through a jumper on the drum. Meanwhile, the output signal from the UHF tuner is fed to the UHF i-f input, through a jumper on the drum, through C_{55} to the base of Q_1 which now functions as an i-f amplifier. The signal is amplified in Q_1, fed to Q_2 and amplified further. From there it is fed to the VHF tuner i-f output. During UHF operation, the VHF oscillator does not operate.
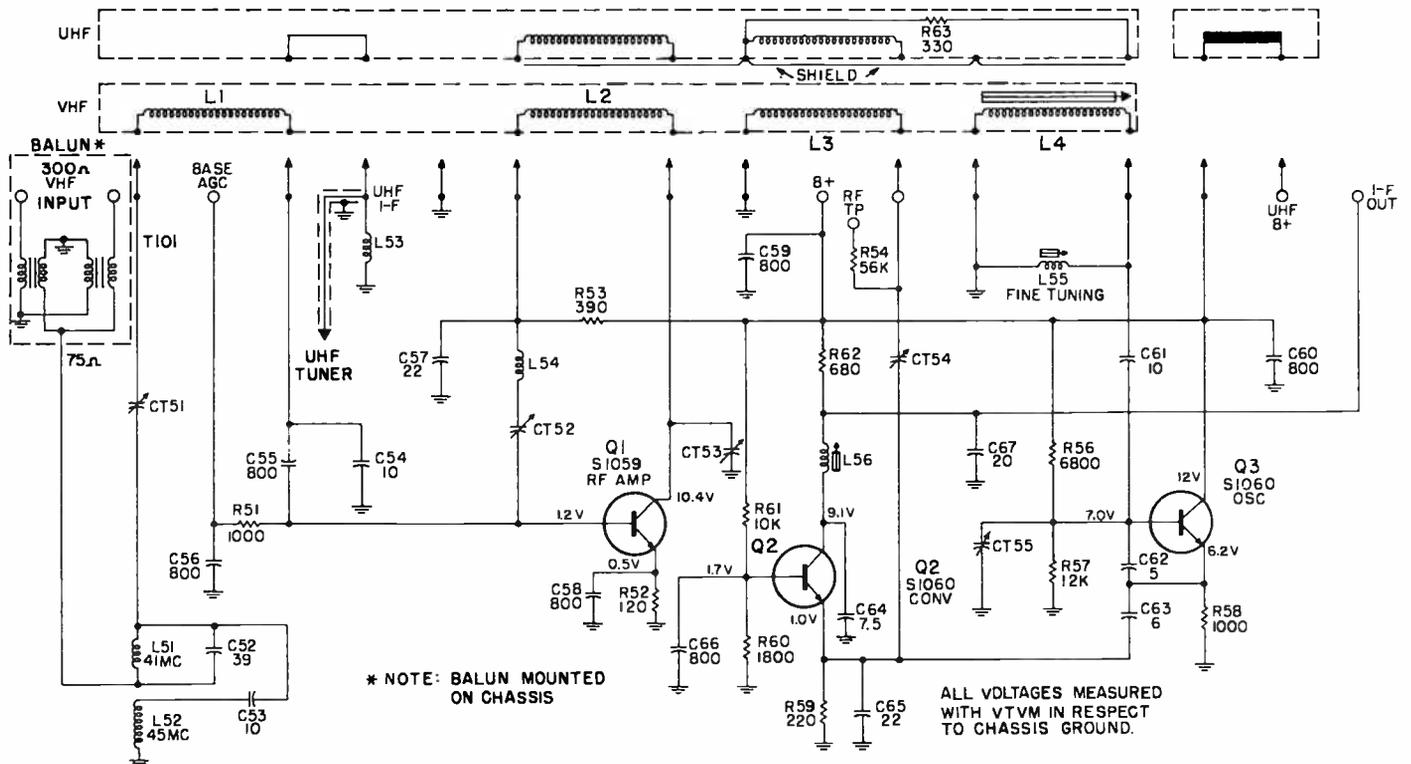
Fig. 44. Schematic of transistor VHF tuner.
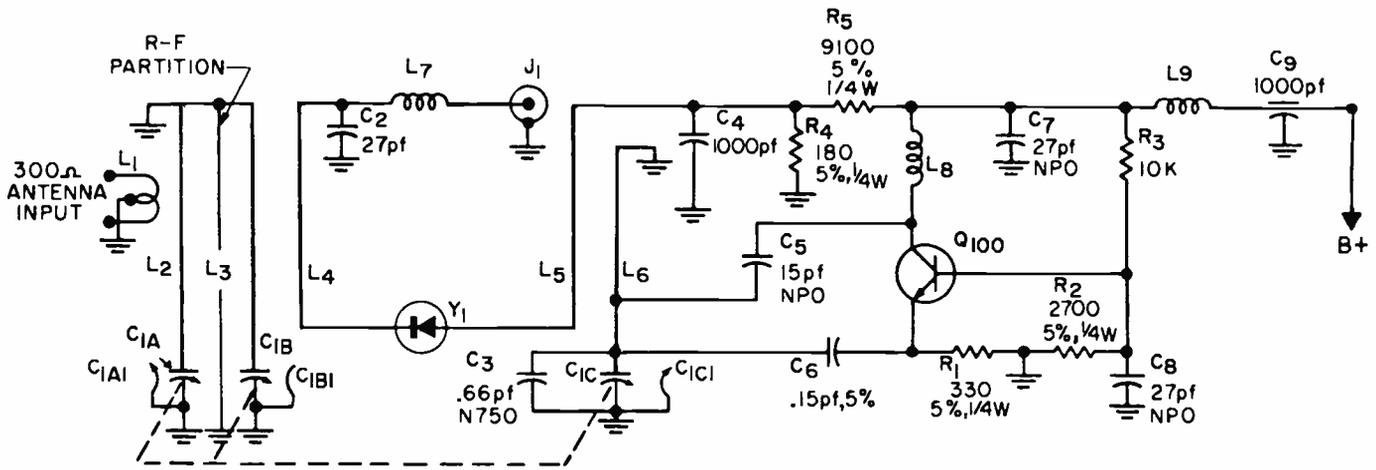
Fig. 45. Schematic diagram of the UHF tuner used in a GE modern portable TV receiver.

THE UHF TUNER

A schematic diagram of the UHF tuner used in this receiver is shown in Fig. 45. The antenna input coil L_1 is coupled to L_2. L_2 and C1A form a resonant cir-

Fig. 46. UHF tuner with one of the side shields removed.

cuit as do L_3 and C1B. L_2 and L_3 are inductively coupled through a window in the rf partition. The signal from L_3 is coupled to L_4 and fed to the diode mixer, Y_1.

The oscillator transistor, Q_{100}, is used in a common emitter circuit. The oscillator resonant circuit is made up of L_6 and C1C. L_6 is inductively coupled to L_5, which injects the oscillator signal into the mixer circuit. The i-f output from the mixer is fed through L_7 to J_1. From J_1 it is fed through a shielded cable to the UHF i-f input on the VHF tuner.

A photo of the UHF tuner with one of the side shields removed is shown in Fig. 46. The major parts in the tuner are labelled. Study the photo carefully and compare it with Fig. 45 to get an idea what the parts used in a UHF tuner look like.
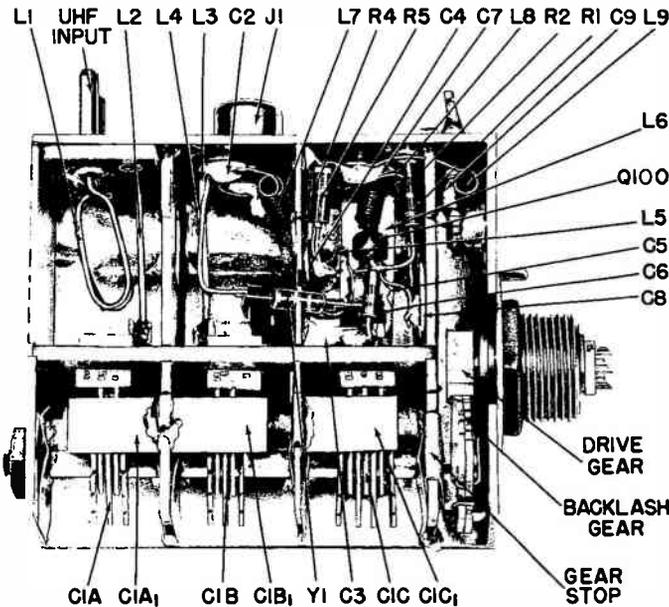
SELF-TEST QUESTIONS

(ag) How is the signal fed from the rf amplifier to the mixer in the tuner shown in Fig. 44?
(ah) What type of transistor circuit is used for the mixer in Fig. 44?
(ai) What function does Q_3 perform during UHF reception?
(aj) How is coupling obtained between L_2 and L_3 in Fig. 45?
(ak) What is Y_1 in Fig. 45?

Servicing Tuners

Fortunately, the most frequent source of trouble in tuners that use vacuum tubes is defective tubes. Tubes may often test good in a tube tester, or work satisfactorily in another circuit, but fail to operate properly in a tuner. Whenever a defect has been isolated to the tuner, if there is the slightest possibility that the trouble may be due to a defective tube, new tubes should be tried.

In replacing the oscillator tube in a tuner it may be necessary to align the oscillator circuit. You will very seldom find two tubes that have exactly the same interelectrode capacities. Therefore, when you change oscillator tubes, since the capacities are very critical at the frequencies used for TV, some re-adjustment of the oscillator circuit may be necessary. If the oscillator is easily aligned, as in tuners having a separate adjustment for each channel, this is not too much of a problem. However, if the tuner is of the type where the adjustment of one channel affects the other channel, as in the tuners shown in Figs. 31, 32, and 33, it is usually worthwhile to try several oscillator tubes in the circuit, in the hope of finding one having approximately the same interelectrode capacities as the original tube, so that alignment will be unnecessary.

When the defect is something other than a tube defect, you may find it somewhat difficult to repair the tuner. The difficulty usually stems from the fact that tuners are so compactly made that it is difficult, in fact almost impossible in some cases, to get at the defective part to make the necessary replacement. However, some tuners are easier to repair than others, and in the following section we will go into some of the commonly encountered defects that apply to both tube type and transistor VHF tuners, and how to repair them.

TURRET TUNERS

The turret tuner is the easiest type of tuner to repair, because when necessary, the entire drum can be removed so you can get at any of the parts in the tuner in order to replace them. In addition, if a defect affects only one channel, the chances are that replacing the strips used on that channel will clear up the trouble.

One of the most common troubles in this type of tuner is noise due to failure of the contacts to make a good connection. As we mentioned earlier, this happens simply because the contacts have become dirty. Contact cleaning strips are available, and they can be installed in this type of tuner by removing an unused set of strips and inserting the cleaning strips in their place. They have a very fine abrasive in place of the metal contacts on a regular strip, which tends to clean the stationary contacts as it passes over them. Contact cleaning strips will reduce the amount of trouble you are likely to encounter from dirty contacts.

If the contacts are already dirty when you are called in to service the tuner, the best procedure to follow is first to clean them to remove the dirt that has already accumulated on the contacts, and then insert a set of contact cleaning strips. You can clean the contacts on the individual strips by wiping them off with a rag with a suitable solvent applied to it. You can buy non-flammable solvents from your local wholesaler. However, this usually will not eliminate the difficulty. The stationary contacts inside the tuner must also be cleaned. To clean these contacts, the drum must be removed from the tuner.

In some receivers, the drum can be removed from the tuner without removing the tuner from the chassis. However, it is generally more convenient to work on the tuner if it is removed from the chassis, and since there are only a few leads connecting to the chassis, this is not too difficult.

The exact procedure that must be followed to remove the drum varies from one tuner to another. However, it is usually not too difficult. You can figure the best way in most cases by carefully studying how the tuner is assembled. Don't forget to refer to the service manual on the receiver. Often it contains information on how to remove the drum from the tuner.

Lubricate Before Reassembly.

If you dismantle a tuner to clean the contacts, don't forget to lubricate the contacts before you reassemble it. Also you should renew the lubricant at the points of contact between the drum shaft and the tuner chassis. A small amount of a conductive lubricant (one containing graphite such as Grapholine) should be used on both ends of the shaft and on the detent ring.

The detent ring is the round ring with indentations in it that is used to lock the tuner in position for the various channels. There is usually some type of spring and roller that rides on this ring and drops into the indentations to hold the drum in position on each channel.

STEP TUNERS

Step tuners using rotary switches are not as easily repaired as the turret tuners. There is no drum that can be removed from this type of tuner to enable you to get to the defective parts. Often it is extremely difficult to reach a defective part to make the necessary replacement.

One of the most common troubles in this type of tuner is in the failure of the rotary switch to make a good contact on one or more channels. This is usually because the contacts are either dirty or sprung.

If the contacts are dirty, cleaning them with a suitable solvent will often clear up the difficulty. To get the solvent on the contacts, many servicemen put the solvent in a small oil can that has a long nozzle. The nozzle can then be placed right on the contacts causing the trouble, the solvent readily applied to the contacts, and then the channel selector switch rotor worked

back and forth. This will usually clear up trouble caused by dirty contacts. Another way of getting cleaner on the contacts is by putting the cleaner in a plastic squeeze bottle. Don't be afraid of squirting the cleaner on parts other than the contacts. As long as you use a nonflammable contact cleaner, it will not cause any trouble.

When the contacts are sprung, the difficulty can be overcome by bending the sprung contacts slightly. To do this, rotate the channel selector switch to a channel other than the one causing trouble and then bend the contacts causing the difficulty very slightly with a screwdriver or some similar object. You can bend the contacts slightly so that the rotating blade (wiper) of the switch will make a better contact. However, you must avoid pushing the contact too far, otherwise it will bind on the wiper. If you should find, in attempting to make a repair of this type, that you bent the contact too much, do not try to force the switch into position. Instead, try bending the contact back slightly. If you try to force the switch, you simply break either the stationary or the rotating contacts.

UHF TUNERS

As you have already seen, there are not many parts in most uhf tuners so there are not many things that can break down. However, if a part does fail, it is essential that you put the replacement part in exactly the same position as the original. Even a slight variation in part placement may render the tuner completely useless.

If you have to replace a diode or a transistor in a tuner, avoid getting either one too hot. You should use a heat sink, such as a pair of longnose pliers, between the device and the point you are soldering. If you apply too much heat either to a diode or a transistor, it will be ruined.

OTHER TUNER DEFECTS

Since there are many different types of tuners, there are many defects that you might encounter. However, most of the defects in tuners are due to either tube failure or mechanical defects. By carefully studying the tuner as you rotate from one channel to another, you can generally see the various contacts that are made on each channel. If a defect is mechanical, and is due to the failure of one of the contacts to make a good connection, using an insulated alignment tool, carefully touch the contacts and apply a small amount of pressure to them one at a time to find the one making poor contact. Once you have located the con-

tact causing the trouble, you can usually eliminate the difficulty either by cleaning it or by bending it slightly as described previously.

A few tuners use circuits where the oscillator tube is extremely critical. Sometimes it is necessary to try several oscillator tubes before you will find one that operates satisfactorily. If you suspect that the oscillator is not operating, try feeding an i-f signal into the mixer to see if a signal can get through the receiver. You can use a modulated rf signal; set the frequency to the middle of the i-f passband. If the signal gets through the receiver, a series of wide horizontal bars will appear on the picture tube. If the i-f signal does get through, change the signal generator frequency to one of the TV channels (preferably one of the channels causing the trouble); tune the channel selector switch to that channel to see if the horizontal bars still appear on the picture tube. If they do not, you can be sure that the oscillator is not operating. Before tearing into the oscillator circuit to look for a defective part, it is usually worthwhile to try at least two or three tubes, in case the first one you try fails to clear up the trouble.

One of the frustrating things about repairing tuners is trying to get replacement parts. There have been so many different tuners made with slightly different versions of each model, that sometimes it is impossible to identify the part number of the defective part. Also, tuner repairs can be very time consuming and therefore unprofitable. There are several organizations that specialize in tuner repairs. They advertise in most service publications and offer prompt repairs at a reasonable price. It is usually worthwhile for the busy service technician to check for defective tubes and dirty or bent contacts or other repairs that can be made quickly. If it looks like a major repair job, it is simpler and probably more economical to send the tuner out for repair.

SELF-TEST QUESTIONS

(al) What must you remember to do after cleaning the contacts on a turret tuner?
(am) Why are oscillator tubes used in tuners critical?
(an) Should you rely on a tube tester to test the tubes in a tuner?
(ao) What precaution must be observed when replacing transistors or diodes in a tuner?
(ap) If one channel in a turret tuner fails to operate, but the other channels work fine, where would you look for the trouble?

Answers To Self-Test Questions

(a) Select the desired signals; produce the desired i-f signals.

(b) Channels 2 through 6, which are in the band 54 to 88 mc.

(c) Channels 7 through 13.

(d) Adjacent channel sound interference.

(e) They act as the first two i-f stages and simply amplify the signal from the UHF mixer.

(f) To change the balanced 300-ohm input circuit, which provides the correct termination for the transmission line, to a 75-ohm unbalanced circuit.

(g) To prevent interference from strong signals below 54 mc.

(h) The triode generates less noise and so can provide a better signal-to-noise ratio.

(i) The triode requires neutralization.

(j) The load impedance (V_2) into which the tube works is too low to develop the feedback signal necessary to produce oscillation.

(k) A very low noise level.

(l) No- they have been replaced by neutralized triode stages using very high gain tubes.

(m) To provide the bandwidth required to pass the entire 6 mc signal.

(n) A parallel-resonant circuit.

(o) Less noise is generated in a triode mixer than in a pentode.

(p) A pentode mixer has a higher gain than a triode.

(q) The oscillator is operated above the sound and video carrier frequencies. Since the sound carrier is higher than the video, the difference between it and the oscillator frequency will be less than the difference between the video carrier and the oscillator frequency.

(r) To keep the noise generated as low as possible.

(s) By changing the dielectric of the capacitor or by changing the spacing between the plates.

(t) By changing the inductance in the circuit.

(u) Turret tuner.

(v) Dirty contacts.

(w) A balun.

(x) To isolate the antenna terminals from B- which will be connected to one side of the power line.

(y) It is a high-pass filter. It passes signals above 54 mc but keeps signals below 54 mc from reaching the grid of the rf tube.

(z) They act as i-f coils when the tuner is in the UHF position so the rf and mixer tubes in the VHF tuner can be used as i-f amplifiers.

(aa) Lower noise level.

(ab) (1) Wider tuning range (2) Better L/C ratio across band.

(ac) Common base.

(ad) To reduce skin effect losses.

(ae) On the VHF channels only.

(af) Below the frequency of the incoming signal.

(ag) By inductive coupling between L_2 and L_3.

(ah) Common Base.

(ai) None -- during UHF reception, the VHF oscillator is inoperative.

(aj) By magnetic coupling through a window in the rf partition.

(ak) It is the mixer.

(al) Lubricate the contacts and the drum shaft where it makes contact with the chassis. Also it is a good idea to lubricate the roller index.

(am) The interelectrode capacities of tubes vary. These small changes in capacity greatly affect the oscillator frequency.

(an) No. Try new tubes.

(ao) You must avoid getting them too hot or they will be ruined.

(ap) The coils used on the inoperative channel.

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. What stages are usually found in a VHF tuner?

2. Is interference from the channel immediately above the channel to which the set is tuned likely to be adjacent-channel sound or adjacent-channel picture interference?

3. What type of mixer is usually used in a UHF tuner? Why?

4. What is the chief advantage of a triode rf stage over a pentode?

5. What are the four coils referred to as L_1 in Fig. 33?

6. If the tuner shown in Fig. 35 is tuned towards 890 mc, L_2 shorts C_2; what is the advantage of this arrangement?

7. Why is a turret-type tuner easier to service than a step-type tuner?

8. What purpose does the rf amplifier stage in the tuner shown in Fig. 33 serve during UHF reception?

9. If a tube tester indicates a tube is good, does this necessarily mean it will work satisfactorily in the oscillator stage of a TV receiver?

10. What type of circuit is used in the rf stage of the tuner shown in Fig. 44?

VIDEO I-F AMPLIFIERS AND DEMODULATORS

●

STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

☐ **1. Introduction** . . . . **Pages 1-7**

Here you review the TV signal and get a general picture of the requirements of the video i-f system.

☐ **2. Typical Video I-F Amplifiers** . . . . **Pages 8-16**

You study typical video i-f amplifiers from both monochrome and color TV receivers. Both vacuum tube and solid state amplifiers are covered.

☐ **3. Video Detectors** . . . . **Pages 17-22**

You learn how the video detector demodulates the video i-f carrier to obtain the picture information. Detectors from both monochrome and color TV receivers are covered.

☐ **4. Video I-F Response Curves** . . . . **Pages 23-28**

You learn what a video i-f response curve is and why correct alignment is important.

☐ **5. Answer Lesson Questions.**

☐ **6. Start Studying the Next Lesson.**
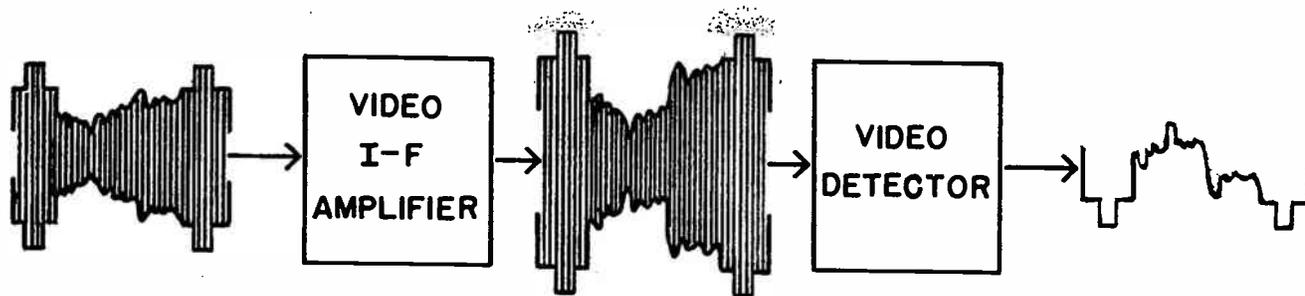
VIDEO I-F AMPLIFIERS AND DEMODULATORS

You already know that the sound and picture information that make up a TV broadcast are contained in a channel that is 6 mc wide. Each TV channel, whether it is a VHF or a UHF channel, is 6 mc wide, and all the information transmitted by a TV station must be contained in that one 6 mc channel.

The complete TV signal is made up of two separate carriers. One carrier is the video carrier, which carries all of the picture information, and the other carrier is the sound carrier, which carries the accompanying sound. The video or picture carrier is always located 1.25 mc above the lower edge of the TV channel. The sound carrier is always located .25 mc below the upper edge of the TV channel. The position of the two carriers in Channel 2 is shown in Fig. 1A.

Channel 2 occupies the space between 54 and 60 mc. The video carrier is placed 1.25 mc above the lower edge of the channel; therefore it will be located at 55.25 mc. The sound carrier is .25 mc below the upper edge of the TV channel; therefore it is located at 59.75 mc. The separation between the sound and picture carriers is 4.5 mc. This spacing between the sound and picture carriers is the same for all TV channels.

Narrow-band FM is used to modulate the sound carrier in order to transmit the sound information. The deviation of the sound carrier is limited to 25 kc. This means that in modulating the carrier the frequency may be shifted 25 kc above and 25 kc below the resting frequency of 59.75 megacycles.

In modulating the carrier, sidebands that fall beyond the amount the carrier is deviated are produced. These sidebands are held to 50 kc above and 50 kc below the resting frequency. In Fig. 1B we have shown TV Channel 2, the video carrier, and the sound carrier along with the space occupied by the FM sound in the channel. You'll notice that the sound signal occupies only a small part of the TV channel. Also notice that there is a space between the upper edge of the sound sidebands and the upper edge of the carrier. This is a so-called guardband where there is no signal present. This space is left, deliberately, to help keep interference between adjacent channels to a minimum.

The video signal containing the brightness information, that is developed by the TV camera, contains video signals of widely different frequencies. The video signals that depict the brightness level of a large object are relatively low-frequency signals, whereas the video signals that are produced by brightness changes in the fine detail of the picture are relatively high-frequency video signals. These complex video signals, which contain a wide range of frequencies, are added to the sync pulses and then used to amplitude-modulate the video carrier.

In an amplitude-modulation process you know that sidebands are produced. The sidebands are equal to the carrier frequency plus and minus the frequency of the modulated signal. In other words, two sidebands are produced. One is equal to the carrier frequency plus the modulating frequency, and the other is equal to the carrier frequency minus the modulating frequency.

In the amplitude-modulation of the video carrier by the video information, two sidebands are produced. However, to make the fullest use of the 6 mc TV channel, part of the low frequency sideband is suppressed. The entire upper sideband, on the other hand, is transmitted.

In Fig. 1C, we have shown the video sidebands and how they are located above and below the video carrier. Notice in Fig. 1C that both the upper and lower sidebands are transmitted for frequencies up to .75 mc from the carrier frequency. Thus, if the modulating signal produces a 500 kc sideband both the upper and lower sidebands would be transmitted. However, if the modulating frequency is above 750 kc, then the lower sideband is either partially or completely suppressed and the upper sideband only transmitted.

To describe the fine detail in a TV picture requires a high-frequency video signal that may be as high as 4 mc. Thus the upper video sideband may extend up to about 59.25 mc; in other words 4 mc above the video carrier.

When the TV station is broadcasting color, the color is transmitted by means of amplitude and phase modulation of a 3.58 mc color subcarrier. This color sub-
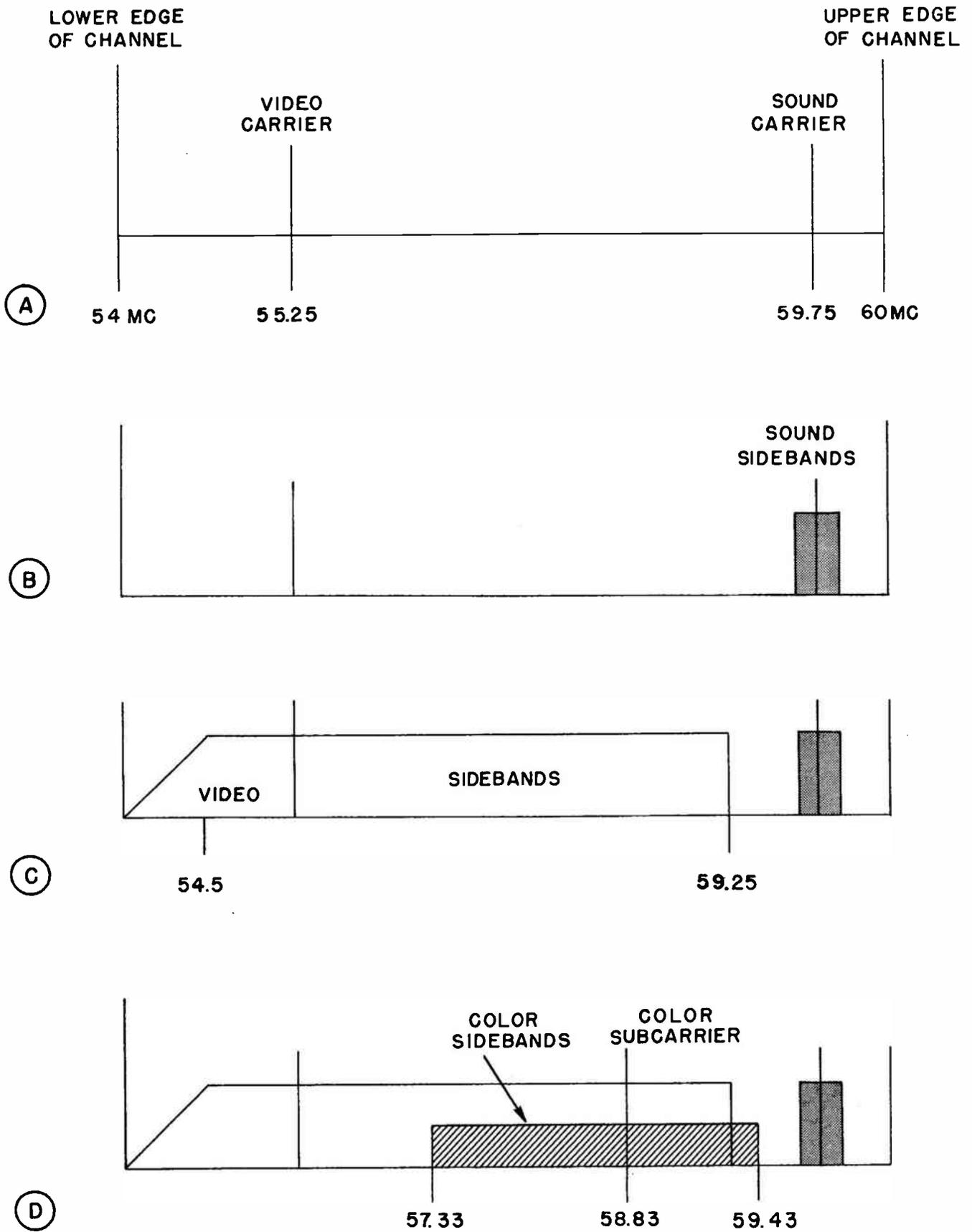
Fig. 1. Relationship of channel boundaries, sound, video, and color signals in Channel 2.

carrier is used to modulate the video carrier. In Channel 2, shown in Fig. 1D, the color subcarrier, when it modulates the video carrier, produces a color subcarrier sideband that falls at 58.83 mc.

Since the color subcarrier is in turn modulated, it also has sidebands. In order to keep the upper sideband from interfering with the sound signal or extending beyond the upper boundary of the channel, we limit the upper sideband to 600 kc. Therefore the upper limit of the color subcarrier sidebands falls at 59.43 mc. However, to provide fine detail in the flesh-tone regions, the lower sideband has a bandwidth of 1.5 mc. This lower sideband may extend down to 57.33 mc.

Fig. 1D shows the complete relationship of the video carrier and its sidebands, the sound carrier and its sidebands, and the color subcarrier and its sidebands to the edges of the TV channel. Notice that practically all of the space inside the 6 mc channel is used to transmit the information required in a color TV broadcast. For that matter, even in a black-and-white broadcast, practically all the space available in the TV channel is used.

In the preceding lesson you studied TV tuners. You know that when the TV receiver is tuned to Channel 2 the incoming signal will be picked up by the antenna and fed to an rf amplifier stage where it is amplified. The signal is then fed to the mixer, where it is mixed with a signal from the local oscillator. When the receiver is tuned to Channel 2, the local oscillator will operate at 101 mc. Thus when the oscillator signal beats with the 55.25 mc video carrier, it will produce a difference frequency of 45.75 mc. This will be the video i-f carrier frequency. When the oscillator beats with the 59.75 mc sound carrier it will produce a 41.25 mc difference frequency. This is the sound i-f carrier frequency. In addition, when the oscillator beats with the 58.83 mc sideband produced by the color subcarrier, it will produce a difference frequency of 42.17 mc. This is the color subcarrier i-f frequency.

In Fig. 2 we have shown the relationship between the sound and video carriers, along with the color subcarrier at the output of the TV tuner. Notice as before that the signals fall in a 6 mc band. In this case, the band extends from 41 mc to 47 mc. By changing the oscillator frequency, as the receiver is tuned from channel to channel, the i-f signals will fall in this frequency range regardless of which channel the receiver is tuned to. In modern receivers, the oscillator is operated 45.75 mc above the video carrier frequency on each channel, so the frequencies shown in Fig. 2 will apply to the i-f of all modern receivers.

Another important point to notice is that the signals have been inverted. When the signal is transmitted by the station, the video carrier is near the low end of the channel and the sound carrier near the upper end. After going through the mixer, the video carrier is at the high end of the channel and the sound carrier at the low end. Similarly, the color subcarrier transmitted by the station is near the high end of the channel, but the color i-f subcarrier is near the low end of the channel. However, notice that the difference in frequency between the various carriers remains the same. The difference between the sound i-f and the video i-f carrier is still 4.5 mc and the difference in frequency between the color subcarrier and the video carrier in the i-f remains at 3.58 mc.

Since the band of frequencies shown in Fig. 2 represents the output from the TV tuner, this is the band of frequencies that the video i-f amplifier in the TV receiver must amplify. At the same time, it must reject interfering signals from below 41 megacycles or above 47 megacycles to prevent interference in the picture or sound. If the bandwidth of the video i-f amplifier is not wide enough to pass the entire band of frequencies shown in Fig. 2, part of the information transmitted by the station will be lost.

For example, if the bandwidth of the i-f amplifier extended from 43 to 47 mc, then the sound signal couldn't get through the video i-f amplifier, nor could the color subcarrier and the lower i-f frequency sidebands. This would mean there would be no sound and
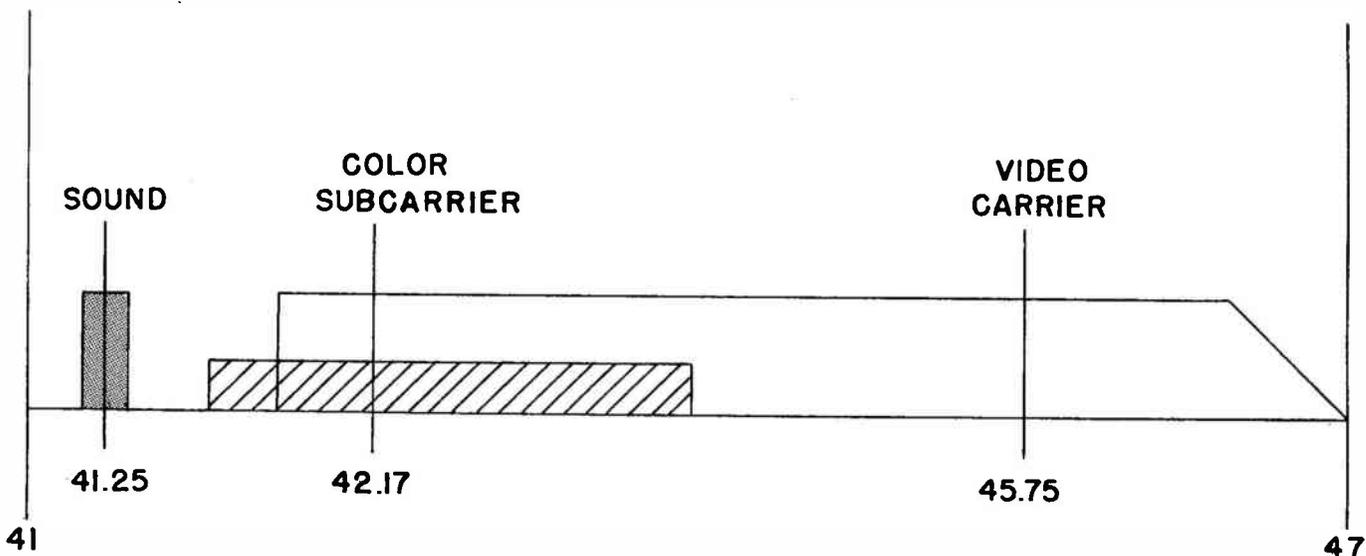
Fig. 2. Relationship of the sound, video, and color signals at the output of the tuner.

no color. When the station was transmitting a monochrome broadcast we would get a black-and-white picture, but it would be lacking in fine detail because the higher video frequencies would be missing.

Now that we see that the video i-f amplifier in a television receiver must pass a wide band of frequencies, let's see how we go about getting the band that is required, and also what we mean when we refer to bandwidth.

BANDWIDTH

Fig. 3 shows a typical response curve of a resonant circuit. The curve could apply either to a series-resonant or a parallel-resonant circuit. Notice that the circuit is resonant at point A. If the circuit is a parallel-resonant circuit, any signal current flowing through it will develop maximum voltage if the signal current has a frequency exactly equal to the frequency represented by A. However, if the frequency is slightly lower or slightly higher, there'll still be a reasonably high signal voltage developed across the resonant circuit. If the frequency is only slightly above or below the resonant frequency, the signal voltage developed will be almost equal to that developed exactly at resonance. On the other hand, if the signal frequency differs from the resonant frequency by a substantial amount, the voltage will be considerably lower than that developed at the resonant frequency.

We say the resonant circuit has a certain bandwidth. By this we mean that signals within a certain frequency range receive an acceptable amount of application. There is no law of physics that defines what the bandwidth of the circuit is, but engineers arbitrarily state that when the voltage developed across a parallel-resonant circuit or the current in a series-resonant circuit falls to 70.7% of the voltage or current at resonance, this will be the limit of the bandwidth of the resonant circuit. In other words, in the circuit shown in Fig. 3, the resonant frequency is indicated at point A. The 70.7% points are indicated at points B and C.

The 70.7% is selected, because at these points the response drops 3 db. This is an arbitrary figure, but remember that whenever we say that the bandwidth of a resonant circuit is a certain width, we mean that the output from that circuit falls within 70.7% of the maximum output over this frequency range. As an example, if we say that the resonant frequency of the circuit is 40 mc and that its bandwidth is 6 mc, then we mean that the response is such that signals from a frequency of 37 mc to a frequency of 43 mc will be passed through the resonant circuit within 3 db of the maximum output obtained at resonance.

Frequency Falls in I-F Passband.

In Fig. 4A we have shown a resonant circuit and a response curve as outlined by curve 1. Notice that the circuit is resonant at 43 mc, and the 3 db downpoints fall at 42.5 mc and 43.5 mc. The frequency of this resonant circuit falls within the TV i-f passband; you can see that a resonant circuit, that has such a sharp response curve as this, would be of little value in the i-f amplifier. The response curve of the circuit is simply too sharp. We could not begin to amplify the wide band of frequencies in the TV i-f channel with resonant circuits that are as sharp as the one shown in curve 1 of Fig. 4A.

Fortunately, by loading the circuit, we can reduce the Q of the resonant circuit. A high Q resonant circuit has a sharp response curve as shown by curve 1 in Fig. 4A. However, a low Q resonant circuit has a broader response curve, as shown by curve 2 of Fig. 4A. This loading of the resonant circuit can be obtained by connecting a resistance across the resonant circuit, or in the case of a coil with a powdered iron slug, by putting a slug in the coil that introduces considerable loss in the coil.

Notice the effect of loading the resonant circuit. The resonant frequency of the circuit has not changed; it still occurs at 43 mc. Notice, however, that the maximum gain or maximum output from the resonant circuit is reduced considerably. However, at the same time the points, C and D, where the output drops to 70.7% of the output at resonance, have been moved out to 42 mc and 44 mc. In other words, we have broadened the response of the resonant circuit. By further loading the resonant circuit, we could pull the gain at resonance down still further and move the 3 db downpoints

RESONANT
FREQUENCY

A

B   C
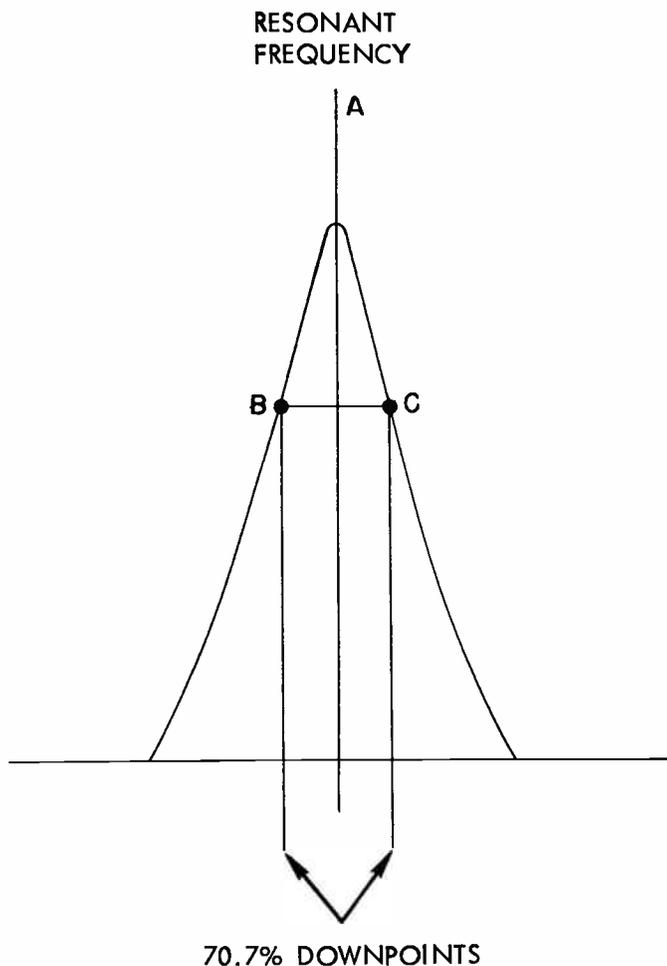
70.7% DOWNPOINTS

Fig. 3. Typical resonant circuit response curve, showing points B and C 70.7% down in the response curve.
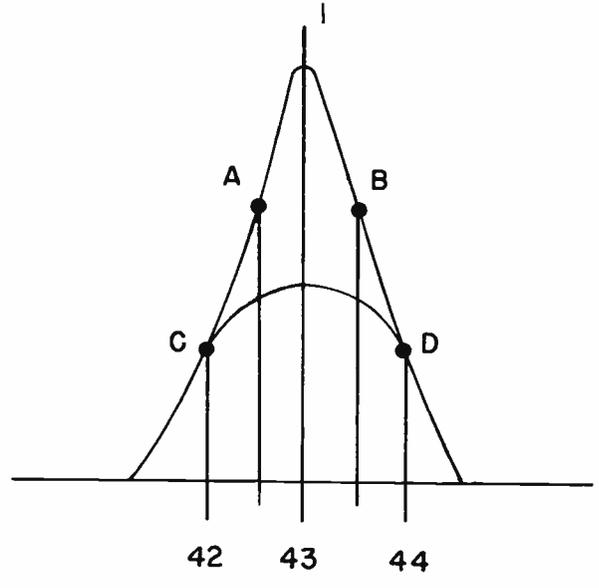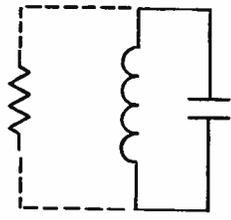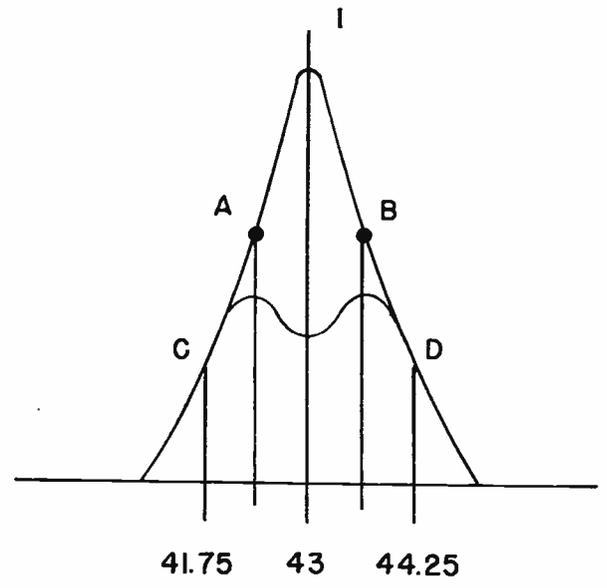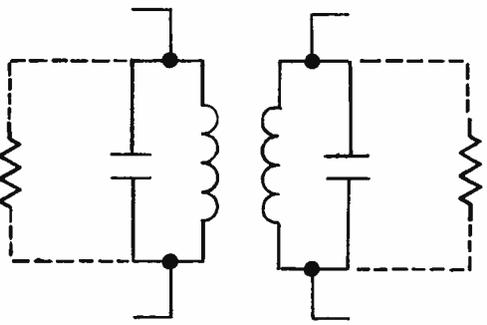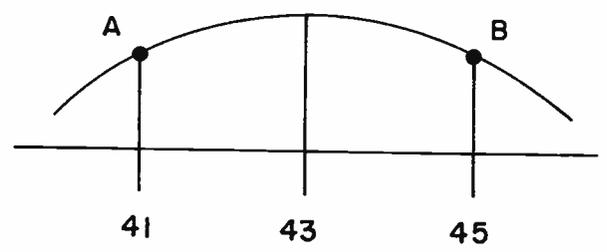
Fig. 4. Response curves showing how Q can be changed to change the bandwidth of resonant circuits.

still further apart on the response curve. This is what we do in some resonant circuits to get the wide bandwidth required.

You already know that when two resonant circuits, such as shown in Fig. 4B, are coupled together that you will obtain maximum output and the sharpest response curve, when the coupling is what we call critical coupling. With critical coupling between two coils the response curve will be similar to curve 1 in Fig. 4B. Once again, if the resonant frequency of the two resonant circuits is 43 mc, we'll obtain a response curve having a peak of 43 mc, and the 3 db downpoints as shown by A and B will be at 42.5 and 43.5 mc as shown. Again, this type of response is too narrow for use in TV.

We can broaden the response curve by increasing the coupling between the two coils beyond the critical coupling point. Then, if we tune the two coils to slightly different resonant frequencies, we'll get a response curve like the one shown in curve 2 of Fig. 4B. Notice that we have what we call a double-hump response curve. We have a peak on each side of 43 mc. One peak is due to the primary resonant circuit, and the other peak is due to the secondary resonant circuit.

By overcoupling the two coils in this way and tuning them to slightly different frequencies, we can get a much wider bandwidth than we can with the two coils at critical coupling and peaked at the same frequency. In the example shown in Fig. 4B, the 3 db downpoints, C and D on curve 2, are 41.75 mc and 44.25 mc.

A still further broadening of the response curve can be obtained by loading the two resonant circuits. We can do this by connecting resistors across the resonant circuit as shown by the dotted lines in Fig. 4B, or as we mentioned before, if the coils are slug tuned, by inserting powdered iron slugs they will introduce considerable loss in the coils. This will lower the Q of the resonant circuits and make the response curve broad and at the same time reduce the gain that can be obtained from each stage using resonant circuits of this type.

In Fig. 4C we have shown another response curve. Here we have an extremely broad curve with the resonant frequency occurring at 43 mc and the 3 db downpoints A and B occurring at 41 mc and 45 mc. This type of response curve can be obtained by using very tight coupling between the two coils and by loading the coils quite heavily. There are two ways we can get this very tight coupling between the two coils. One method is to wind the secondary winding right on top of the primary winding. This provides extremely close coupling. As a matter of fact, the coupling is so tight that a single slug is used to tune the two coils and both coils will have the same resonant frequency.

Another type of coil used to get this type of coupling is what is called a bifilar wound coil. In a coil of this type the two windings of the two coils are interwound, as shown in Fig. 5A. With this type of winding, extremely tight coupling between the two coils can be obtained. Again, only a single slug is used to tune the two windings, since they are so tightly coupled it is impossible to tune them to different resonant frequencies. The schematic symbol used to indicate bifilar wound coils is shown in Fig. 5B.

Loading Lowers Impedance.

You might wonder about loading the resonant circuits in the video i-f of a TV receiver. You may wonder if this doesn't reduce the gain of the stage in which the i-f transformer is loaded? The answer of course is that loading a resonant circuit with a resistance does lower the impedance of the circuit, and it does reduce the gain that can be obtained in the stage. However, we must have the wide bandwidth in order to be able to amplify all the frequencies in the i-f channel. Therefore we have to sacrifice some gain in order to get this bandwidth.

In modern TV receivers it is comparatively easy to get the needed gain simply by using one or more extra stages. For example, suppose we needed a gain of 100 in an amplifier. We can get that gain by using a single stage that has a gain of 100 or by using two stages each of which has a gain of 10. The gain of the two stages will be $10 \times 10 = 100$. Thus we can use two stages and load the stages to get the required bandwidth. At the output of the two stages, each with a gain of 10, we will end up with the same amount of gain as we get from a single stage with a gain of 100. If we cannot get the bandwidth required with two stages having a gain of 10 each, we might have to have three stages each with a gain of 5. This would give us a total gain of $5 \times 5 \times 5 = 125$ which would be more than ample and still permit us to obtain the bandwidth needed.

There are a number of stages in the video i-f amplifier of a television receiver. Usually the resonant circuits are tuned to somewhat different frequencies. For example, we might have three resonant circuits in a typical video i-f amplifier. Two of these circuits might be comparatively sharp and one extremely broad. The broad one would usually be tuned to the center of the i-f passband, one of the sharp ones tuned to the
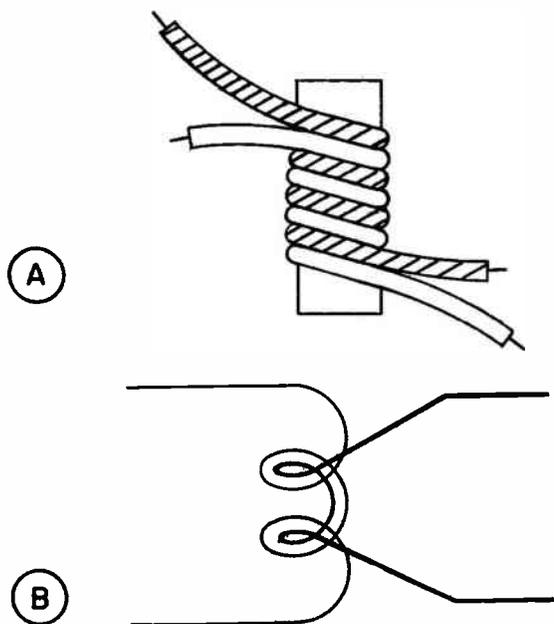
Fig. 5. (A), How a bifilar coil is wound; (B), its schematic symbol.
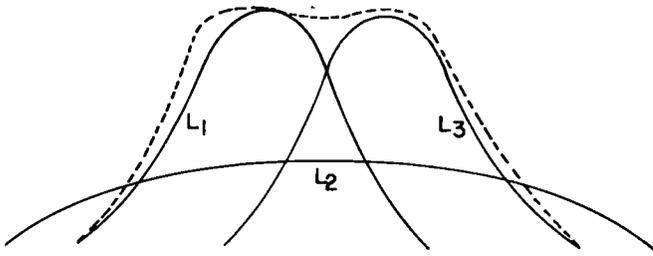
Fig. 6. Several resonant circuits tuned to different frequencies provide the overall bandwidth required.

lower end of the i-f band, and the other one tuned towards the upper end, as shown in Fig. 6. Notice that L_1 is tuned towards the low end of the band, L_2 which is very broad is tuned to the center and L_3 is tuned towards the high end of the i-f band. Together all three result in a response curve similar to the dotted curve shown in the figure and have a bandpass sufficient to pass the entire band of frequencies required.

TRAPS

In addition to the amplifier stages feeding resonant circuits, you will also find traps in the video i-f amplifier. The traps are used in the i-f amplifier in order to channel the various signals to different circuits, and they are also used to prevent interference from signals that are outside the video i-f band.

You will run into three types of traps in video i-f amplifiers: parallel-resonant traps, series-resonant traps, and absorption traps. Actually, absorption traps are a form of series-resonant traps.

In Fig. 7A, we have shown a parallel-resonant trap and how it is used. The input signal divides between the resonant circuit and the load. The parallel-resonant circuit will have a high impedance at its resonant frequency. Therefore, if a signal of this frequency is applied to the input, most of the signal will be dropped across the resonant circuit and very little signal voltage will appear across the load. If the resonant circuit has a high Q, it will offer a high opposition to signals of the resonant frequency, but little or no opposition to frequencies above and below its resonant frequency.

A series-resonant circuit is shown in Fig. 7B. The circuit simply acts as a low impedance at the resonant frequency. Therefore signals fed into the input circuit shown in Fig. 7B see a low impedance at the resonant frequency and are simply bypassed to ground, and very little signal at the resonant frequency appears in the output.

An absorption-type trap is shown in Fig. 7C. The trap is coupled to the parallel-resonant frequency, which may be in the output or the input of one of the video i-f amplifiers. The absorption trap absorbs energy at the frequency at which it is resonant. The trap coil is inductively coupled to the resonant circuit, so a voltage is induced in series with the coil in the trap. This causes a high circulating current at the resonant frequency in the trap. Thus the energy

at the resonant frequency is dissipated in the series-resonant trap circuit.

Now that you understand some of the requirements of video i-f amplifiers, let's go ahead and look at some typical video i-f amplifiers. You will remember that the amplifier must have a wide bandpass, in order to amplify all of the signal frequencies in the video i-f passband. Remember that you can expect to find loaded resonant circuits in order to get the wide passband required. Also remember that you can expect to find traps in the circuit in order to prevent interference from outside the i-f channel, and also to help direct the various signals in the i-f channel into the circuits where we want them to go.

There is very little difference between the video i-f amplifier of a monochrome TV receiver and the video i-f amplifier of a color TV receiver. However, there is one very important difference, and that is where the sound is separated from the picture signal. In order to see why we do not use the same type circuitry in both monochrome and color, we'll look at a couple of typical monochrome i-f amplifiers first, and then we'll see a couple of typical color video i-f amplifiers. You'll see when you study these circuits that they are quite similar, but there is one important difference.
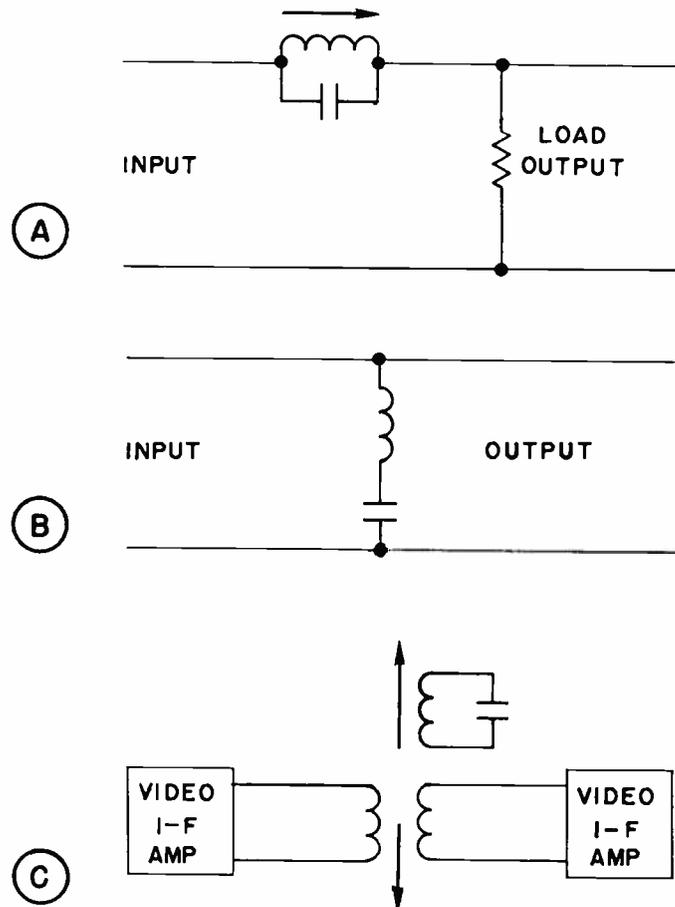
Fig. 7. Video i-f traps. (A), a parallel-resonant trap; (B) a series-resonant trap; (C), an absorption trap.

Typical Video I-F Amplifiers

In the early days of black-and-white television the video i-f signals and the sound i-f signals were separated at the output of the tuner and amplified by means of separate i-f channels. A trap was inserted in the input of the video i-f amplifier to keep the sound i-f signals out of the video amplifier. Actually, we had two completely separate i-f amplifiers, one for the sound signal and the other for the picture signal. In addition, a picture i-f of 25.75 mc and a sound i-f of 21.25 mc was almost universally used.

In later television receivers the sound signal was allowed to pass through one or two stages in the video i-f amplifier, where it was amplified and then was separated from the video signal, given further amplification and then fed to a sound detector. A sound trap was used in the video i-f amplifier between the sound take-off point and the video detector to keep the sound from reaching the video detector. The next step in the evolution of the television receiver was to permit the entire video i-f amplifier to amplify the sound i-f signal as well as the video signal. In the video detector, the two signals beat together and there they produce two new signal frequencies, one equal to the sum of the two and the other equal to the difference. The sum of the two signal frequencies is a very high frequency, and is immediately bypassed to ground by the bypass capacitor in the video detector output.

However, the sound and video signals will always differ in frequency by 4.5 mc. Thus a new 4.5 mc signal is produced in the video detector, and this signal is both amplitude-modulated by the video information and frequency-modulated by the sound information. By feeding this 4.5 mc signal to a separate narrow-band sound i-f amplifier and then into an FM detector, the sound information can be extracted from the 4.5 mc signal.

SYSTEM IS UNIVERSALLY USED

All modern receivers use this system of letting the sound go through most of the video i-f amplifier and producing a 4.5 mc signal by heterodyning the sound i-f and video i-f signals in a detector. Monochrome receivers permit the sound signal to go through the entire video i-f amplifier and produce the 4.5 mc sound signal at the output of the video detector. However, in color TV receivers, sound and video signals are usually taken off at the output of the last video amplifier and fed to a separate diode to produce a 4.5 mc sound signal, and then the sound signal is fed to a separate 4.5 mc amplifier.

The reason for the difference between monochrome and color TV receivers lies in the fact that if the sound i-f signal and the color i-f subcarrier are both fed to the video detector, they also will beat together and produce a new signal equal to their difference frequency. This signal will have a frequency of about 920 kc, which is well within the band of frequencies that the video amplifier in the

TV receiver must amplify. This 920 kc signal will produce picture interference. To avoid this problem, the sound signal is removed before the video detector, and then traps are inserted in the output of the last video i-f amplifier circuit to keep the sound signal from getting through to the video detector and producing interference of this type.

In order to give you an idea of what you can expect in the video i-f amplifiers of modern television receivers, we'll look at a couple of monochrome video i-f amplifiers first, and then a number of video i-f amplifiers from color television receivers. You'll notice that there is a great deal of similarity between the amplifiers, and also you will readily see the differences between them.

We'll start with the monochrome amplifiers first because they appeared in television before the color video i-f amplifiers. This may be somewhat of a review, but be sure to go over this section of the lesson carefully because a thorough understanding of the monochrome video i-f amplifier will help you with color video i-f amplifiers.

MONOCHROME VIDEO I-F AMPLIFIERS

A typical video i-f amplifier from a black-and-white television receiver is shown in Fig. 8. In this amplifier, the oscillator in the tuner operates at a frequency 41.25 mc above the sound carrier and 45.75 mc above the video carrier, so that the video i-f frequency is 45.75 mc and the sound i-f frequency is 41.25 mc. As we pointed out, this is standard procedure in modern TV receivers.

Notice that the signal from the tuner is fed to a double-tuned i-f transformer, T_1. The primary is tuned to 45.7 mc and the secondary is tuned to 42.6 mc. This staggered tuning of the primary and secondary windings of the transformer are used to give the wide bandwidth required in the input circuit.

From the grid of the first i-f tube, V_1, to ground is a series-resonant trap, made up of L_1 and C_1, tuned to 47.25 mc. This trap is designed to eliminate adjacent channel sound interference. The sound from the channel immediately below the channel to which you are tuned will beat with the local oscillator in the tuner, and produce an i-f signal of 47.25 mc. The series-resonant trap used in the input circuit provides a low-impedance path for this signal and effectively prevents it from reaching the grid of the first i-f amplifier stage.

Notice that feeding the grid of the first stage, as well as the grid of the second stage, we have a signal marked agc. This is a dc voltage; agc stands for automatic gain control. The video i-f amplifier of a television receiver must be capable of handling comparatively weak signals from distant stations, and at the same time very strong signals from nearby local stations. The agc voltage is developed in another circuit in the TV receiver (you will study this circuit
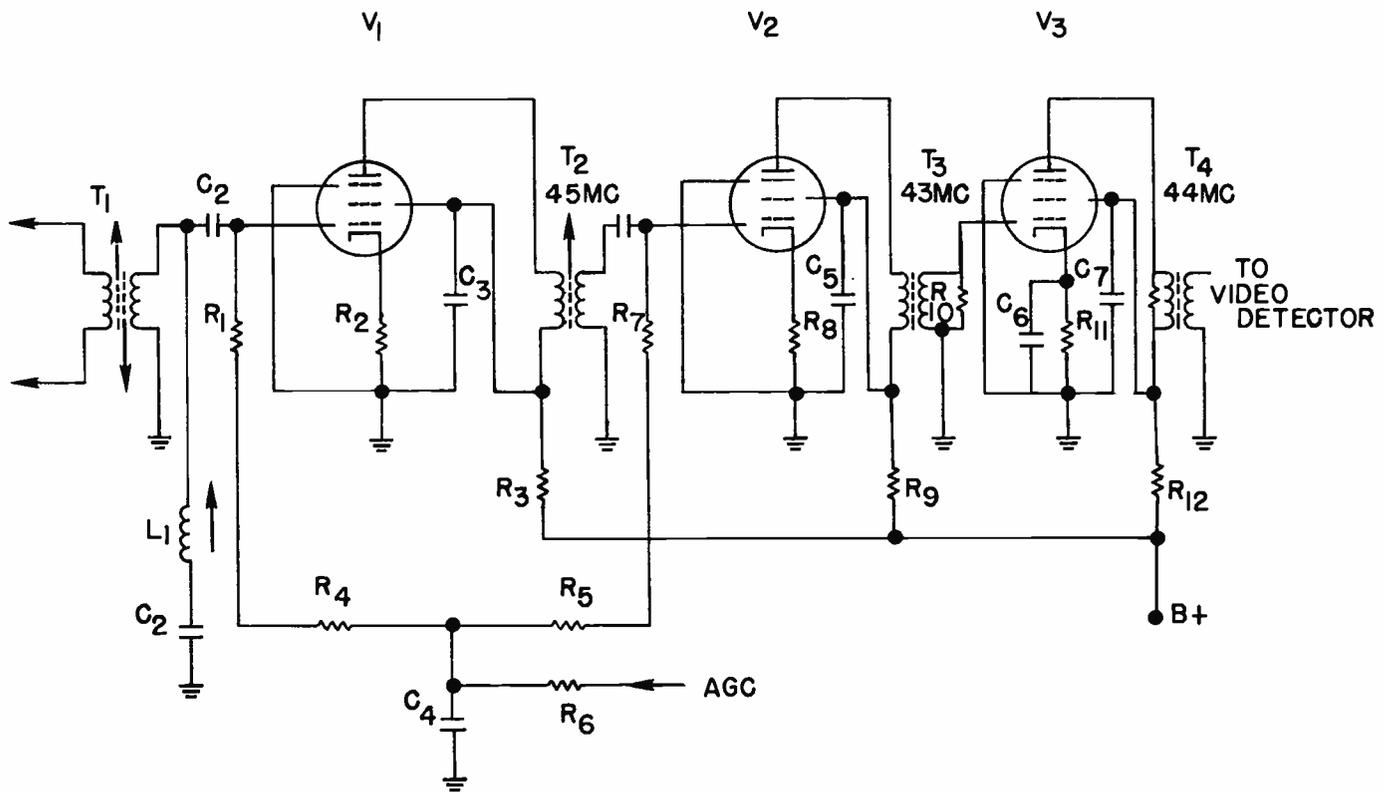
Fig. 8. A typical three-stage monochrome video i-f amplifier.

later) and is applied to the grids of the first two stages to regulate or control the gain of these two stages.

You will remember that in a radio receiver we can reduce the gain of an amplifier by applying a high negative bias to the grid of the tube. In effect the agc voltage does exactly this. When you tune to a strong local station, the agc reduces the gain of the video i-f amplifier by increasing the negative bias applied to V_1 and V_2. On the other hand, when you are tuned to a weak distant station, the agc voltage is very low, so that V_1 and V_2 can operate at, or near full volume.

The i-f transformer, T_2, that is used between V_1 and V_2 is an overcoupled transformer. A single slug is used to tune both primary and secondary windings of the transformer. The transformer is tuned to resonance at about 45 mc so that it is capable of passing the entire video i-f passband. Notice that there are no capacitors across the windings of the transformer; the tube capacities and the stray wiring capacities provide all the capacity needed in the resonant circuits.

The signal from the first i-f stage is fed through T_2 to the grid of the secondary video i-f amplifier V_2 where it is amplified further, and then fed through T_3 to the third i-f stage V_3. The video i-f transformer, T_3, is tuned closer to the low end of the band. Notice that T_2 is tuned higher than T_3. The two have a tendency to peak, as shown in Fig. 9A.

The amplified signal from V_2 is fed through T_3 to the third i-f stage, V_3. The output from this stage is fed to T_4 to the video detector. The video detector transformer, T_4, is a very broad transformer with a low Q and the resonant frequency falls in the center of the passband as shown in Fig. 9B. The passband of

this transformer is labelled curve 1. The dotted curve represents the response curve of T_2 and T_3, and the curve labelled 2 represents the overall response of the entire i-f amplifier. Notice that at 47.25 mc we have a dip in the response curve. This is due to the trap in the input of the video i-f amplifier circuit.
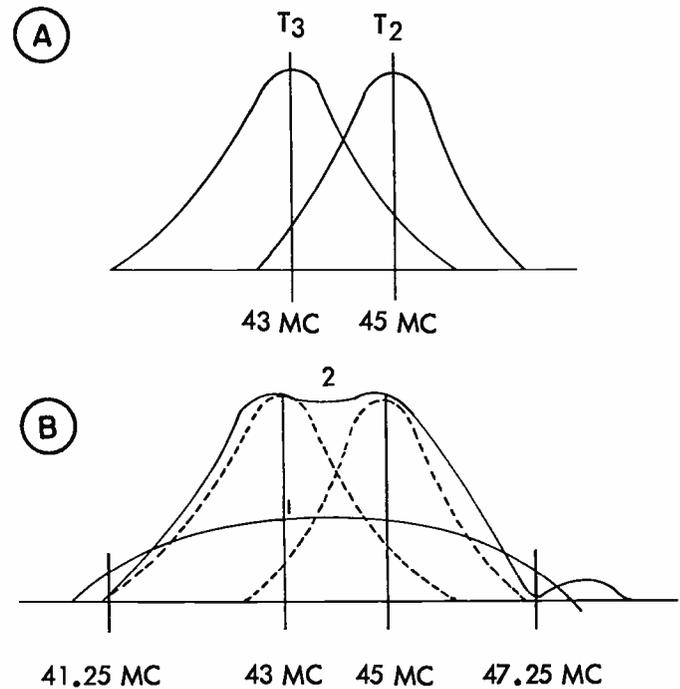
Fig.9. I-F response curves for the circuit in Fig. 8.

Both the sound and video signals are amplified by the i-f amplifier shown in Fig. 8, and both of these signals will be fed to the video detector. You notice that the sound i-f signal at 41.25 mc is well down on the response curve, so it does not receive as much amplification as the video signals. This is done deliberately to avoid developing too strong a 4.5 mc signal in the video detector. You will study video detectors later in this lesson, and we'll go into detail on exactly what happens in this circuit at that time.

The circuit shown in Fig. 8 is a three-stage video i-f amplifier using tubes. There have been many monochrome television receivers manufactured using only two video i-f amplifiers. With modern tubes, that have a mutual conductance of between 20,000 and 30,000, it is comparatively easy to obtain sufficient gain in a two-stage video i-f amplifier, even though the resonant circuits used in the amplifier might have a comparatively low Q.

TRANSISTOR VIDEO I-F AMPLIFIERS

In Fig. 10 we have shown a schematic diagram of a three-stage transistor video i-f amplifier. This is a typical amplifier from a monochrome TV receiver. To help you understand how it works, we'll go through the various circuits.

The signal from the tuner is fed to the input capacitor C_1. Across the input from ground, we have a series-resonant circuit consisting of C_2, L_1 and C_3. This circuit is tuned to resonance at 41.25 mc. You will remember that this is the sound i-f frequency, and the series-resonant circuit cuts down the amplitude of the sound signal. This is done deliberately, in order to prevent an excessively strong 4.5 mc signal at the output of the video detector. The 4.5 mc signal could get through the video amplifier and cause a 4.5 mc interference pattern on the face of the picture tube.

The series-resonant circuit consisting of C_4 and L_2 is tuned to 47.25 mc. This is the adjacent-channel sound trap. It is designed to eliminate interference from the sound of the channel immediately below the channel to which the receiver is tuned.

The coil L_3 is tuned, along with the output coil in the tuner, in order to obtain a broad passband from the output of the tuner to the input of the first transistor amplifier, Q_1. The coil in the tuner is tuned close to the sound i-f, and L_3 is tuned close to the video i-f.

The input transistor, Q_1, is an NPN transistor, as are the other transistors in the video i-f amplifier. All the transistors are used in a common-emitter circuit. The signal from the tuner is fed through the bandpass circuit and through R_3 to the base of the transistor. The amplified signal is fed to the primary winding of T_1. Notice that the resistor R_5 is connected across the primary of T_1 to load the transformer and give the required wide bandpass.

Notice that the B+ voltage is applied through R_7 to a center tap on the primary of T_1. One end of T_1 is connected to the collector of the transistor Q_1. The other end will have a signal voltage which is 180° out-of-phase with the voltage fed to the transformer from the collector. This signal voltage is fed through C_7 and R_3 back into the base of the transistor. This is a neutralizing circuit, used to prevent the input i-f stage Q_1 from going into oscillation.

The second video i-f amplifier Q_2 is essentially the same as the first stage. A neutralizing voltage is fed from the primary T_2 to C_{17} back to the base of Q_2 to prevent oscillation.

Notice that the forward bias applied to Q_1 and Q_2 is controlled by an agc voltage. Again, this voltage is used to control the gain of these two stages so that the video i-f amplifier will operate at maximum gain on weak signals and a minimum gain on strong local signals. The agc voltage fed into this circuit is a negative voltage which reduces the forward bias applied to these transistors and in so doing reduces the gain of the two stages.

Both T_1 and T_2 are loaded by resistors to broaden their response. T_1 is loaded by the resistor R_5 and T_2 is loaded by the resistor R_{11}.

The signal from the secondary of T_2 is fed to the base of Q_3, the third video i-f amplifier. The gain of this transistor is constant. It is controlled by the forward bias applied to the base by the voltage-divider network consisting of R_{14} and R_{15}. The amplified signal in the output is fed to the primary of T_3 and from the secondary of the transformer on to the video detector.

The transformer T_3 is very heavily overcoupled, and in addition the secondary will be loaded by the comparatively low resistance in the video detector. This will give this transformer a wide frequency response. In an amplifier of this type, T_3 is usually tuned to the center of the passband. T_1 is tuned somewhat towards the high end and T_2 somewhat towards the low end, so that the overall response in the video amplifier is such that it will pass the entire band of frequencies reaching it from the tuner.

You'll notice the resistors connected between the emitter of the three transistors and ground. These resistors are placed in the emitter circuit to prevent thermal runaway, which might occur as the operating temperature of the transistors increases.

The video i-f amplifiers shown in Fig. 8 and Fig. 10 are typical of the amplifiers you'll encounter in monochrome television. It would be worthwhile to go over these circuits several times. You'll see that there are many similarities between the two. Generally speaking, you'll find one or more traps in the input of the first video i-f stage to prevent interference that will fall outside of the channel. You'll also frequently find a sound trap, such as you did in the circuit shown in Fig. 10, to reduce the amplitude of the sound signal. You'll also find that the i-f transformers are usually stagger-tuned, one towards the high end, one towards the low end, and if a third one is used it will be a broadband transformer that is tuned to the middle of the i-f passband.

Now let's go ahead and look at some video i-f amplifiers designed for color TV receivers.
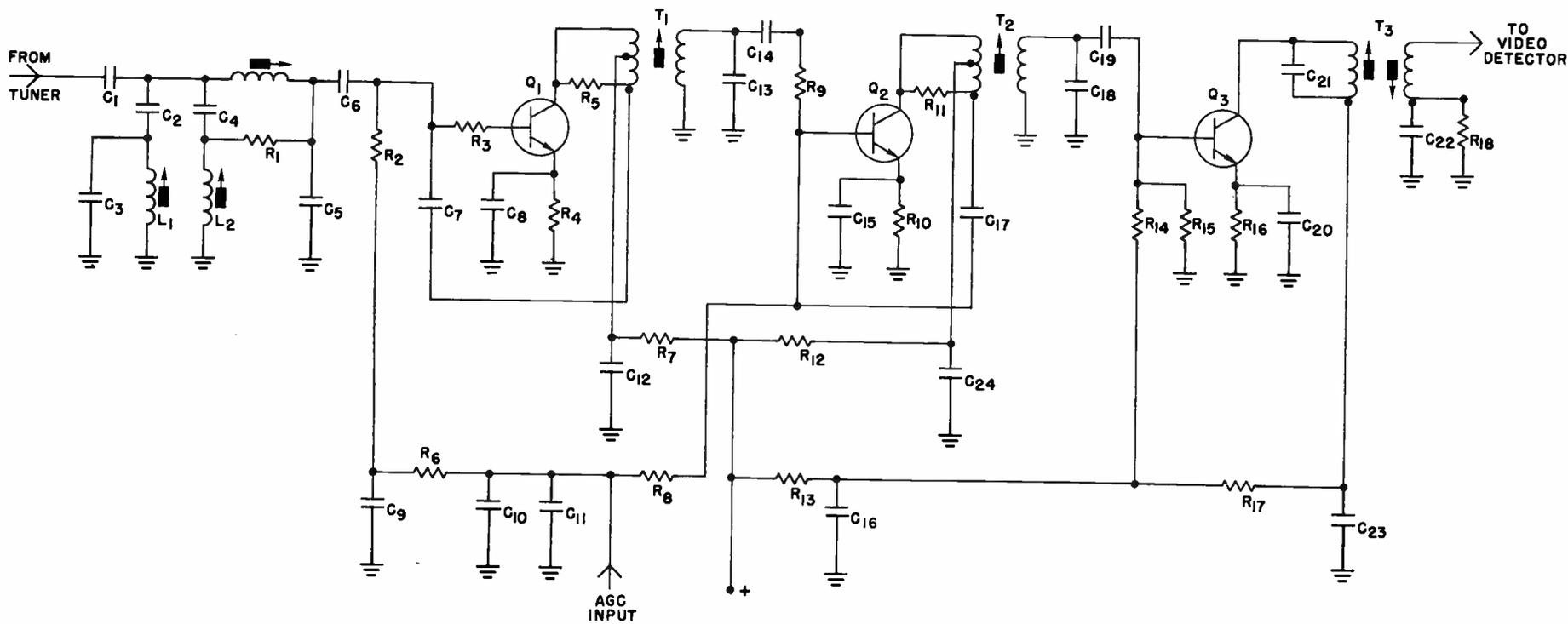
Fig. 10. Schematic of a three-stage transistor video i-f amplifier.

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Fig. 11. A two-stage color video i-f amplifier.
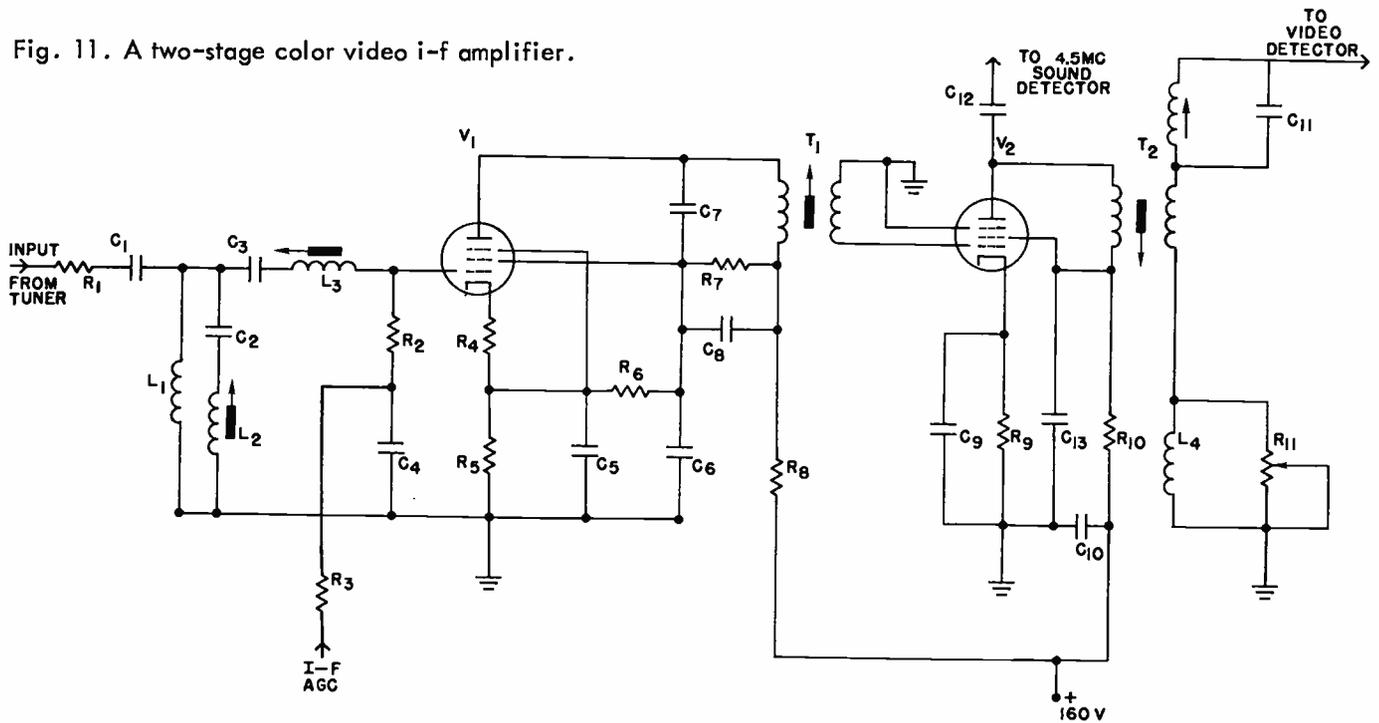
A TWO-STAGE COLOR VIDEO I-F AMPLIFIER

The schematic diagram of a two-stage video i-f amplifier designed for color TV reception is shown in Fig. 11. Actually, this circuit is not too different from the two video i-f amplifiers that you have seen previously, but we'll go through the circuitry in detail.

The input signal is fed from the tuner through R_1 and C_1 into the video i-f amplifier input. L_1 is a comparatively high-inductance coil and it is used in conjunction with the coil in the tuner and L_3 in the input of the i-f amplifier to obtain a broad passband. The tuner coil is tuned close to the 45.75 mc video i-f frequency. The coil L_3 is tuned toward the lower end of the band to give an overall broad passband.

The capacitor, C_2, and coil L_2 form a series-resonant circuit. This circuit is tuned to resonance at 47.25 mc to prevent adjacent channel sound interference from reaching the grid of the first video i-f amplifier, V_1.

The signals reaching the grid of V_1 are amplified by this stage and fed to T_1. T_1 is very highly over-coupled. In addition, it is loaded by the resistor R_7 to give it a low Q and a broad passband. Thus the entire video signal consisting of the video i-f carrier and its sidebands, the color subcarrier and its sidebands, and the sound i-f signal are passed by T_1 and fed from V_1 to V_2. The sound signal does not receive as much amplification as the video signal and its sidebands or the color subcarrier and sidebands; it is near the edge of the band passed by T_1.

The signal fed to the grid of V_2 is amplified by this stage and then fed to the output video i-f transformer, T_2. The primary winding of this transformer is tuned to resonance at about 43 mc. The secondary winding, which consists of two coils, one of which is parallel with C_{11}, is tuned to resonance at 41.25 mc. This forms a parallel-resonant trap, so that the sound signal is trapped and kept as low as possible in order to feed as little of the sound signal as possible to the video detector.

The secondary of T_2 is adjusted along with R_{11} to keep the 41.25 mc signal reaching the video detector as low as possible. As we mentioned previously, the reason that we want to do this is that the 4.5 mc sound signal and the 3.58 mc color subcarrier will beat together to produce a 920 kc interference signal at the output of the video detector. By keeping the 41.25 signal as low as possible, we can keep this interference as low as possible.

At first glance you might wonder how we get a parallel-resonant circuit in the secondary of T_2. Actually the secondary consists of two separate coils. The lower secondary coil is inductively coupled to the primary, the upper one is not. Thus the output signal is induced in the lower secondary coil. The signal developed is then fed to the video detector through the parallel-resonant trap tuned to 41.25 mc.

This trap actually could be separate from T_2, but it is placed in the shielded i-f can with the primary and secondary of T_2 to get better shielding and thus keeps the 41.25 mc signal fed to the video detector as low as possible.

Notice that there is a capacitor, C_{12}, connected to the plate of the second video i-f amplifier. This capacitor is a comparatively small capacitor, but it feeds both the video i-f signal and the sound i-f signal to a diode detector. In the diode detector, the two signals beat together to produce a 4.5 mc signal. This difference signal, as we mentioned previously, is both amplitude-modulated with the video information and FM-modulated with the sound information. We feed this signal to a 4.5 mc amplifier and then to an FM detector, where the sound information is removed from the carrier.

You might at first wonder why it is possible to get the bandwidth and gain that is required from a simple two-stage video i-f amplifier as that shown in Fig. 11. The answer lies in the fact that the tubes used in this amplifier have a very high mutual conductance. This amplifier has as much or more gain than the video i-f amplifiers used in some of the first monochrome receivers, where three or four stages were used employing tubes with a comparatively low mutual conductance.

A THREE-STAGE COLOR VIDEO I-F AMPLIFIER

The schematic diagram of a three-stage color video i-f amplifier is shown in Fig. 12. You'll notice that it is not too different from the circuit shown in Fig. 11; the primary difference is the addition of the additional stage. However, there are some differences that should be brought to your attention, because you are likely to run into other amplifiers of this type.

First, notice that the input from the tuner is fed to a trap circuit consisting of C_1, L_1, and C_2. This circuit forms a series-resonant circuit that is resonant at 41.25 mc. The purpose of this circuit is to keep the sound signal to a low value. We mentioned previously that we don't want any sound signal to reach the video detector; otherwise we'll have 920 kc interference from the sound signal beating with the color subcarrier. One of the best ways of preventing this type of interference is to reduce the sound signal as much as we can right in the input of the video i-f amplifier.

The signal is then fed through C_4 to the primary winding of the input video i-f transformer, T_1. This transformer has comparatively broad response and when adjusted correctly in conjunction with the resonant circuit in the output tuner will pass the entire video i-f passband.

The circuit consisting of L_2 and C_5 forms a series-resonant circuit that is resonant at 47.25 mc. This is the adjacent channel sound trap, used to prevent interference from the sound channel below the channel to which the receiver is tuned. L_3 and C_6 form a series-resonant trap that is resonant at 39.75 mc. This is an adjacent picture trap and is used to prevent interference from the picture carrier of the channel above the channel to which the receiver is tuned.

The signal from the secondary of T_1 is fed to the grid V_1, where it is amplified and then fed to the primary winding of T_2. T_2 is an overcoupled transformer having a wide bandpass; the secondary of this transformer feeds the amplified signal to the grid of V_2.

Notice that the plate resistor R_7, in the plate circuit of V_1, is connected to the cathode of V_2 through R_9. The two tubes are actually connected in series across the 250-volt power supply. The purpose of this connection is to eliminate the necessity of voltage-dropping resistors to reduce the plate and screen voltages to the two tubes. With the two tubes connected in this manner, each is operating on a dc plate and screen voltage of about 125 volts.

Notice the capacitors C_7 and C_9. These are special capacitors having one common plate. The large plate
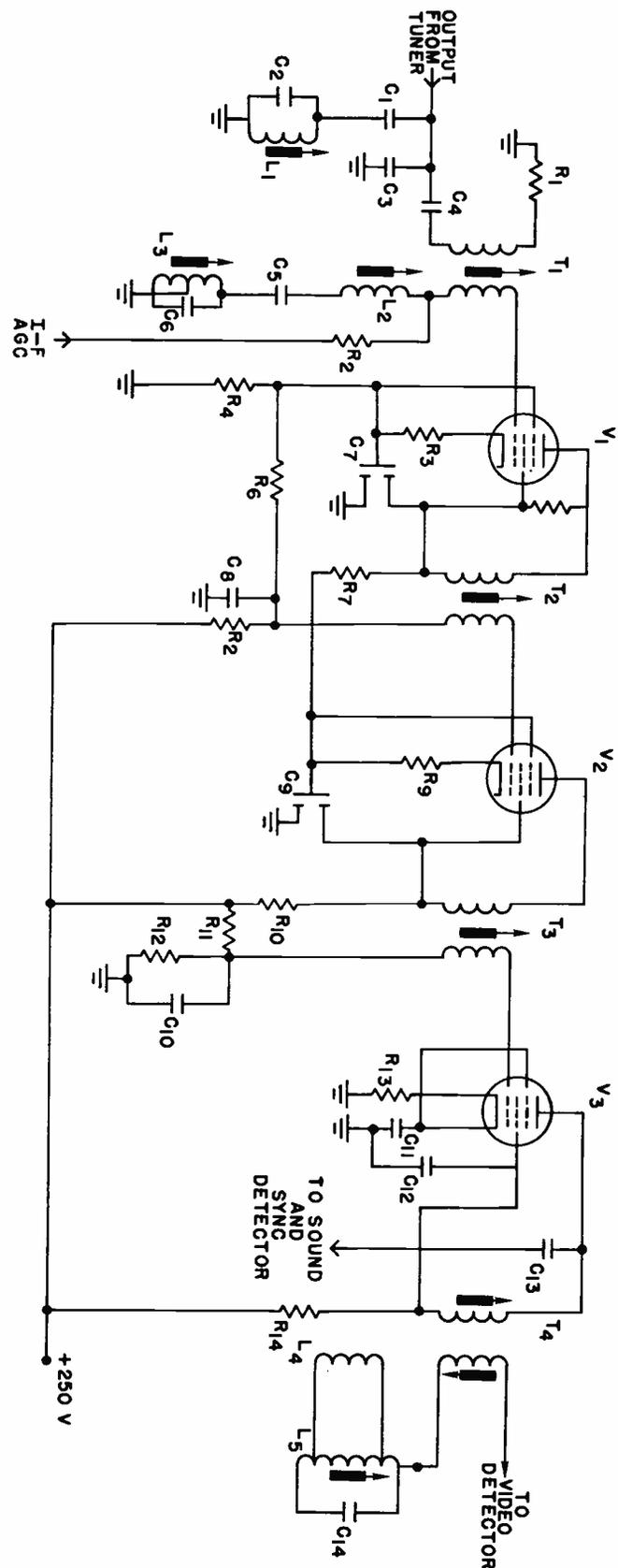
Fig. 12. A three-stage color video i-f amplifier.

is the common plate. This is used to bypass the cathode and the screen of both tubes to ground.

The output signal from V_2 is coupled through T_3 to the third video i-f amplifier, V_3. Here notice the symbol used for the cathode of V_3. This symbol indicates the cathode has separate cathode connections. One is used to provide a dc bias path, and the other an ac bypass. If you should ever have to replace either the cathode bypass capacitor or the cathode bias resistor, it is important that you connect the replacement to the correct terminal.

In the plate circuit of V_3 we have a primary winding of T_4. This is the output video i-f and the secondary of this transformer connects to the video detector. We also have a resonant circuit in the output consisting of L_5 and C_{14}. This is a form of absorption trap that is tuned to resonance at 41.25 mc. The purpose of this trap is to remove any 41.25 mc sound signal from the secondary of T_4 and thus prevent its reaching the video detector.

We have already mentioned that in color receivers the sound signal is taken from the output of the last video i-f amplifier and fed to a separate sound detector. In this circuit, the signal is fed through C_{13} to a combination sound and sync detector. You will remember that we said that the 4.5 mc signal, produced when the 45.75 mc video carrier and the 41.25 mc sound carrier beat together in a detector, is both amplitude-modulated with the video information and FM-modulated with sound information. In this receiver we take advantage of the fact that the 4.5 mc signal is both AM and FM modulated. By using an FM detector, we extract the sound signal from the 4.5 mc signal. By using an AM detector, we produce the video signal from the 4.5 mc carrier. Then the video signal is fed to another circuit, where the video and the sync information are separated.

This method of taking both the sound and the sync from the output of the video i-f amplifier has been used in a number of different color TV receivers. It does not add any great problems to the video i-f amplifier, but it does simplify the video amplifier somewhat, as it is not necessary to take off a sync signal when the sync has already been removed from the video i-f amplifier.

A THREE-STAGE TRANSISTOR VIDEO I-F AMPLIFIER

The schematic diagram of a three-stage color video i-f amplifier using transistors is shown in Fig. 13. Again, this circuit is not too different from the circuit shown in Fig. 12, except we have used transistors instead of tubes. However, we have analyzed the circuit to help you understand what happens in it.

The input coil L_1 is tuned in conjunction with the coil in the collector circuit of the mixer in the tuner to the center of the i-f passband, in other words to about 43 mc. This provides the wide passband width required to pass the video signals, the collector subcarrier, and the sound signal on to the first transistor, Q_1.

The network consisting of C_2, C_3, L_2 and R_1 forms what is called a bridged T trap. This trap is tuned to resonance at 47.25 mc, and as in the previous cases is an adjacent channel sound trap.

The circuit consisting of L_3 and C_7, along with C_5, forms a 39.75 mc trap. You'll remember that this is an adjacent channel video trap and is used to trap out interference from the video carrier of the channel above the channel to which the receiver is tuned.

The signal getting by the traps is fed through C_6 to the base of the first video i-f amplifier, Q_1. The transistors used in this amplifier are all NPN transistors, and all are used in a common-emitter circuit. The signal is amplified by Q_1 and fed to the primary of T_1. You'll notice that the primary winding of T_1 is loaded by the resistor R_4 to reduce the Q of the circuit and broaden the response.

Also, C_9 and C_{10} are connected across the primary of the transformer and the center tap is grounded, so that in effect the center tap of the coil is at ground potential. This means that signals are developed at the two ends of the primary winding of T_1 that are $180°$ out-of-phase with each other. A signal is fed from the one end through C_8 back to the base of the transistor to neutralize the first stage. As before, this neutralization is needed in order to prevent oscillation.

Notice the resonant circuit consisting of L_4 and C_{11}. This resonant circuit forms a trap at 35.25 mc. This is to eliminate sound interference from the channel above the channel to which the receiver is tuned. In other words, in this receiver we have two adjacent channel sound traps, one tuned at 47.25 mc to eliminate the interference from the channel below the channel to which the receiver is tuned, and one tuned to 35.25 mc to eliminate interference from the channel above the channel to which the receiver is tuned.

HAS BROAD BANDWIDTH

The transformer T_1 is highly overcoupled and loaded so that it has a broad bandwidth. The signal from the secondary is fed through C_{13} to the base of the secondary i-f stage Q_2. Notice that a similar circuit is used in the output so that neutralization is fed through C_{15} back into the base of Q_2.

The second video i-f transformer, T_2, couples the signal from Q_2 to Q_3, the third video i-f stage. In the plate circuit of Q_3 we take off a signal which is fed to the 4.5 mc sound detector. Remember that both the sound and video signals are actually taken off from this point, and the 4.5 mc signal produced by beating the two together in a detector.

T_3 is a dual winding transformer which has close coupling between the primary and secondary windings to provide a wide bandpass. The secondary of T_3 is connected to the video detector. Notice that both the primary and secondary windings of the transformer are tuned independently. One is tuned somewhat above the mid-frequency and the other somewhat below the mid-frequency to get the wide bandwidth required.

The coil consisting of L_6 and L_7 picks up a certain amount of the 45.75 mc signal and feeds the signal through what is called a fine-tuning indicator circuit,
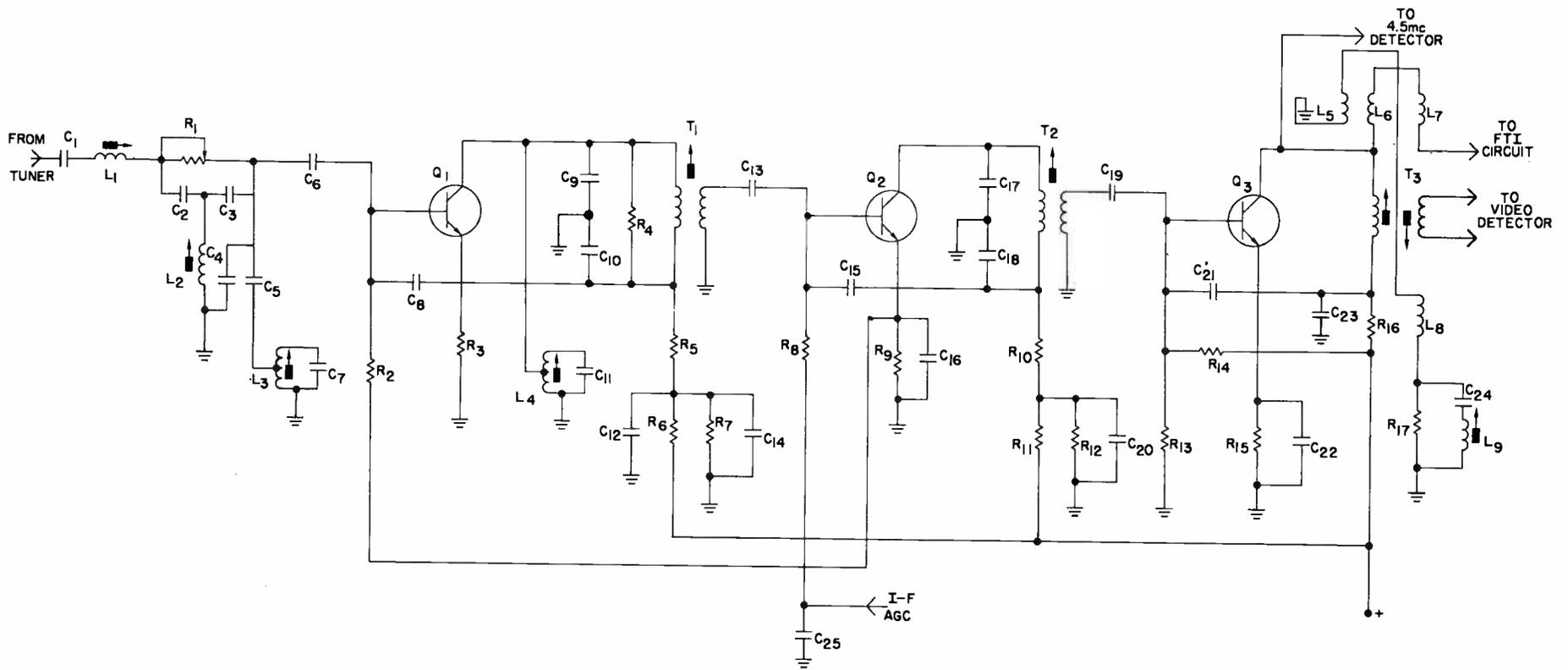
Fig. 13. A three-stage transistor i-f amplifier from a color TV receiver.

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abbreviated FTI circuit. In this circuit, a light goes on to indicate when the fine tuning on the receiver is set correctly. If the fine tuning is not set correctly, the color subcarrier may be positioned in such a position on the response curve that it receives little or no amplification. Under these conditions, you will not be able to get color on the face of the cathode-ray tube. The FTI circuit enables the viewer to easily see when the fine tuning is set correctly. We'll go into this circuit later in this lesson to see how it works.

Coupled to L_6 you'll notice a coil marked L_5, and coupled to the secondary of T_3 a coil, L_8. Both of these coils are designed to absorb energy from the output i-f transformer. They are fed to the series-resonant circuit consisting of C_{24} and L_9, which is adjusted to 41.25 mc. Thus this circuit is used to keep the 41.25 mc signal out of the video detector; once again we use this sound trap to keep the sound signal from the video detector in order to avoid the production of a 920 kc interference signal in the video detector.

The video i-f amplifiers that you studied so far in this section of this lesson are typical of what you are going to find in modern television receivers. You have seen that the main difference between the video i-f amplifier and a monochrome receiver from that of a color television receiver lies in where the sound is trapped from the video signal. In a color TV receiver the sound i-f signal is prevented from reaching the video detector in order to prevent 920 kc interference due to the sound i-f and color i-f subcarriers beating together. In a monochrome receiver the sound i-f is permitted to reach the video detector, where it beats with the video i-f carrier to produce a 4.5 mc sound signal. The 920 kc interference signal is not particularly objectionable in the monochrome receiver, because in most cases the video i-f amplifier of the monochrome receiver is not as broad as the video i-f amplifier in a color television receiver.

Usually the video i-f color subcarrier receives very little amplification in the video i-f amplifier of a monochrome receiver. As a result the video i-f

color subcarrier reaching the video detector is comparatively weak. The sound i-f signal reaching the video detector is also weak, but it is amplified further in order to get sufficient sound. On the other hand, the 920 kc signal produced by the two signals beating together is of such low amplitude, that even after it is amplified by the video amplifier it is not sufficiently strong enough to cause an objectionable interference pattern on the face of the picture tube.

SELF-TEST QUESTIONS

(a) Which signal transmitted by a TV station is the higher frequency, the video carrier signal or the sound-carrier signal?

(b) Which signal has the higher frequency, the video i-f signal or the sound i-f signal?

(c) Is the color subcarrier transmitted by the station higher in frequency or is it lower in frequency than the sound carrier transmitted by the station?

(d) Which sideband of the video modulation is partially suppressed?

(e) What do we mean by the bandwidth of a circuit?

(f) What do we mean when we say that two coils are overcoupled?

(g) What is a bifilar-wound coil?

(h) What three types of traps can you expect to find in the video i-f amplifiers of modern television receivers?

(i) In the circuit shown in Fig. 8, what is the purpose of L_1 and C_2?

(j) What purpose do C_2 and L_1 in Fig. 10 serve?

(k) What purpose does the agc voltage applied at the agc input shown in Fig. 10 serve?

(l) What kind of trap is used in the output video i-f transformer T_2 in the circuit shown in Fig. 11, and to what frequency is it tuned?

(m) What traps are used in the circuit shown in Fig. 12 and to what frequency are they tuned?

(n) What purpose does C_8 in the circuit shown in Fig. 13 serve?

Video Detectors

The final requirement of the video i-f system is to detect or demodulate the video i-f carrier fed to it to obtain the picture brightness information transmitted on the carrier. In addition, in a color television system the video i-f carrier must beat with the color i-f subcarrier to produce the 3.58 mc color signal. In monochrome television, the video i-f carrier beats with the sound i-f carrier in the video detector to produce a 4.5 mc sound signal.

Actually, the 3.58 mc color subcarrier and the 4.5 mc sound signals act essentially like any high-frequency video information that might be transmitted on the video i-f carrier. Therefore a diode detector that is capable of detecting the video brightness information will usually handle the color subcarrier signal in a color set or the sound signal in a monochrome receiver satisfactorily.

Since the video i-f signal is amplitude-modulated because the video carrier signal is amplitude-modulated, we can use a conventional diode-type detector as the video detector. However, the diode must be connected to obtain a proper output polarity, and the diode load resistor must be a low value in order to prevent loss of the high-frequency components of the video information. In addition, the video detector circuit must be designed to provide proper filtering of the intermediate frequencies and their harmonics. It must also be designed to keep radiation at a minimum. To get a better understanding of the way the video detector works, let's consider what the modulated video i-f signal fed to it looks like.

The modulated video i-f signal applied to the video detector is in the form of an envelope with positive and negative excursions above the zero axis, as shown in Fig. 14. The greatest peak-to-peak amplitude vari-
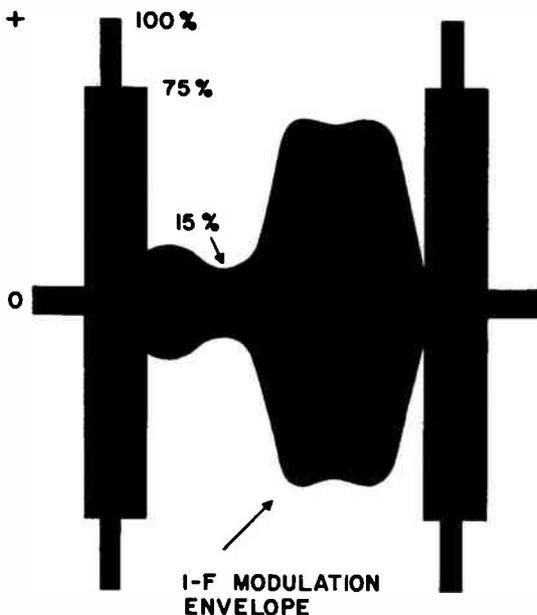
Fig. 14. The modulation information on the video i-f carrier is in the form of an envelope, as shown here.

ation occurs during the sync-pulse interval. During the sync-pulse interval the amplitude modulation reaches 100% or very close to this value. During the transmission of the blanking pedestal, the amplitude declines to 75% of the sync-pulse value. The amplitude of the blanking interval is the same as the maximum amplitude of the video signal, which occurs when black is being transmitted.

As the screen brightness increases, the peak-to-peak variation of the video i-f signal falls and reaches a minimum value of about 15% of the peak-sync pulse amplitude. This minimum value corresponds to the brightest portion of the picture. This method of transmission in which the greatest signal amplitude is for black and the least is for the brightest scene in the picture, which will be white, is referred to as a negative transmission.

Let us now observe how this modulation envelope and the relative peak-to-peak variations influence the output of a typical diode detector. However, before we do this, let's look at Fig. 15. Fig. 15A is the sche-
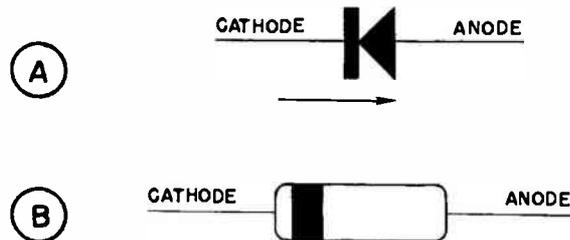
Fig. 15. A diode video detector. (A) schematic symbol; (B) location of cathode and anode connections.

matic symbol used to represent a solid-state diode detector. The bar represents the cathode, and the arrowhead the anode. Current flows through the diode from the cathode to the anode, but will not flow through it in the other direction. The direction of current flow is shown by the arrow in Fig. 15A. Fig. 15B shows you how the actual diode connection can be identified. The cathode end of the diode is identified by means of a black band around the end of the diode closest to the cathode. Sometimes this band is a thick band, other times it is comparatively thin. There may also be some colored bands on the diode which enable you to identify the diode type number.

Diodes are identified by preceding the number with "1N" followed by a group of numbers that indicate the type. The standard color code that is used to identify a resistor is also used to identify the type. For example, suppose the diode was a 1N295, then the colored bands would be red, white, and green. These bands would appear in that order from the right side or anode side, as shown in Fig. 15B, to the left or cathode side.

Before going ahead and studying the operation of the diode it would be worthwhile to remind you that whenever it is necessary to replace a diode you should use some kind of heat sink when soldering the diode in
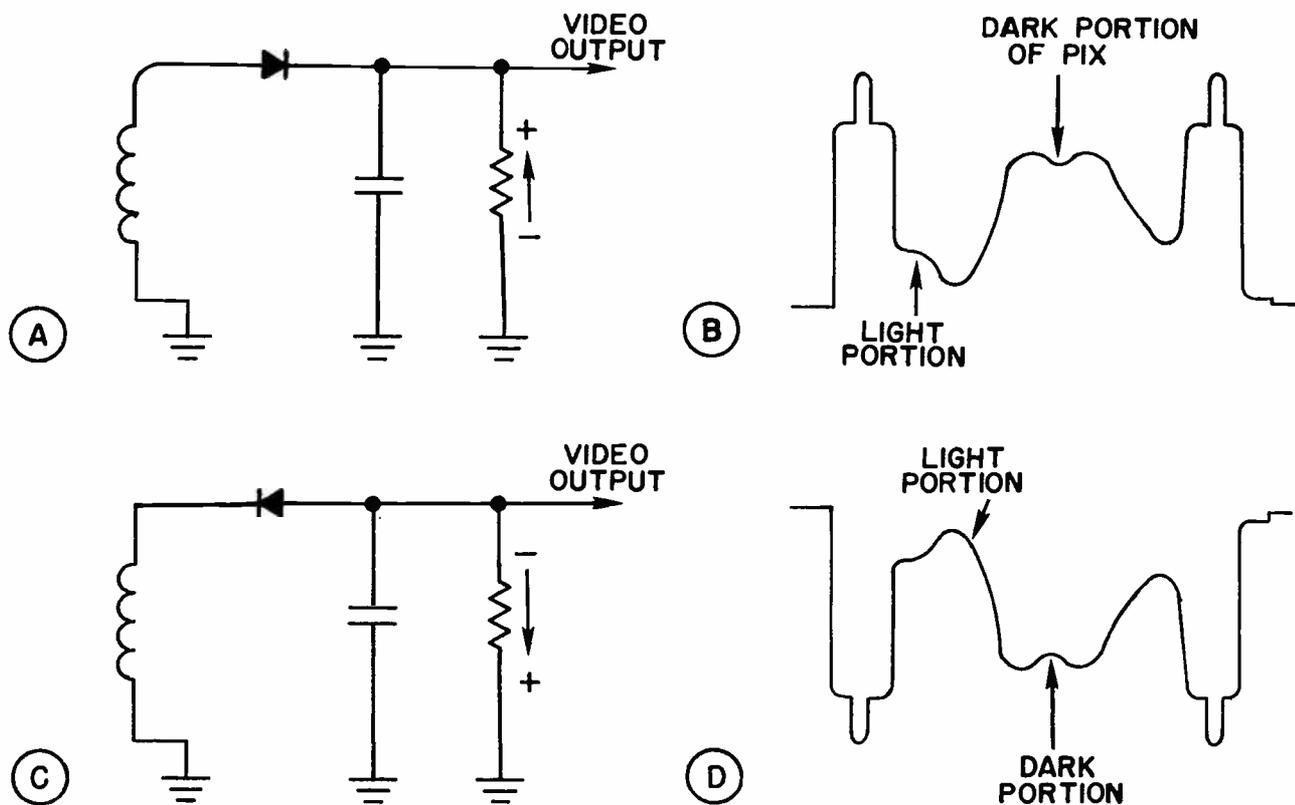
Fig. 16. Video detectors and output signals obtained from a video i-f signal such as that shown in Fig. 14.

place. Small signal diodes are very easily damaged by excessive heat. Hold the lead of the diode, between the body of the diode and the point where you are applying solder, with a pair of longnose pliers. This will usually keep the diode from getting too hot. The pliers will act as a heat sink and carry off much of the heat. The soldering operation should be performed as quickly as possible in order to avoid excessively heating the diode.

Getting back to the operation of the diode, when the modulation in the form of an envelope (as shown in Fig. 14) is applied to the anode of a video detector (such as shown in Fig. 16A) the detector will conduct only on the positive portion of the envelope. During the negative half of each cycle the anode will be negative with respect to the cathode and the diode will not conduct.

The output of the video detector will therefore be a series of pulses produced by the positive half of the video i-f carrier. The amplitude of the pulses will vary with the modulation. For example, during any of the sync pulses the voltage applied to the diode anode is maximum, and therefore, the diode passes maximum current. When this current charges the diode load capacitor, it develops a positive output voltage, as shown in Fig. 16A, with the sync pulse itself being the most positive part of the output signal. The pulses of current flowing through the diode actually charge the diode load capacitor and develop a voltage across the load resistor. The amplitude of the charge on the capacitor and the voltage across the load resistor depends upon the amplitude of the video i-f carrier at that particular instant.

As we mentioned previously, during maximum amplitude modulation the highest positive output voltage is produced in the output of the detector, as shown in Fig. 16A. For white information, the peak diode current will be substantially less, because the amplitude modulation on the carrier will be at its minimum during white transmission. Therefore the positive voltage developed across the diode load will be substantially smaller. An example of what will be developed in the way of an output for the diode circuit shown in Fig. 16A, when the video i-f carrier as shown in Fig. 14 is fed to this diode, is shown in Fig. 16B.

It is also possible to connect the diode so that it conducts on the negative half of the modulation envelope instead of on the positive half. In other words, the diode conducts when a negative signal is applied to its cathode, but does not conduct when a positive signal is applied. This circuit is shown in Fig. 16C, and the output video waveform in Fig. 16D. Notice that the signal in Fig. 16D is inverted from the signal shown in Fig. 16B. In Fig. 16B the sync pulses point in a positive direction, whereas in Fig. 16D they point in a negative direction.

As far as producing the video signal is concerned, it does not matter whether the negative or positive portion of the envelope is used. Both halves contain the same modulation information, but the polarity of the output signal changes. The important thing is to have the correct polarity signal when the video signal is fed to the picture tube. In color television, the video brightness information is fed to the cathodes of the tri-gun color tube. Since the picture tube is to be blanked or cut off during the sync pulses and the dark

portion of the picture, this means we need a positive-going signal such as shown in Fig. 16B. The sync pulses driving the cathode in a positive direction will cut off the picture tube. However, this doesn't necessarily mean that the video detector must develop a signal of this polarity. You will remember that video amplifiers are used between the video detector and the picture tube. A video amplifier, if it is used in a grounded-cathode circuit, will invert the phase of the picture 180°. Therefore if we have one video amplifier between the video detector and the picture tube, we would want a negative-going signal, such as that shown in Fig. 16D, if we are to feed the signal to the cathode of the picture tube. The single video amplifier will invert the signal so that the sync pulses will be going in a positive direction at the output of the video amplifier.

On the other hand, if we have a two-stage video amplifier, where the signal is inverted twice, then we would want a positive-going signal at the output of the video detector. When it is inverted twice by the two video amplifier stages, the sync pulses will once again be pointing in a positive direction and will be of the correct polarity to cut off the picture tube.

In monochrome television receivers, sometimes the signal is fed to the grid of the tube and at other times it is fed to the cathode of the picture tube. The polarity required at the output of the video detector depends upon whether the signal is to be fed to the cathode of the picture tube or to the grid of the picture tube and the number of times the signal is inverted by the video amplifier. With a two-stage video amplifier, where the signal is inverted twice, if we are going to feed the signal to the grid of the picture tube, we want a negative-going sync pulse such as produced by the detector shown in Fig. 16C. On the other hand, if the signal is to be amplified by a single stage and fed to the grid of the picture tube then we'd want a detector that produces a positive-going sync pulse, such as shown in Fig. 16B.

We often have occasion to speak of the polarity of the composite video signal. When we do this we actually refer to the polarity of the sync pulse. In Fig. 16B we say that the video signal has a positive polarity because the sync pulses swing in a positive direction. On the other hand, when we have the sync pulses swinging in a negative direction as shown in Fig. 16D, we say that the video signal has a negative polarity. Be sure to remember what we mean by these terms, because when you start studying video amplifiers it will be important that you will be able to follow the video signal through the amplifier and also keep track of the signal polarity as you go through the amplifier.

FREQUENCY RESPONSE OF VIDEO DETECTOR OUTPUT CIRCUITS

The operation of a video detector is not too different from the operation of a sound amplitude modulation detector. Looking at the circuit shown in Fig. 16A, when the anode of the diode is positive, current will flow through the diode which depends upon the amplitude of the signal applied to the diode. If the amplitude of the signal is high, a comparatively high current

flows and this current charges the diode filter capacitor. During the next half-cycle when the signal applied to the anode of the diode is negative, there'll be no current flow through the diode and the capacitor begins to discharge through the load resistor. However, the resistance of the load resistor is comparatively high compared to that of the diode, when the diode is conducting, so the capacitor discharges very little. When the next positive half-cycle comes along the capacitor charges back to maximum again, and then again discharges a little through the diode load resistor during the negative half-cycle. The charge on the capacitor is able to follow the amplitude of the video signal because its time constant is long enough to filter out variations due to the i-f signal, but the time constant of the rc network is short enough to permit the capacitor to discharge and follow the video variations.

The output from the video detector for a given signal input is not nearly as high as the output from the same type of detector in an AM radio. The diode load resistor in the average radio receiver may be a megohm or more, but in the video detector it is limited to a few thousand ohms to help prevent the loss of the high-frequency components of the video modulation. Loss of the high-frequency components is caused by the capacity in the detector circuit, even though it is small, that shunts the diode load resistor. As you have learned the reactance of any capacitor decreases with frequency. Therefore, the higher the video frequency, the lower the reactance, and the more shunting effect the capacitor has on the diode load.

The high-frequency response of the video detector is usually improved by using peaking coils in the detector circuit. Peaking coils are simply small inductors that are placed in the circuit to resonate with the fixed and distributive capacities in this circuit. Thus these coils form resonant circuits with the capacity in the circuit to aid in extending the high-frequency response. You will go into detailed study of peaking coils in the lesson on video amplifiers; for the present you should be aware how and why they are used in detector circuits.

TRAP CIRCUITS

You'll also find trap circuits in typical video detector circuits. Traps are frequently used in the video detector circuit of a color television receiver to keep the 4.5 mc sound signal from the video amplifier. You'll remember that you have already seen 41.25 mc traps in the output circuit of the last video i-f amplifier of the typical color circuits you have studied. However, in spite of these traps, some of the 41.25 mc signal will get through the circuit and reach the video detector. In the video detector it will beat with the video i-f picture carrier and produce a 4.5 mc signal.

Traps are inserted in the detector to suppress this 4.5 mc signal, because if it gets through the video detector circuit to the video amplifier it will be amplified, and then beat with the 3.58 mc color subcarrier to produce the 920 kc picture interference.

Now let us go ahead and look at a number of typical video detector circuits.

TYPICAL VIDEO DETECTOR CIRCUITS

A typical video detector from a monochrome TV receiver is shown in Fig. 17. The transformer represented by T_1 is the secondary winding of the output video i-f transformer. The signal from the primary winding is inductively coupled into the secondary winding. When the cathode of the diode D_1 is negative, current will flow from the upper end of T_1 to D_1 and through the diode load resistor R_1 and the peaking coil L_3. Current will also charge the diode capacitor C_1.

The diode capacitor C_1 is the capacitor that charges and discharges as the amplitude of the video signal varies. L_1 is a peaking coil and it is used to split the capacity in the circuit. Effectively it isolates the input capacity of the video amplifier and other distributed capacities from the diode detector circuit. In so doing, it helps prevent the loss of the high video frequencies in the detector output circuit.

L_3 is what we call a shunt-type peaking coil. It resonates with the distributed capacity in the circuit to form a parallel-resonant circuit that is resonant up near the high end of the video response required. As the output from the amplifier begins to fall down at higher frequencies due to the capacity in the circuit, L_3 forms a resonant circuit, which has a high impedance and effectively increases the value of the diode load resistor, and in so doing increases the output from the detector.

The circuit consisting of C_2 and L_2 is a series-resonant circuit that is resonant at 4.5 mc. The series-resonant circuit will provide a low-impedance path for the 4.5 mc signal developed in the video detector by the sound i-f and video i-f signals beating together. The signal will be bypassed by this low-impedance path, and thus kept out of the video amplifier. At the same time, since there is a high current flowing through this series-resonant circuit, there will be considerable voltage developed across the coil L_2.

A portion of this voltage is tapped and fed to a 4.5 mc sound i-f amplifier. This signal will be amplified by the amplifier and then fed to the 4.5 mc FM detector in order to extract the sound information.

A typical video detector from a color receiver is shown in Fig. 18. The coils L_1 and L_2 are inductively coupled together to the primary of the video output i-f transformer. Thus a signal will be induced in L_1, and this signal is fed to the diode detector D_1. At the same time, the signal from L_2 is fed to the trap consisting of L_3 and C_1. This trap acts essentially like an absorption trap, and keeps the 41.25 mc signal at a very low level and prevents it from reaching the diode detector.

When the cathode of the detector is negative, the diode D_1 will conduct and charge the capacitor C_2. The amplitude of the charge on the capacitor will depend upon the amplitude of the video i-f signal fed to the diode detector. The diode load resistor is R_2; it is connected in series with L_5 which is a shunt peaking coil similar to L_3 in the preceding circuit. L_4 is a series-peaking coil. It is placed in the circuit to isolate the output capacity of the video detector from the input capacity of the video amplifier. By splitting these capacities we can improve the high-frequency response.

In spite of the fact that we have a 41.25 mc trap in the detector circuit, some of the 41.25 mc signal will get through and reach the video detector. This signal will beat with the 45.75 mc video carrier and produce a 4.5 mc difference frequency. The coil L_6 and capacitor C_3 form a parallel-resonant circuit that is resonant at 4.5 mc. This parallel-resonant circuit offers a high impedance path to the 4.5 mc signal. Thus any 4.5 mc signal developed in the video detector will be almost entirely lost across this parallel-resonant circuit.

Notice the peaking coil L_7 with the resistor R_4 across it. Quite frequently a peaking coil will have too high a Q. When this happens, we can get oscillation
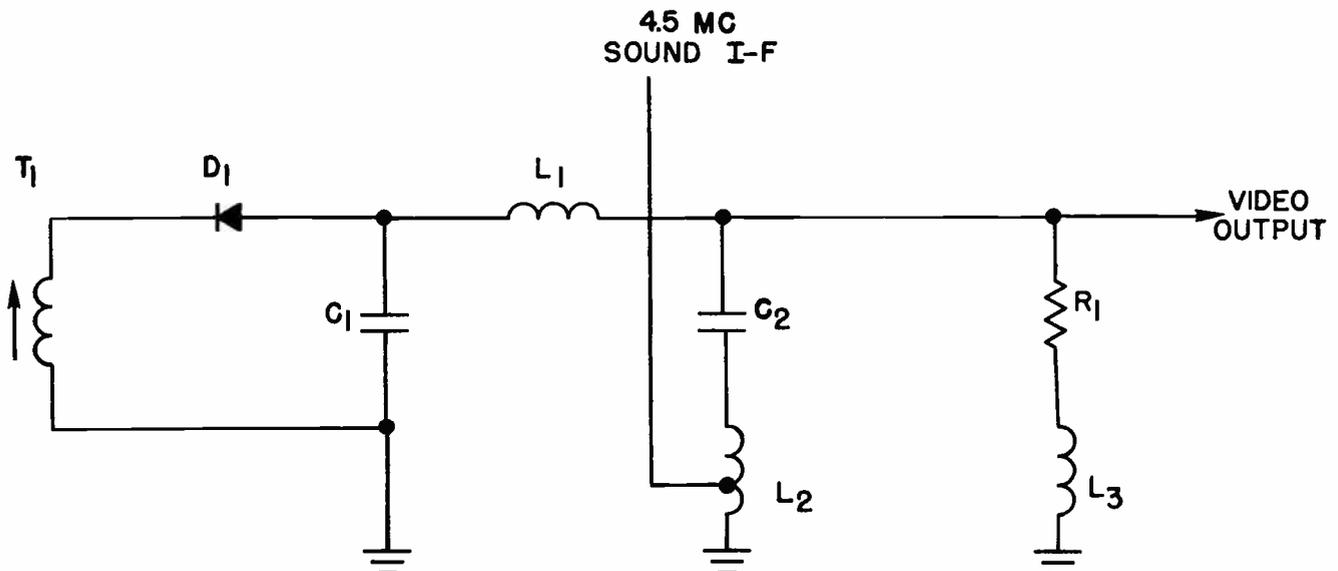
Fig. 17. A typical video detector from a monochrome receiver.
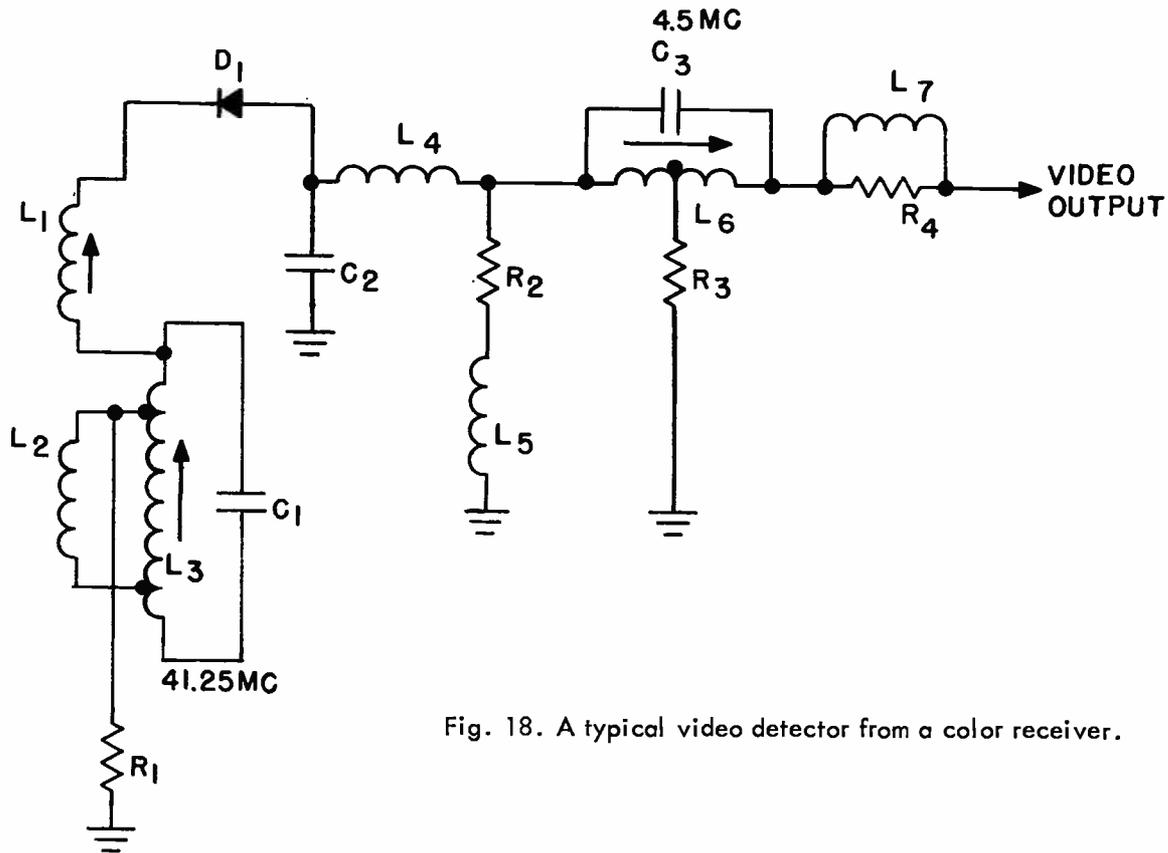
Fig. 18. A typical video detector from a color receiver.

in the circuit where the peaking coil is used. To prevent this oscillation, the peaking coil is loaded by connecting a resistor across it. In actual practice, the manufacturer simply winds the coil right on the resistor body. The two are then connected in parallel. The peaking coil helps improve the high-frequency response, and the resistor lowers the Q of the coil to prevent oscillation in the circuit.

Another interesting video detector circuit is shown in Fig. 19. This is the video detector that is used with the video i-f amplifier shown in Fig. 13. If you refer back to Fig. 13 you'll see that we have a 41.25 mc sound trap in the circuit as part of the output i-f transformer T_4. The secondary of this transformer connects to a trap made up of L_1 and C_2. The trap forms a resonant circuit at 41.25 mc to keep the 41.25 mc signal amplitude as low as possible.

The signal from the secondary of the video i-f transformer is fed to the cathode of the diode detector D_1. When the cathode is negative, the diode conducts and the diode filter capacitor C_4 will be charged according to the amplitude of the video i-f signal being received.

L_2 and L_3 are series-peaking coils. There is no reason why one coil with a total inductance of this group could not have been used. However, for some reason the manufacturer chose to use two separate coils.

The circuit consisting of L_4 and C_5 is a parallel-resonant circuit. This circuit is resonant at 4.5 mc and is put in the circuit to keep any 4.5 mc signal developed by the video detector out of the video amplifier. Notice that even though we have two 41.25 mc

traps in the input to the video detector circuit, that there is still some 41.25 mc signal available to get through and reach the diode detector.

This will beat with the 45.75 mc video carrier and produce the 4.5 mc sound signal. Even though this signal may be very small at the output of the video detector, if it is permitted to go on through to the video amplifiers or to any of the color circuits it can cause interference. Therefore, this possibility is prevented by means of the parallel-resonant circuit made up of C_5 and L_4 which will attenuate and reduce to a very low value any 4.5 mc signal that is produced in the video detector.

Notice that in the three video detector circuits shown in Figs. 17, 18, and 19 that in each case the video signal at the output has a negative signal phase. By this we mean that the sync pulses developed a negative voltage across the diode load resistor. You will find that this is the signal phase at the output of the video detector in most monochrome receivers, but this is not necessarily true of color receivers. You'll find the diode connected with the polarity shown in Fig. 18 and Fig. 19 in many color TV receivers, but you'll also find others with the diode reversed so that we have a positive signal phase at the output of the video detector. As we mentioned previously, the picture phase required at the output of the video detector depends upon the number and type of stages used in the video amplifier.

We have shown only solid state diodes in the video detector circuits described. However, there are many TV receivers in use that use vacuum tube video detectors. This is particularly true of older TV re-
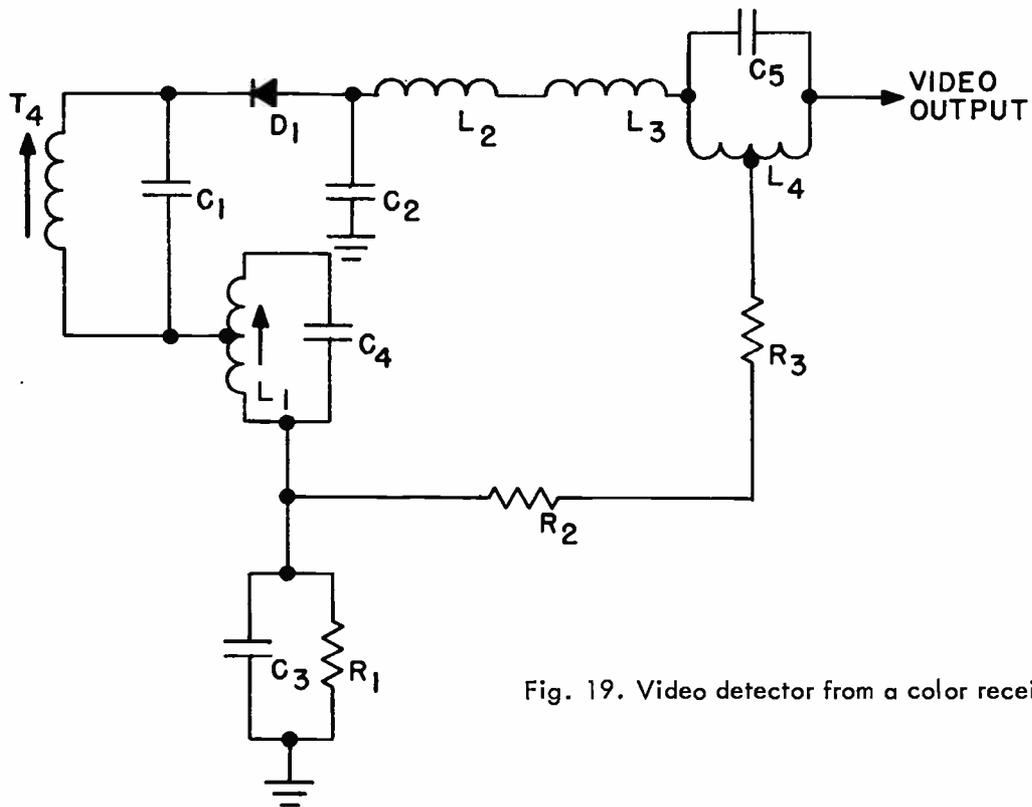
Fig. 19. Video detector from a color receiver.

ceivers. It makes no difference whether a solid state diode or a vacuum tube diode is used as the video detector; they work in exactly the same way. It is often convenient to use a combination pentode and diode in the last video i-f stage instead of a single pentode tube. With the dual purpose tube, the pentode section is used as the last video i-f amplifier and the diode section as the video detector.

SELF-TEST QUESTIONS

(o) Draw the schematic diagram used to represent a solid-state diode detector, label the cathode and anode and indicate by an arrow the direction

in which current will flow through the diode.

(p) When we say that the video signal has a negative phase, or is a negative-going signal, what do we mean?

(q) In the diode detector circuit shown in Fig. 17, what purposes do C_2 and L_2 serve?

(r) What will the polarity of the sync pulses at the output of the detector shown in Fig. 17 be?

(s) What is the purpose of the 41.25 mc trap consisting of L_3 and C_1 in the detector circuit shown in Fig. 18?

(t) What purpose does the trap consisting of C_3 and L_6 in the detector circuit shown in Fig. 18 serve?

(u) What are the coils L_2 and L_3 in the detector circuit shown in Fig. 19?

Video I-F Response Curves

A video i-f response curve is a curve that shows you in graphic form the response of the video i-f amplifier at various frequencies. The response curve tells you how well the video i-f amplifier will amplify signals of different frequencies. The curve is important to the technician; when it is necessary to re-align the video i-f amplifier of a TV receiver, you must have some idea of the capability of the amplifier and the response that the i-f amplifier is capable of producing.

We are not going to go into the video i-f amplifier alignment in this lesson. However, it is important that you have some familiarity with video i-f response curves, because it will help you to better understand some of the problems encountered in video i-f amplifiers and also when you do study alignment, you'll know what you are shooting for.

Before going ahead with the video i-f response curve, let's review some of the fundamentals of amplitude detection. This will help us to see why the video i-f amplifier is aligned in the manner in which it is.

AM DETECTORS

In the standard AM radio broadcast band, the carrier is modulated by the audio signal to be transmitted and produces two sidebands. You will remember that we have the lower sideband, which is equal to the carrier frequency less the audio frequency, and the upper sideband, which is equal to the carrier frequency plus the audio signal. Both of these sidebands are transmitted along with the transmitter carrier.

In the receiver, the bandwidth of the tuned circuits is sufficiently wide to pass the carrier along both of the sidebands. In Fig. 20 we have shown a typical radio receiver response curve showing how the station carrier frequency falls in the center of the response curve, and how both the upper and lower sidebands are capable of passing through the tuned circuits. Thus we have these three signals fed to the detector.

In the receiver, both the upper and lower sidebands contribute to the output from the detector. If for some reason we were to transmit only one sideband along with the carrier, the output from the detector would
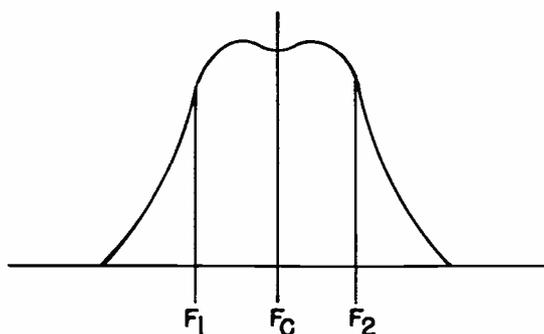
Fig. 20. Response curve with equal upper and lower sidebands.
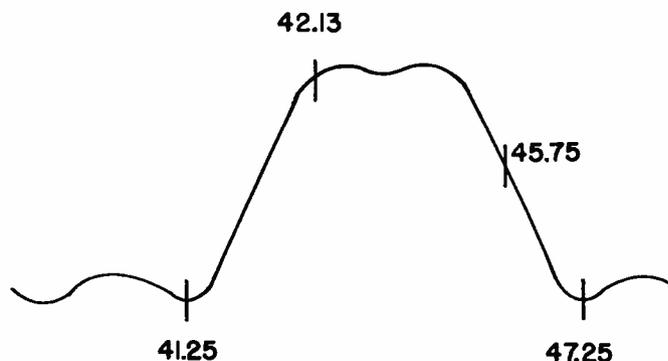
Fig. 21. A typical video i-f response curve.

be half of what it is normally when both sidebands are transmitted.

The important thing for you to remember from this brief review of the detection of amplitude-modulated signals is that both sidebands contribute to the detector output. If either of the sidebands is missing, the output from the detector would be reduced. Now let's go back to the video i-f signal and consider the problems encountered in the video detector.

VESTIGIAL SIDEBAND DETECTION

You will remember that earlier when we talked about the video signal transmitted by the station we made the point that only part of the lower sideband is transmitted in order to save space in the frequency spectrum. If you refer back to Fig. 1 you'll see that the video carrier for Channel 2 is 55.25 mc. The lower sideband is transmitted with full amplitude down to 54.5 mc. In other words, the upper and lower sidebands are both transmitted, providing they fall within 750 kc of the video carrier frequency. If the sideband falls 1 mc above and below the video carrier, the upper sideband will be transmitted, but the lower sideband will be attenuated and transmitted at reduced amplitude. If the lower sideband is 1.25 mc below the video carrier it will not be transmitted at all; only the upper sideband is transmitted.

Thus we have a situation where part of the signal reaching the video detector contains both the upper and lower sidebands transmitted at full amplitude. Part of the video signal contains an upper sideband transmitted at full amplitude with a reduced amplitude lower sideband, and still another part of the video signal reaches the video detector with an upper sideband only. To compensate for this type of signal, the i-f response curve must be adjusted so that the different sideband signals receive different amounts of amplification, so that the output from the video detector will be equal for video signals of equal amplitude.

In Fig. 21 we have shown a typical video i-f response curve. You'll remember that when the incoming video signal beats with the local oscillator it produces a video i-f frequency of 45.75 mc. In the typical i-f response

curve this frequency is located midway up on the slope of the response curve. Thus sidebands close to the video carrier, where both sideband signals are present, will produce the same output from the video detector, where only one of the sideband signals is transmitted.

Another important point on the response curve is 42.13 mc. This is the color i-f subcarrier frequency. Notice that it is located pretty well near the lower end of the response curve, but is positioned so that it receives maximum amplification. If the 42.13 mc color subcarrier were to slide too far down on the response curve slope, the color i-f subcarrier would not receive sufficient amplification and you would be unable to obtain any color at all or the color saturation would be limited.

The 41.25 mc sound i-f carrier is located in a trap. The trap is positioned at this frequency deliberately to keep the sound i-f from getting through to the video detector and beating with the 42.13 mc color signal and producing the 920 kc interference signal we mentioned previously. Even in a monochrome TV receiver the 41.25 mc signal is usually located in a trap and kept at a very low amplitude. This is done to avoid producing an excessively strong 4.5 mc signal in the video detector. If the 4.5 mc signal produced in the video detector is too strong, it will be impossible to trap it out and the result will be that the signal will get through the video amplifiers into the picture and produce a grain-like effect in the picture.

The other point we have marked on the response curve is 47.25 mc. This is the adjacent-channel sound i-f frequency and it usually is located in a trap as shown. Again, the trap is used in the receiver to prevent interference from the sound channel of the station operating in the channel beneath the one to which the receiver is tuned. At the same time it enables you to slope the response curve of the i-f amplifier in such a way as to provide an essentially flat output from the video detector from the different modulating frequencies that are fed to it.

The importance of correct setting of the fine tuning control that adjusts the frequency of the local oscillator in the tuner is shown in Fig. 22. Once the i-f response curve of the receiver is established, then the various signals will receive the correct amount of amplification providing they fall at the correct points on the response curve. However, if the oscillator should be set so that its frequency is too high, then the difference frequency between the various signals in the TV channel and the oscillator signal will be higher than normal.

This will result in the signals being positioned on the response curve as shown in Fig. 22A. Notice that the video i-f carrier is well down on the response curve, so that we will not get equal output from low-frequency sideband signals and high-frequency sideband signals. Low-frequency sideband signals will produce lower than normal output.

At the same time, the color subcarrier will receive full amplification and the sound i-f carrier will receive excessive amplification. This will result in sound getting through the traps in the receiver, because the

sound i-f frequency will be different from what it should be, and also because the sound i-f signal is substantially up on the curve. This will produce a strong 4.5 mc signal in the video detector which may be difficult to eliminate, and will also produce a 920 kc beat signal between the sound and color subcarriers that we cannot eliminate. Even though the oscillator may be tuned to the wrong frequency, the difference between the frequency of the various signals in the individual channel will remain the same. Therefore the 920 kc signal and the 4.5 mc signals will both be produced and both cause interference because of their excessive amplitude.

In addition, notice that the adjacent-channel sound signal falls out of the trap. Thus if you tune to a channel like Channel 3, and there is a nearby station operating on Channel 2, the chances are that the sound signal from Channel 2 will cause interference in the picture.

The effects of setting the oscillator frequency too low are shown in Fig. 22B. Here the picture carrier is too high on the response curve, with the result that low-frequency video signals will receive excessive amplification. Also the adjacent-channel sound signal will fall on the response curve and the lower channel could cause sound interference.

Another important problem is that the color i-f subcarrier falls well down the response curve. This would probably make it impossible for you to get color in the picture. If you were able to get any color, it would be weak and washed out. In addition, the sound i-f signal is misplaced out of the sound i-f trap, and therefore would get through the amplifier to the detector and once again produce interference.

The importance of correctly setting the fine tuning control in the tuner oscillator circuit, particularly in
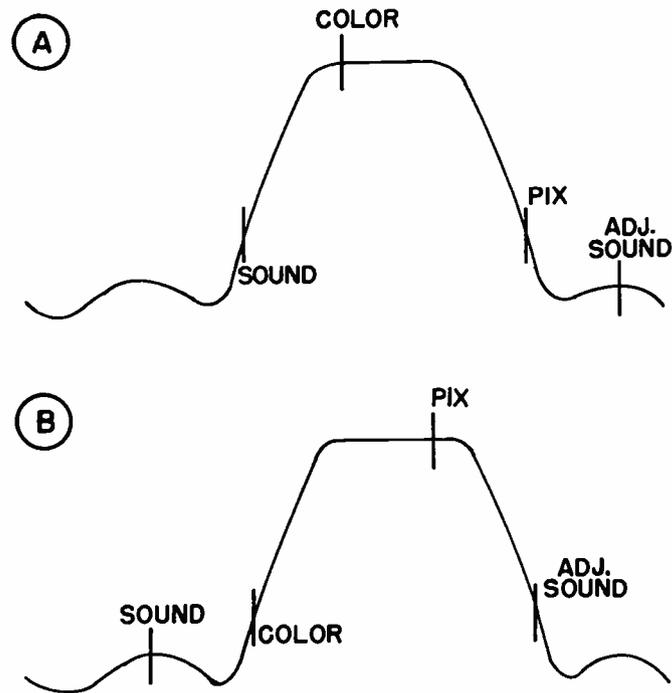
Fig. 22. Effects of incorrect setting of oscillator fine tuning. (A) oscillator frequency is too high; (B) too low.
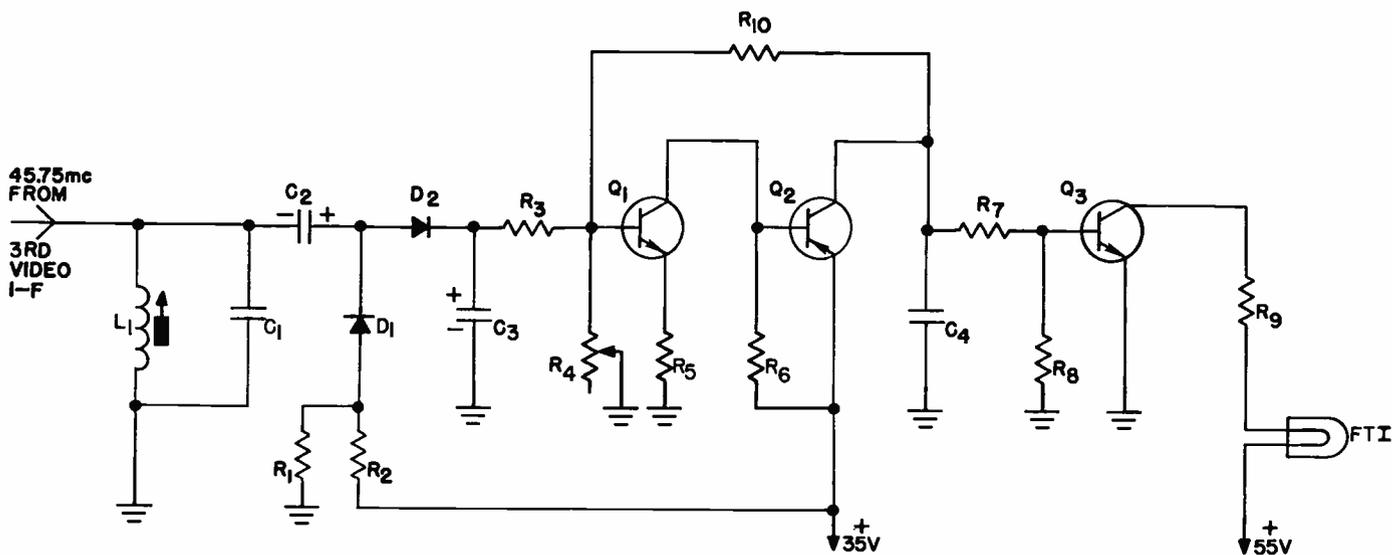
Fig. 23. Schematic diagram of Fine Tuning Indicator circuit.

color TV reception, has led manufacturers to use different schemes to aid the set owner to set the fine tuning correctly. One system is to use automatic frequency control; another is to use a fine tuning indicator which tells you when the oscillator is set correctly. We pointed out once before when you were studying i-f amplifiers that one of the receivers has a circuit to take off the signal for use with a fine tuning indicator circuit. Now let's look at that circuit.

FINE-TUNING INDICATOR CIRCUITS

The purpose of a fine tuning indicator circuit, as we mentioned previously, is to enable the set owner to correctly set the fine tuning in the oscillator circuit. The set circuit is frequently referred to as an FTI circuit.

The schematic of a fine tuning indicator circuit is shown in Fig. 23. In this circuit some of the 45.75 mc video carrier signal is taken from the output of the third video i-f amplifier and fed to a very high Q parallel-resonant circuit consisting of L_1 and C_1. This high Q circuit will produce a maximum output signal at 45.75 mc, a greatly reduced signal from frequencies slightly removed from this value.

The 45.75 mc signal is fed through C_2, which is a very small capacitor, so that the resonant circuit is very lightly loaded and maintains its sharp response to the voltage-doubler circuit consisting of D_1 and D_2. These two diodes act like a voltage-doubler circuit from a power supply. When the polarity of the signal developed across L_1 and C_1 is such that the end connected to C_2 is negative, electrons will flow into the one plate of C_2 and out of the other plate through D_1 and R_1 to ground. This will charge the capacitor C_2 with the polarity shown. When the signal polarity across L_1 and C_1 reverses, the positive voltage across these two components will be placed in series with the voltage across C_2. This will cause a current to flow through D_2 and charge the capacitor C_3 with the polarity indicated.

The positive voltage across C_3 is fed through R_3 to the base of Q_1 and causes the transistor to conduct. With no signal across C_3, the setting of R_4 is adjusted so that there is no forward bias on Q_1 and the transistor is not conducting.

Once Q_1 begins to conduct, there will be a voltage drop across R_6, which places a forward bias across the emitter-base junction of the PNP transistor Q_2 and causes this transistor to conduct. When Q_2 conducts it in turn will place a high forward bias across the NPN transistor Q_3 and cause it to conduct, and the collector current which flows through R_9 and through the pilot light causes the light to light, indicating that the receiver is tuned correctly. Once the fine tuning is tuned so that the signal frequency reaching the high Q input circuit is no longer 45.75 mc, the output across C_3 drops and the transistors are returned to the stable state where they are not conducting. When the transistors stop conducting, the current through the bulb drops to zero and the bulb goes out, indicating that the fine tuning is not set correctly.

The circuit shown in Fig. 23 is not particularly difficult to follow. We've gone through the circuit details briefly but you should be able to trace out each of the individual circuits and see what happens when the positive voltage is developed across C_3, causing the input transistor Q_1 to conduct. Notice that Q_1 and Q_3 are NPN transistors and that Q_2 is a PNP transistor. The pilot light is labelled FTI on the diagram and is located in the collector circuit of Q_3. The resistor R_9 that is in series with the pilot light is used to limit the current through the pilot light to prevent its burning out, and also to limit the collector current of Q_3 to prevent it from exceeding the rating of the transistor.

Other fine tuning indicator systems have been used in TV receivers, but they generally follow a system somewhat similar to the one shown in Fig. 23. This circuit has the advantage of being relatively simple, extremely sharp and trouble free. Once the adjustment control R_4 is set correctly, the circuit will

perform almost indefinitely without any further adjustment.

Automatic Fine Tuning.

An accessory that you will find on some color TV receivers is automatic fine tuning, along with an automatic fine-tuning indicator. An example of a circuit of this type from a Motorola color TV receiver is shown in Fig. 24.

The manufacturer refers to this as a fine-tuning indicator and lock. In this circuit the 1 pf capacitor connects to the output of the last video i-f stage. A signal is fed through this capacitor to the base of the fine tuning lock (FTL) amplifier, which is an emitter-follower circuit. The emitter-follower circuit is used along with the small coupling capacitor (1 pf) to keep the loading on the last video i-f stage at a minimum.

In the fine-tuning indicator circuit, the amplified signal is taken from the emitter of the FTL amplifier and fed through a 3.9 pf capacitor to a very high Q parallel-resonant circuit which is tuned to resonance at 45.75 mc. When the fine tuning is set correctly the video i-f frequency will be 45.75 mc and a maximum i-f signal will be developed across this coil. This will cause the current flow through the FTI detector to increase. The 1500 pf capacitor will filter the emitter voltage so that in effect we'll have an increase in the positive voltage on the emitter of the detector. This is fed directly to the base of the FTI output stage, causing the current flow through this transistor to increase. The current flow through the transistor increases the voltage drop across the 120K resistor in the collector circuit, causing the voltage across the neon bulb to drop to such a low value that the bulb goes out. This indicates that the fine tuning is set correctly.

When the fine tuning is not set correctly the voltage developed across the 45.75 mc high Q tank coil will be comparatively low. As a result, little or no voltage is developed on the emitter of the FTI detector, so that the current through the FTI output stage is very low. This means that the voltage drop across the 120K resistor is limited so that the voltage applied to the neon bulb is high enough to cause the bulb to light.

In the automatic fine-tuning circuit, which the manufacturer refers to as the fine-tuning lock, the signal is modified by the FTL amplifier and fed to the FTL output amplifier, which amplifies the signal still further. From the collector to this stage the signal is fed to the FTL discriminator transformer.

If the oscillator in the receiver front end is set correctly, the video i-f frequency once again will be 45.75 mc. This will cause equal and opposite voltages to be developed across the two 33K resistors and the two diodes. When the lower end of the secondary of the discriminator transformer is positive and the other end negative, current will flow from the upper end of the transformer through the 33K resistor, and develop a voltage drop across it with a polarity that makes the end connected to the transformer negative.

Current flowing out of the other side of the resistor will flow into the 1500 pf capacitor connected to ground and then through the diode to the lower end of the

secondary of the transformer. During the next half-cycle, when the lower end of the secondary is negative, current will flow through the 33K resistor to ground, again developing a voltage across it with the end connected to the i-f transformer negative. From there electrons will flow into the 1500 pf capacitor, discharging it, and then through the diode back to the upper end of the transformer.

Notice that due to the polarity of the voltage across the resistors the diodes cannot in effect discharge this voltage. If the fine tuning control is set exactly right, then the voltages across the two 33K resistors will be exactly equal and opposite in polarity, so that the net voltage fed to the tuner oscillator circuits will be zero. If the fine tuning is not set correctly, then either a positive or a negative voltage will be developed and fed back to the tuner oscillator circuit.

In the tuner oscillator circuit a varactor is connected across the oscillator tank circuit. A varactor is a form of capacitor that is voltage-sensitive. In other words, changing the voltage applied to this capacitor changes its capacity. Therefore if a dc voltage is developed by the discriminator circuit, indicating that the oscillator is off frequency, this voltage is fed back to the varactor, which changes the capacity of the varactor and hence the frequency of the oscillator. The change will correct the frequency so that the oscillator will go back on the right frequency.

Compensates for Drift.

In tuning a receiver using a circuit of this type the usual procedure is to turn off the automatic fine tuning, set the receiver to the channel desired, and then adjust the fine tuning until the fine tuning indicator light goes out. This indicates that the oscillator is operating at the correct frequency. Then the automatic fine tuning should be reengaged. The discriminator circuit will help compensate for any tendency for the oscillator to drift.

If you try to set the fine tuning with the automatic frequency control circuit turned on, then the chances are that as you approach the correct setting of the oscillator the fine-tuning control voltage will take over and suddenly pull the oscillator to the right frequency. If you leave the fine tuning set there, you'll actually have it set more or less on the edge of its range. There may be some tendency for the oscillator frequency to drift out of the range that can be controlled by the automatic frequency control. If you do tune the fine tuning with the automatic frequency control on, you should discover the range of the fine-tuning control over which the automatic frequency control will keep the oscillator on the right frequency. Then set the fine tuning in the center of this range.

There are many variations of both the automatic frequency control circuit and the fine-tuning indicator circuits. However, generally in both cases you'll have some high Q resonant circuits. In the automatic frequency control circuit, a discriminator that is frequency-sensitive is always used. Thus a voltage of one polarity is developed, if the oscillator frequency is too low, and a voltage of the opposite polarity is developed if the oscillator frequency is too high. The fine-tuning indicator circuit will have a high Q circuit
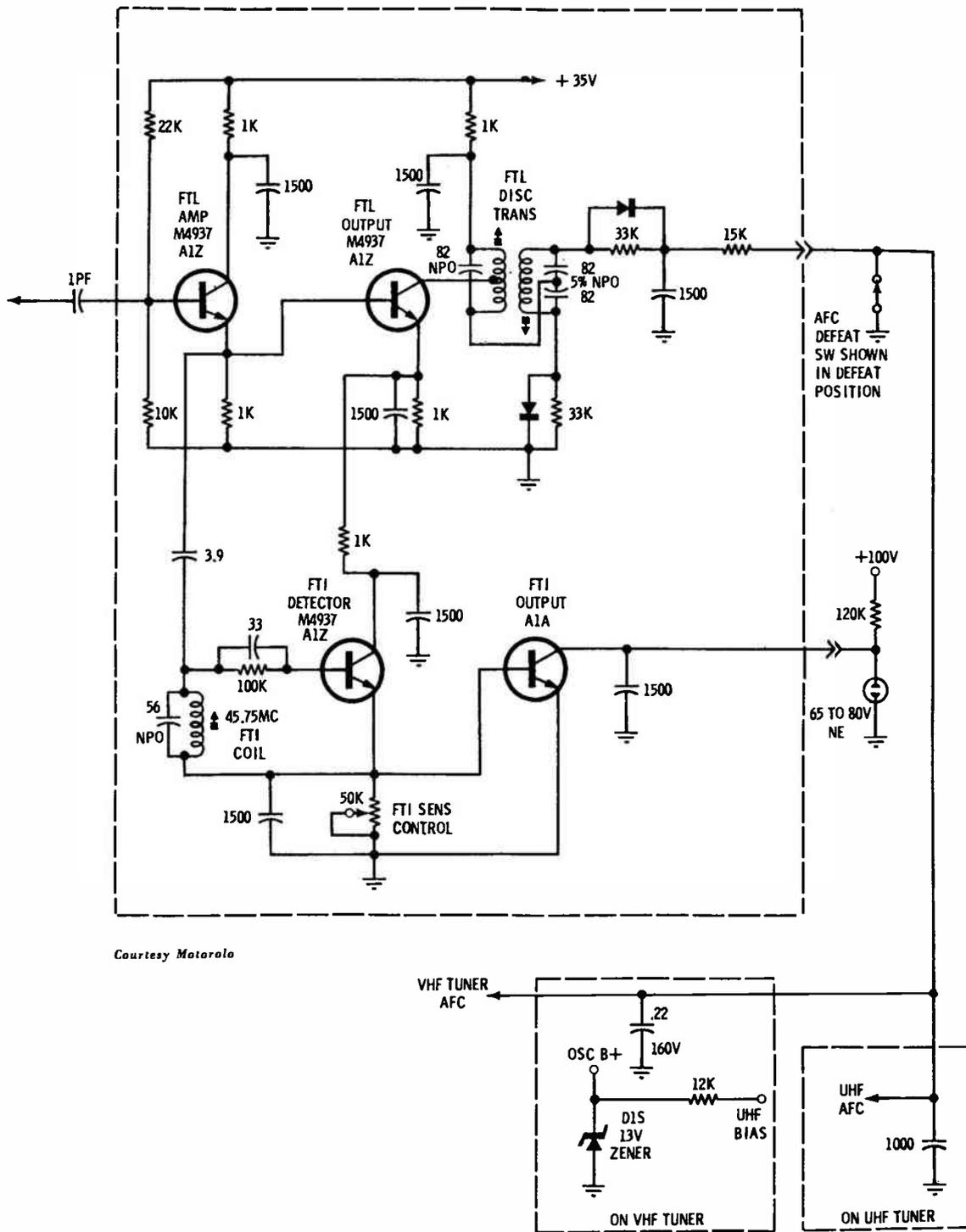
Fig. 24. Schematic diagram of a fine-tuning lock and indicator.

that develops a voltage that either turns on or turns off a tuning light or some similar indicator when the oscillator is operating at the correct frequency.

SELF-TEST QUESTIONS

(v) In amplitude detection, which of the sidebands contribute to the output from the detector?

(w) At what point on the response curve is the video i-f carrier usually located in a typical receiver?

(x) What two signals are usually located in traps on the response curve?

(y) If the local oscillator in a TV receiver is tuned too high, will this prevent you from getting a color signal through the i-f amplifier?

(z) What is likely to be the effect on the color signal when the local oscillator is set at too low a frequency?

Answers to Self-Test Questions

(a) The sound-carrier signal is always 4.5 mc higher in frequency than the video-carrier frequency.

(b) The video i-f signal is always higher than the sound i-f frequency. The spacing between the two signals will always be 4.5 mc; this is controlled at the transmitter.

(c) It is lower in frequency than the sound carrier. The color subcarrier transmitted by the station is always 3.58 mc higher in frequency than the video carrier. The sound carrier, however, is 4.5 mc higher than the video carrier, therefore it must be higher than the color subcarrier.

(d) The lower sideband.

(e) The bandwidth of the circuit is the band of frequencies that the circuit will pass with a gain or output within 3 db of the maximum output from the circuit.

(f) Overcoupled coils are coils that are closely coupled together so that the coupling is greater than the critical coupling.

(g) A bifilar-wound coil is a coil that is wound so its primary and secondary windings are interwound. In other words, if you start tracing the turns of the coil you'll come first to a primary turn, then a secondary; then a primary, then a secondary and so on.

(h) The three types of traps used in video i-f amplifiers are parallel-resonant, series-resonant and absorption traps.

(i) In Fig. 8, L_1 and C_2 form a series-resonant trap. The trap is resonant at 47.25 mc and is called an adjacent-channel sound trap. It is designed to eliminate interference from the sound from the channel below the channel to which the receiver is tuned.

(j) C_2 and L_1 form a series-resonant circuit trap that is resonant at 41.25 mc. The purpose of this trap is to reduce the amplitude of the sound i-f carrier so that the 4.5 mc sound signal produced in the video detector will not be excessively strong.

(k) The agc voltage is the automatic gain control. The purpose of this voltage is to reduce the gain of the first and second video i-f amplifiers on strong signals. On weak signals, the two stages are allowed to operate at or near maximum gain.

(l) The output trap in the output transformer T_2 is a parallel-resonant circuit. It is tuned to 41.25 mc and is used to prevent the sound i-f carrier from reaching the video detector. If the sound signal reaches the video detector, it will produce a 4.5 mc signal which will cause picture interference. It also beats with the video i-f color subcarrier to produce a 920 kc difference frequency signal, which can also cause picture interference.

(m) In the circuit shown in Fig. 12 there are three traps. We have a trap consisting of C_1, C_2 and L_1. This is a series-resonant trap tuned to 41.25 mc and is used to keep the 41.25 mc sound sig-

nal down. We also have a series-resonant trap made up of L_2 and C_5. This trap is tuned to 47.25 mc and is an adjacent-channel sound trap. In addition, we have a trap consisting of L_3 and C_6, which is tuned to 39.75 mc and is an adjacent-channel picture trap.

(n) C_8 is a neutralizing capacitor. It feeds energy from the output circuit back into the base of the transistor that is $180°$ out-of-phase with energy fed through the transistor from the collector back to the base. The neutralizing signal is necessary to prevent the transistor Q_1 from going into oscillation.

(o) See Fig. 15.

(p) When we say that the video signal is a negative signal, we mean that the blanking and sync pulses point in a negative direction as shown in Fig. 15D.

(q) C2 and L_2 form a 4.5 mc series-resonant trap. The low impedance of the series-resonant trap keeps the 4.5 mc signal from the input of the video amplifier. At the same time, the series circuit is used as a method of taking the 4.5 mc sound i-f signal off to feed it to the sound i-f amplifier.

(r) The sync pulses will point in a negative direction.

(s) The 41.25 mc trap is used to prevent the 41.25 mc sound signal from reaching the video detector. The sound signal in this circuit is taken off in the last video i-f amplifier, and the trap is used to keep the signal from reaching the detector where it can beat with the color subcarrier and cause interference.

(t) The parallel-resonant trap consisting of C_3 and L_6 is tuned to 4.5 mc. It is used to prevent any 4.5 mc signal that may be produced in the detector, because a small amount of 41.25 mc signal might get through and reach the detector, from reaching the video amplifier and beating with the 4.5 mc color subcarrier.

(u) The coils L_2 and L_3 in the detector circuit shown in Fig. 19 are peaking coils. The purpose of these coils is to improve the high-frequency response of the circuits in the output of the video detector and thereby prevent the loss of the high-frequency video signals.

(v) Both sidebands contribute to the output from the detector.

(w) The video i-f carrier is usually located about midway up on the response curve.

(x) The 41.25 mc sound i-f signal and the 47.25 adjacent-channel sound i-f signal.

(y) No. However, the sound signal will also come through the amplifier and the sound i-f and the color i-f signals will beat together and produce a strong 920 kc interference pattern which it will be impossible to eliminate.

(z) The color i-f signal reaching the video detector will be extremely weak; you will either be unable to get any color at all, or if you do it will be weak and washed-out.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. Why is partial sideband suppression used in television?

2. In a resonant circuit, how does resistive loading affect (a) the bandwidth; (b) the gain?

3. What is the difference frequency between the sound and picture carriers in the video i-f amplifier?

4. What are we referring to in color TV when we refer to 920 kc interference? How is it produced?

5. If a TV receiver is tuned to Channel 3, what type of interference can we get (a) from Channel 2; (b) from Channel 4?

6. What is an absorption trap?

7. Where is the sound signal taken off in (a) a monochrome receiver; (b) a color TV receiver?

8. What do we mean by a positive-going composite video signal?

9. Why are 41.25 mc traps used in a video-detector circuit of a color TV receiver?

10. What is an FTI?

VIDEO AMPLIFIERS

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STUDY SCHEDULE

> For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

VIDEO AMPLIFIERS

The video amplifier of the television receiver follows the video i-f system and the demodulator. It must increase the amplitude of the brightness signal at the output of the video detector to the peak-to-peak voltage necessary to drive the picture tube.

In the early TV receivers, the video had a bandwidth from about 10 cycles to 4 mc to reproduce as faithfully as possible all the brightness information transmitted by the TV station. However, in an effort to reduce TV receiver costs, manufacturers soon began building receivers with narrower band video i-f amplifier and video amplifier stages. This resulted in some loss of frequency detail, but nevertheless the reproduced picture remained satisfactory.

As network television grew, the TV networks began limiting the high-frequency detail transmitted, in order to reduce the cost of the transmission lines used to send programs to the different stations. Manufacturers reduced the bandwidth of the TV receivers still further; there is no point in building a receiver to receive signals that are not being transmitted.

The video amplifiers of monochrome receivers manufactured today usually have a bandwidth of about 3 mc. This is more than ample to give a satisfactory picture in the small screen receiver. The bandwidth may be slightly higher on a large screen TV, but it is usually less than 3.5 mc, to eliminate an interference pattern on the screen of the picture tube due to the 3.58 mc color subcarrier. The color subcarrier will go through the video i-f and video amplifier of a monochrome receiver if the bandwidth is wide enough. Since most broadcasts today are in color, it is best to restrict the video amplifier bandwidth to reduce this type of interference.

In color TV receivers, the 3.58 mc color signal is amplified by one or more stages in the video amplifier before it is separated from the brightness infor-

mation. Therefore these stages must have a wide enough bandwidth to pass the brightness signal along with the color subcarrier and its sidebands.

After the color signal is separated from the brightness signal, the brightness signal receives additional amplification. These video amplifier stages are usually designed to cut off sharply at some frequency below 3.5 mc, to prevent the color subcarrier from reaching the picture tube and producing an interference pattern.

In addition to amplifying the video signal, there are a number of other things the video amplifier should do. It should retain the average brightness level of the received picture, and reproduce the picture with the proper contrast range. For example, the video information should not be compressed in the white or black regions or the various shades of gray will not be faithfully reproduced in monochrome transmission, and in color transmission you'll be unable to get fully saturated colors.

The contrast and brightness controls are associated with the video amplifier and the grid circuit of the picture tube. The contrast control usually varies the gain of the video amplifier system so that the gain will be high when the input signal is weak, and low when the signal is strong. The contrast and brightness controls are adjusted jointly for the most pleasing picture.

The 3.58 mc color subcarrier take-off point is located in the video amplifier. It must be designed to keep high level video signals, as well as any 4.5 mc sound signals, out of the color channel.

The sound take-off point in monochrome receivers is located in the video amplifier. Suitable circuits must be used to give a maximum sound signal and at the same time prevent sound interference from modulating the picture.

The sync take-off point, where part of the composite
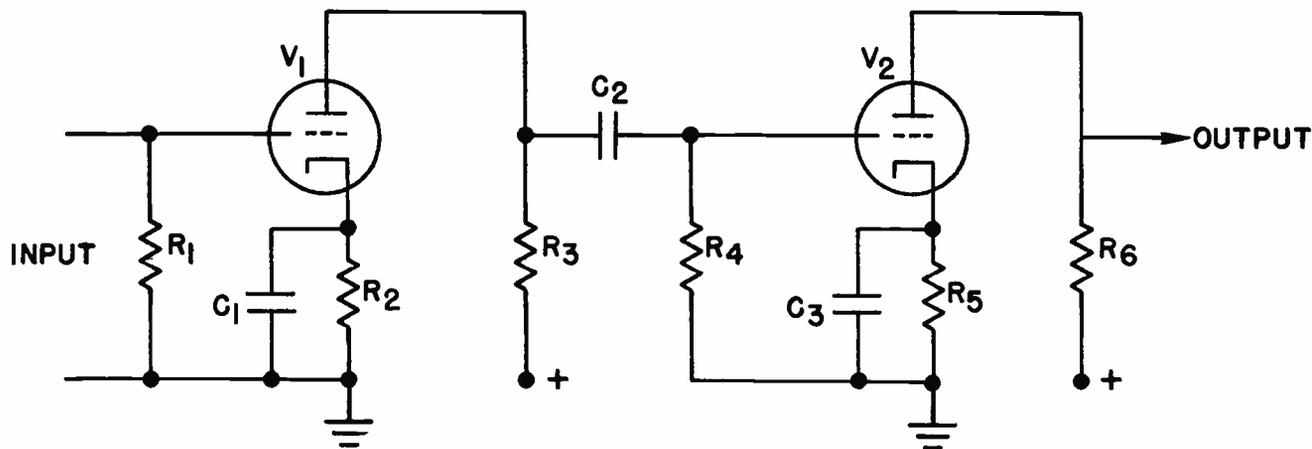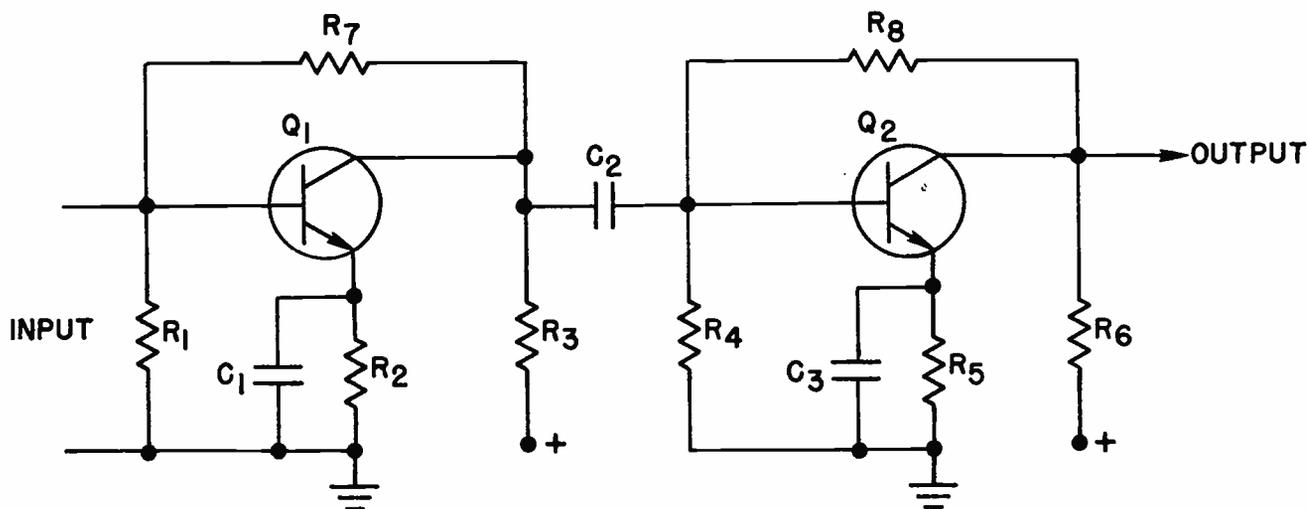
Fig. 1. Two two-stage resistance-capacitance coupled amplifiers.

video signal is channeled into the synchronizing circuits, is also located in the video amplifier in most receivers. The sync take-off circuit, which we will discuss later, must be arranged to supply the composite signal to the sync circuits without causing any loss in picture detail in the video amplifier, nor can it affect the 3.58 mc color signal or color take-off circuit in a color receiver.

RESISTANCE-COUPLED AMPLIFIERS

Before you study video amplifiers, you must understand how simple resistance-coupled amplifiers work. Let us review a few of the basic facts about resistance-coupled amplifiers so that you will understand the problems of video amplification.

Two typical resistance-capacitance coupled amplifiers are shown in Fig. 1. The circuit shown in Fig. 1A uses vacuum tubes; the circuit shown in Fig. 1B uses transistors. You'll notice that there is considerable similarity between the two amplifiers, and in fact the problems encountered with these amplifiers when they are used as video amplifiers are essentially the same. Both the low frequency response and the high-frequency response of the two amplifiers will fall off unless special steps are taken to keep the response up at low frequencies and at high frequencies.

Looking at the circuit shown in Fig. 1A, we see that the first amplifier, V_1, uses a cathode resistor, R_2, to provide bias for the stage. When an input signal is applied across the grid resistor, R_1, this causes the bias applied between the grid and cathode of the tube to vary. The varying bias causes the plate current to

vary; this in turn causes a varying current to flow through the plate-load resistor, R_3. An amplified voltage will appear across this resistor; the exact amount of amplification that will be obtained in the stage will depend primarily upon the amplification factor of the tube and the size of the plate-load resistor.

In the circuit shown in Fig. 1B, forward bias is provided across the emitter-bias junction primarily by the voltage-divider network system consisting of R_7 and R_1. The transistor Q_1 is an NPN transistor, and we forward-bias this transistor by making the base positive with respect to the emitter. The resistor R_2 in the emitter circuit is not used to provide bias, as in the case of the cathode resistor in the vacuum tube stage, but rather is inserted in the emitter circuit to prevent thermal runaway. (You have studied this problem previously.)

When the input signal is applied across R_1, it varies the forward bias across the emitter-base junction, and this causes the number of electrons crossing this junction to vary; hence the collector current varies. The varying collector current flowing through the collector resistor R_3 produces an amplified voltage

across this resistor. The amplification obtained in the stage will depend primarily upon the beta of the transistor and the size of the collector resistor, R_3.

In the case of each amplifier stage, we have an amplified voltage appearing in the output of the first stage. The big problem at low frequencies is to get this amplified voltage over to the following stage. The coupling capacitor C_2 is supposed to feed the signal from the output of the first stage to the input of the second stage. However, at low frequencies, the reactance of the coupling capacitor may be high when compared with the input resistor, R_4, of the next stage. When this happens the coupling capacitor and the resistor act like a voltage-divider network so that only part of the amplified signal from the first stage reaches the input of the second stage.

At high frequencies, shunt capacities reduce the effective value of the load resistor, R_3, so that the amplified voltage developed by V_1 or Q_1 will drop. This must be avoided or kept to a minimum in video amplifiers. Let us look at how video amplifiers are designed to overcome these problems before looking at typical video amplifiers.

Broadband Video Amplification

A video amplifier is identical in theory of operation to that shown in Fig. 1, except for more carefully chosen parts values and the addition of a few other components to improve the performance of the amplifier at frequencies above and below the audio range.

The wide-band response necessary in a video amplifier is obtained by modifying the basic resistance-coupled audio amplifier. A good quality audio amplifier might have a frequency range extending between 100 cycles and 10,000 cycles, but a video amplifier must amplify linearly a span of frequencies from about 10 cycles to 3 mc or more -- over 300 times the range of the audio amplifier.

We have already mentioned that the frequency range of the video signal covers the frequencies from 10 cycles per second up to 3 mc or more. A good video amplifier must be able to amplify equally any frequencies within this range. In other words, if we have a video amplifier with a gain of 10 and feed a 1-volt signal to the input of the amplifier, the output should be 10 volts, regardless of whether the frequency of the signal is 10 cycles or 3 mc, or any frequency between these two.

If the video amplifier cannot amplify the various video frequencies equally, the quality of the reproduced picture will suffer. If the gain of the video amplifier falls off at higher frequencies, so that a high-frequency video signal either is lost completely or does not receive the same amplification as the low-frequency or middle-frequency video signals, the reproduced picture will not contain the fine detail being sent by the transmitter. While this might not be too objectionable on small size screens, it is very noticeable on larger ones.

If, on the other hand, the video amplifier operates satisfactorily at the middle and higher video frequencies, but the gain falls off at the low frequencies, large objects in the picture will be smeared. In addition, if the synchronizing signal is taken off at the output of one of the video amplifier stages, the vertical synchronizing signal will be affected and as a result, the stability of the vertical oscillator will be poor. This will cause the picture to roll up or down from time to time, regardless of how carefully you set the vertical hold control.

A careful examination of the reproduced picture will usually permit you to classify video amplifier defects as follows:

(1) Dead stage.
(2) Poor low-frequency response.
(3) Poor high-frequency response.

The first defect is likely to be caused by the same defects that could cause a similar complaint in an audio amplifier. In other words, you may have a defective tube or transistor, an open resistor, a shorted capacitor, no plate or screen voltage on the tube, or no collector voltage or forward bias on the transistor,

etc. However, the second and third classes of defects may be somewhat more difficult to localize. In the following sections you will review how the required broadband amplification is obtained. You will study the function of the various components in the circuit, particularly the components that limit the video amplifier response, and learn what steps are taken to improve it. When you run into a video amplifier lacking the required broadband response, once you can identify the defect as either poor high-frequency response or poor low-frequency response, you will know what parts are likely to be causing the trouble.

LOW FREQUENCY AMPLIFICATION

In amplifying the low-frequency video signals, there are two types of distortion that must be avoided. These are amplitude distortion and phase distortion.

Both of these types of distortion may be caused by the coupling capacitor that feeds the signal from the output of one stage to the input of the next. In the amplifiers shown in Fig. 1, C_2 is the coupling capacitor. The cathode bypass capacitor, C_1 in Fig. 1A, and the emitter bypass capacitor, C_1 in Fig. 1B, may also introduce degeneration at low frequencies, which will result in a falling off in the low-frequency gain of the stage. Before we go into detail about the steps taken to eliminate these problems, let us review a few basic points about capacitors, and circuits consisting of capacitors and resistors in series.

You already know that if a voltage is applied to a circuit that contains pure resistance, the current flowing in the circuit will be in phase with the voltage. In other words, as an ac signal starts at zero and the voltage builds up to a maximum, the current will be exactly in step with the voltage, starting at zero at the same time as the voltage and reaching the maximum when the voltage reaches the maximum.

In a circuit that contains nothing but capacitance, the current flowing in the circuit will lead the voltage by 90°. This means that when the voltage is zero, the current will be at the maximum. As the voltage builds up toward a maximum, the current will decrease until at the instant when the voltage has reached a maximum, the current will be at zero.

For convenience, phase relationships of this type are often represented by means of vector diagrams. Fig. 2A is a vector representation of the current and
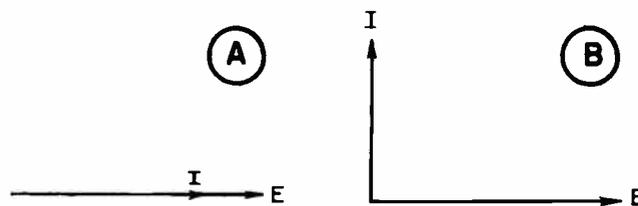
Fig. 2. Vector diagrams of voltage and current. A, voltage and current are in phase; B, current leads the voltage by 90°.
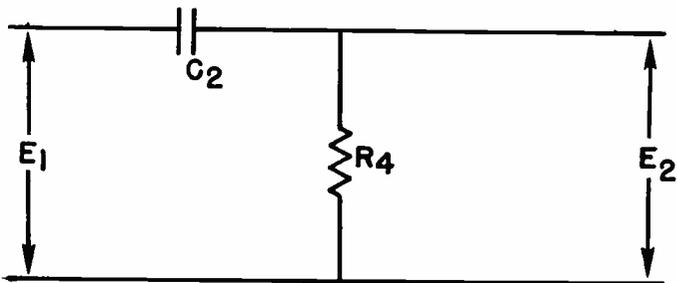
Fig. 3. At some low frequency, the reactance of C_2 will become appreciable when compared to the resistance of R_4. At this frequency and all lower frequencies, C_2 and R_4 will form a voltage divider, so that E_2 will be appreciably less than E_1.

voltage in a circuit containing only resistance. Since the current and voltage are in phase, the current vector falls on top of the voltage vector. A vector representation of the current and voltage in a capacitive circuit is shown in Fig. 2B. The current leads the voltage by $90°$. This is represented by drawing the current vector at an angle of $90°$ counterclockwise with respect to the voltage vector.

In the amplifiers shown in Fig. 1, the amplified signal voltage developed at the output of the first stage is applied to a series circuit consisting of C_2 and R_4 (shown in Fig. 3). The voltage E_1 represents the voltage between the plate of V_1 and ground in the circuit in Fig. 1A, and between the collector of Q_1 and ground in Fig. 1B. The voltage E_2 is the voltage that is fed to the input of the second stage, which is the grid of V_2 in Fig. 1A and the base of Q_2 in Fig. 1B.

In the circuit shown in Fig. 3, we have a series circuit consisting of C_2 and R_4. When a voltage is applied to a series circuit consisting of a resistance and a capacitance, the phase relationship between the voltage and the current flowing in the circuit will depend upon the reactance of the capacitor and the resistance of the resistor. If the reactance of the capacitor is small and the resistance of the resistor is high, the circuit will act almost like a pure resistance circuit, and the current will be almost in phase with the voltage. Fig. 4A represents this condition, with the voltage represented by E_1 and the current by I.

We know that the voltage across the resistance element in the circuit will be in phase with the current. Therefore, we have drawn the vector E_2, representing the voltage across the resistor, coinciding with the current, which leads the voltage E_1 only slightly. Therefore, the voltage E_2 will be only slightly ahead of the voltage E_1. The voltage across the capacitor will lag the current by $90°$ and therefore E_c is drawn $90°$ behind the current I and voltage E_2.

There are two important things you should notice in Fig. 4A: first, that E_2 is almost equal to E_1, and second, that it is almost in phase with it. In fact, at middle and high video frequencies this represents a distorted picture of the actual conditions. The reactance of C_2 will be so small compared to the resistance of R_4 that the circuit will be close to a pure resistive circuit. Then vectors I, E_1, and E_2 would practically coincide if we tried to construct a precise vector diagram. The actual phase displacement between E_1 and E_2 is insignificant -- we can consider them as being in phase.

Now let us investigate what happens when the reactance of the capacitor is equal to the resistance of the resistor. In this case, the characteristics of the circuit will be mid-way between those of a circuit having pure capacitance. The current will lead the voltage by $45°$. This is shown in Fig. 4B. Notice that we have drawn E_2 $45°$ ahead of E_1 (counterclockwise), because the voltage E_2 will be in phase with the current, and therefore it will coincide with the current vector. The voltage E_c is drawn $90°$ behind I -- the voltage across the capacitor will be $90°$ behind the current through it.

In comparing Figs. 4A and 4B, there are two things that you should notice in each one. In Fig. 4A, the voltage vector E_2, which is the output voltage, is almost equal to the input voltage, E_1, and the phase angle between the two voltages is comparatively small. However, in Fig. 4B, E_2 leads E_1 by an appreciable angle and E_2 is considerably shorter than E_1. This means that the output voltage E_2 is smaller in amplitude than E_1 and also that an appreciable phase shift has been introduced.

The vector diagram is Fig. 4C represents a circuit where the reactance of the capacitor is much larger
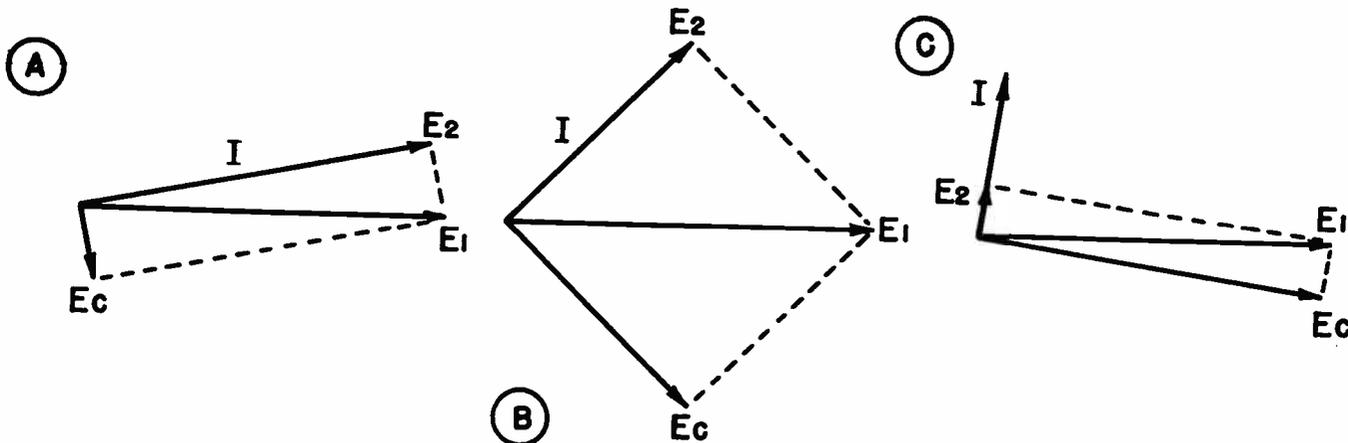
Fig. 4. A vector representation of the attenuation and phase shift in the coupling network of Fig. 3.

than the resistance of the resistor. The circuit acts almost like a pure capacitor. The current I is almost $90°$ ahead of the voltage E_1. Again, since E_2 will be in phase with the current flowing in the circuit, the voltage E_2 is drawn, coinciding with the current vector, and then E_c is drawn $90°$ behind it. Notice that in this figure, the voltage E_2 is much smaller than E_1, and that it leads it by almost $90°$.

We do not need to go into a great deal of vector theory in order to understand what happens in a circuit similar to Fig. 3. The important thing to understand is that if the reactance of the capacitor is small in comparison to the resistance of the resistor, the output voltage E_2 will be almost equal to E_1, and it will be almost in phase with it. However, as the reactance of the capacitor increases, the output voltage E_2 decreases, and at the same time, an appreciable phase angle between E_2 and E_1 develops.

You will remember that the reactance of a capacitor varies inversely with frequency. In other words, for a given size of capacitor, as the frequency of the ac signal decreases the reactance of the capacitor increases, and conversely, if the frequency increases, the reactance decreases. Therefore, if in Fig. 3 the frequency of the input voltage E_1 is high, the reactance of C_2 will be low, and E_2 will, for all practical purposes, be equal to E_1 and in phase with it. However, if the frequency is low, then the reactance of C_2 may be high enough to be either equal to or greater than the resistance of R_4. When this happens, the output voltage E_2 will be smaller than the input voltage E_1, and it will lead it by an appreciable phase angle.

If the coupling network consisting of C_2 and R_4 had to pass only one frequency, we would not have to be concerned about the attenuation and phase shift that might be introduced. However, since it must pass a wide range of video frequencies, the attenuation and phase shift become a serious problem, because they will change as the frequency changes. The lower the

frequency of the input signal applied to the network, the greater the attenuation and phase shift will be. This means that there will be a time displacement of the low-frequency video signals. In other words, if low-frequency and high-frequency video signals are fed into the input at the same time, they will not appear across the output at exactly the same instant.

The effect of low-frequency attenuation and phase shift is shown in Fig. 5. Notice that there is a general displacement of picture information. This is shown in particular by the long trailers that follow low-frequency information (large letters). Phase shift is not difficult to understand if we consider it in terms of the delay it causes between a component of one frequency, and another component of a higher or a lower frequency. Some portions of the signal are displaced with respect to other portions, and information is not positioned on the picture tube screen in exactly the same order as it was released at the camera.

The situation shown in Fig. 4B merits some special attention. Here the reactance of C_2 is equal to the resistance of R_4. You might think at first, since C_2 and R_4 form a voltage divider, that only one half of E_1 would appear across R_4. However, this is not the case. E_1 will be equal to the vector sum of the voltages across R_4 and C_2. Each of these voltages will be equal to .707 times E_1. In other words, when the reactance of C_2 equals the resistance of R_4, E_2 will be equal to $.707E_1$. Under these circumstances we can compare the ratio of these two voltages in decibels as:

$$db = 20 \log \frac{E_1}{E_2}$$

$$= 20 \log \frac{E_1}{.707E_1}$$

$$= 20 \log 1.42$$

$$= 3 \ db$$

Thus we say that E_2 is 3 db down with respect to E_1. You'll often hear this called the 3 db down-point. It represents just about the maximum attenuation of the signal that can be tolerated.

The cathode bypass capacitor, C_1 in Fig. 1A and the emitter bypass capacitor, C_1 in Fig. 1B, also cause some difficulty. In each case, its purpose is to bypass the resistor R_2. At low video frequencies, its reactance may be as high as or higher than the resistance of the resistor. Under these conditions it will not bypass the resistor, and degeneration will occur.

At the frequencies where the cathode bypass capacitor is effective, there will be no signal voltage developed across the resistor R_2. The entire input signal voltage will be applied directly between the control grid and cathode of V_1 in Fig. 1A and the emitter and base of Q_1 in Fig. 1B and receive maximum amplification by the tube or transistor.

At low frequencies, C_1 is no longer an effective bypass. In the tube circuit, the plate current flowing through R_2 develops a signal voltage which is $180°$ out of phase with the input signal voltage. This reduces
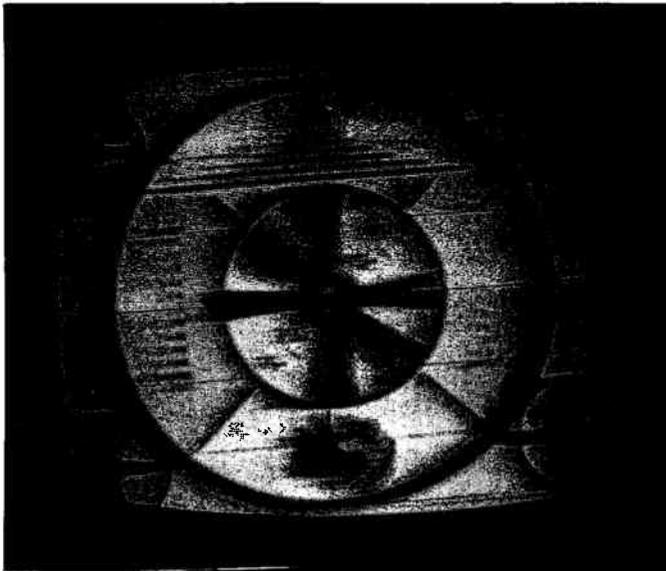
Fig. 5. Loss of fine detail due to loss of high frequencies.
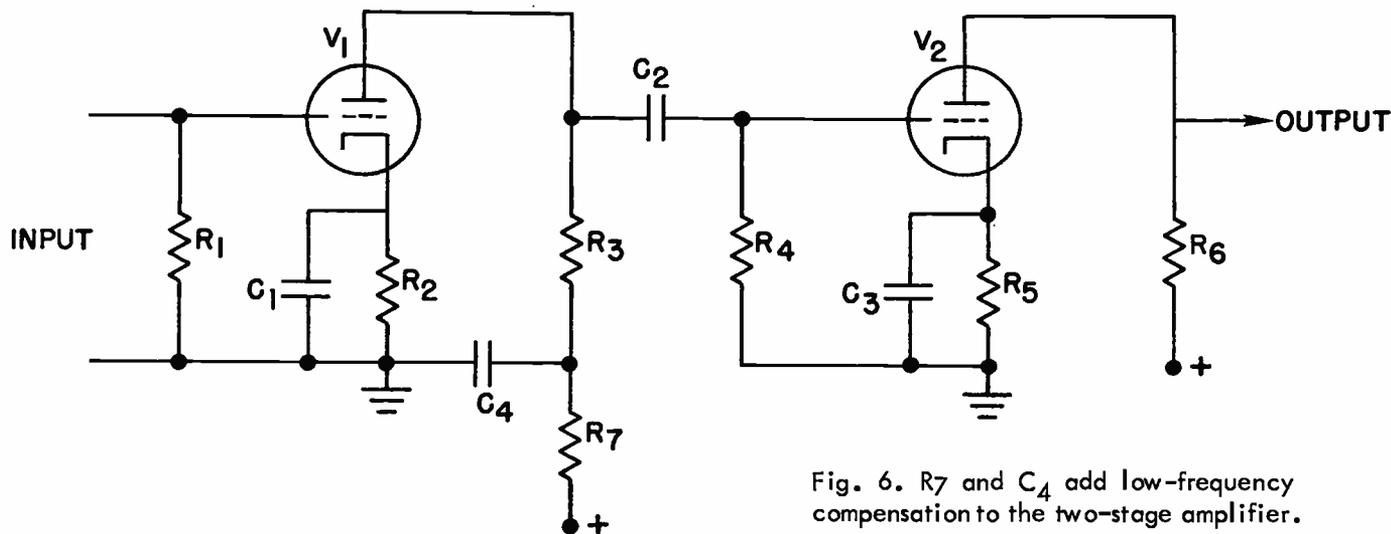
Fig. 6. R_7 and C_4 add low-frequency compensation to the two-stage amplifier.

the effective signal voltage applied between the control grid and the cathode of V_1, so that the output from the stage drops off. In the transistor circuit, the emitter current flowing through R_2 develops a signal voltage which is 180° out of phase with the input signal voltage. This reduces the signal voltage applied between the base and the emitter of Q_1 so that the output from the stage drops off.

Low Frequency Compensation.

By proper choice of circuits and component parts, low-frequency response can be extended so that satisfactory results can be obtained at the lowest video frequency to be amplified. While poor low-frequency response can be caused by the same parts in Fig. 1A and Fig. 1B, the actual problems are somewhat different, and therefore the methods of overcoming them are different. We will discuss the tube circuit in Fig. 1A first, and then the transistor circuit in Fig. 1B.

In the interstage coupling circuit, the value of the capacitor and the resistor must be made sufficiently large to prevent serious degeneration of low frequencies. Usually the results will be satisfactory if the reactance of the capacitor is smaller than the resistor of the resistor. Therefore, the grid resistor (R_4 in Fig. 1A) is made as large as possible. There is a limit to how large the resistor can be made, of course, but this depends on the characteristics of the tube -- how much grid current you can expect the tube to draw. Usually the resistance in the grid circuit of a resistance-capacitance coupled video amplifier will be somewhere around 1 megohm.

Increasing the size of the coupling capacitor will also improve low frequency response of an amplifier. But this, too, has practical limits. Large capacitors are expensive and so bulky that they introduce shunt capacities that upset the high-frequency response of the amplifier.

The problem of degeneration caused by the cathode bypass capacitor can also be overcome. If it is necessary to use a rather low value of cathode resistor to obtain proper bias for a video stage, that resistor must be shunted by a large value cathode capacitor to maintain a linear frequency response down to the low-frequency limit.

Some video amplifier stages that have a cathode re-

sistor do not have any cathode bypass capacitor. This method of operation prevents low-frequency attenuation, because although the overall gain of the video amplifier is reduced by degenerative action, all frequencies are equally affected, and the bandwidth remains essentially linear. When the cathode resistor is left unbypassed, the size of the resistor is kept as small as possible to avoid introducing too much degeneration into the circuit. With the very high Gm tubes that are available for video amplifier use, some small loss in gain to get wide bandwidth can be tolerated.

It is possible to use a special compensating circuit to emphasize the low-frequency range. Such a compensating circuit is generally in the form of a resistor-capacitor combination in the plate circuit of the video stage, as shown by R_7 and C_4 in Fig. 6.

The values of C_4 and R_7 are chosen so that at high frequencies the reactance to C_4 is negligible. As a result C_4 effectively shorts R_7 out of the circuit so that the plate load of V_1 is equal to the resistance of R_3. However, at low frequencies, where the reactance of C_1 becomes high and introduces degeneration into the first stage, and the reactance of C_2 also becomes high and reduces the signal fed from V_1 to V_2, the reactance of C_4 becomes appreciable, and it no longer shorts R_7 out of the circuit. Thus the plate load of V_1 consists of R_3 plus the impedance of the parallel combination of C_4 and R_7.

The increase in load impedance increases the gain of the stage, compensating for the loss due to degeneration in the cathode circuit and the loss in the coupling capacitor. The capacity and resistance values of C_4 and R_7 must be carefully selected to provide the correct amount of compensation.

The problem encountered in the transistor amplifier shown in Fig. 1B is the same, to the extent that the coupling capacitor C_2 and the bypass capacitor C_1 both limit the low-frequency response of the amplifier. However, the actual problems encountered are somewhat different. For example, when a vacuum tube is operated as a class A amplifier, the grid does not draw any current. As a result, in the voltage divider made up of C_2 and R_4, the resistance in the circuit is controlled entirely by the resistance of R_4 in the vacuum-tube grid circuit. We can extend the frequency

at which the reactance of the capacitor is equal to the resistance of the resistor simply by making R_4 as large as possible. In other words, if we have a .5 megohm resistor in the grid circuit, and the reactance of the capacitor reaches .5 megohms at a frequency of 100 cycles, we can change the resistor to a 1 megohm resistor and in so doing extend the 3 db down point to 50 cycles.

In a transistor amplifier there is a current flow between the emitter and the base. Therefore, although in the circuit shown in Fig. 1B we might use a large value for R_4, the actual resistance in the input circuit of Q_2 is controlled by the current flow from the emitter to the base of the transistor and the forward bias across the emitter-base junction.

The input resistance of the transistor Q_2 will be comparatively low, and therefore the value of R_4 is relatively unimportant insofar as limiting the low-frequency response of the amplifier is concerned. The low-frequency response is governed primarily by the coupling capacitor C_2 and the input resistance of the following transistor stage, Q_2.

In transistor amplifiers, we keep the reactance of the capacitor low by using a relatively large capacity electrolytic capacitor for coupling. We can do this in transistor amplifiers because transistors operate at relatively low voltages. Thus we can use a low-voltage electrolytic, and modern manufacturing techniques permit us to make capacitors of this type relatively small physically. Thus to extend the low-frequency response and keep the effect of the coupling capacitor from reducing the low-frequency response, we simply use an electrolytic capacitor having a capacity large enough to give us a response down to the low-frequency limit desired.

In the emitter circuit of Q_1, we also use an electrolytic capacitor to bypass the emitter resistor R_2. However, we can also leave the emitter resistor unbypassed and put up with the degeneration this introduces to avoid any low-frequency degeneration caused by the bypass capacitor. If the value of R_2

is comparatively low, then the best thing to do is to leave it unbypassed. However, many transistors operate on a comparatively low current and in this case the value of R_2 may be relatively high. In this case, we can use a large capacity, low-voltage electrolytic capacitor to bypass the resistor. The physical size of the capacitor will not be so large as to make this prohibitive.

A low-frequency compensating network can also be used in transistor amplifier circuits, but it is usually not as effective as in vacuum-tube circuits. In Fig. 7, we have shown a transistor amplifier to which we've added low-frequency compensation. The low-frequency compensation network consists of the resistor R_9 and the electrolytic capacitor C_4. The network is effective when a relatively small value of collector-load resistor, R_3, is used. You will see later that this is often the case; a low-value resistor is used to improve the high-frequency response of the amplifier. Thus by using the compensating network, when the reactance of C_4 becomes appreciable, the load resistance for the first transistor becomes R_3 in series with the parallel combination of R_4 and C_9. This increases the value of the collector load and increases the output from Q_1 to make up for the losses due to degeneration in the emitter circuit and for losses in the coupling network, consisting of C_2 and R_4 in parallel with the transistor input resistance.

HIGH FREQUENCY AMPLIFICATION

The problem of extending the response of a resistance-coupled amplifier so that it will amplify the high video frequencies is somewhat similar to that of extending the range to amplify low-frequency signals. However, the difficulties that are encountered at high frequencies are somewhat different from those encountered at low frequencies, and therefore they must be corrected in a different way.

Attenuation.

High frequencies are attenuated by any capacity that shunts or is placed in parallel with the signal path.
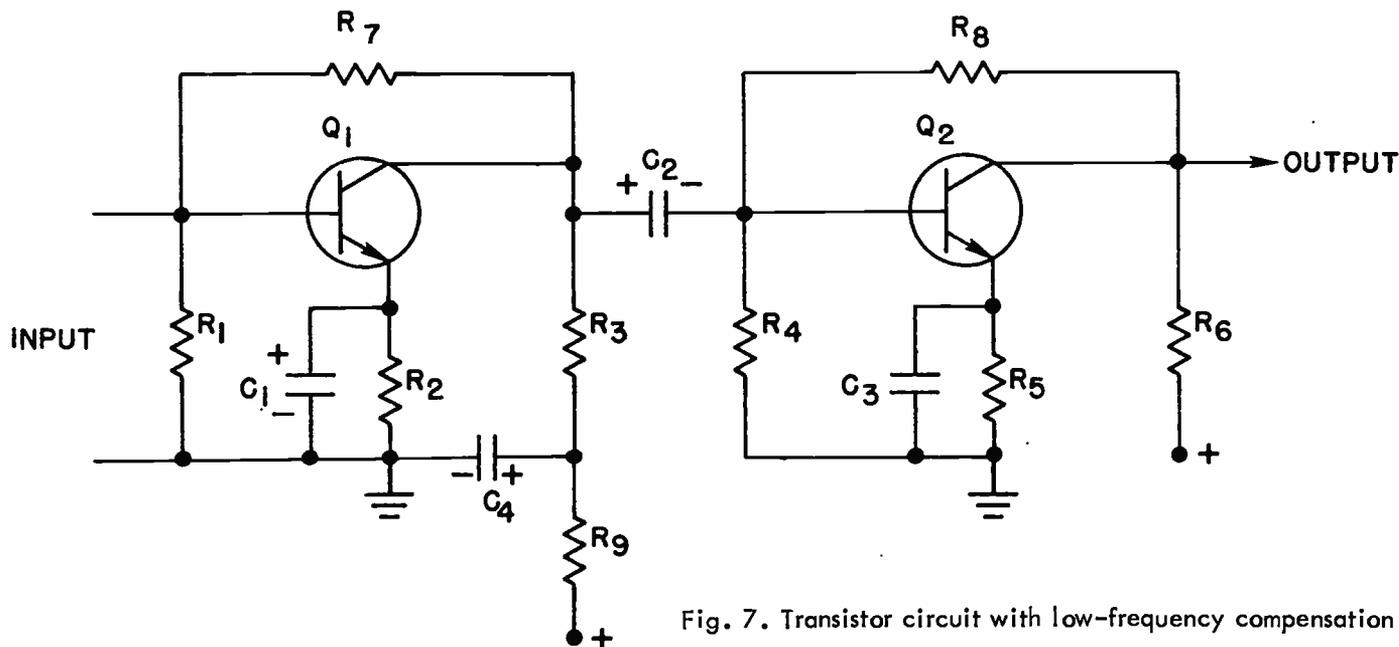
Fig. 7. Transistor circuit with low-frequency compensation.
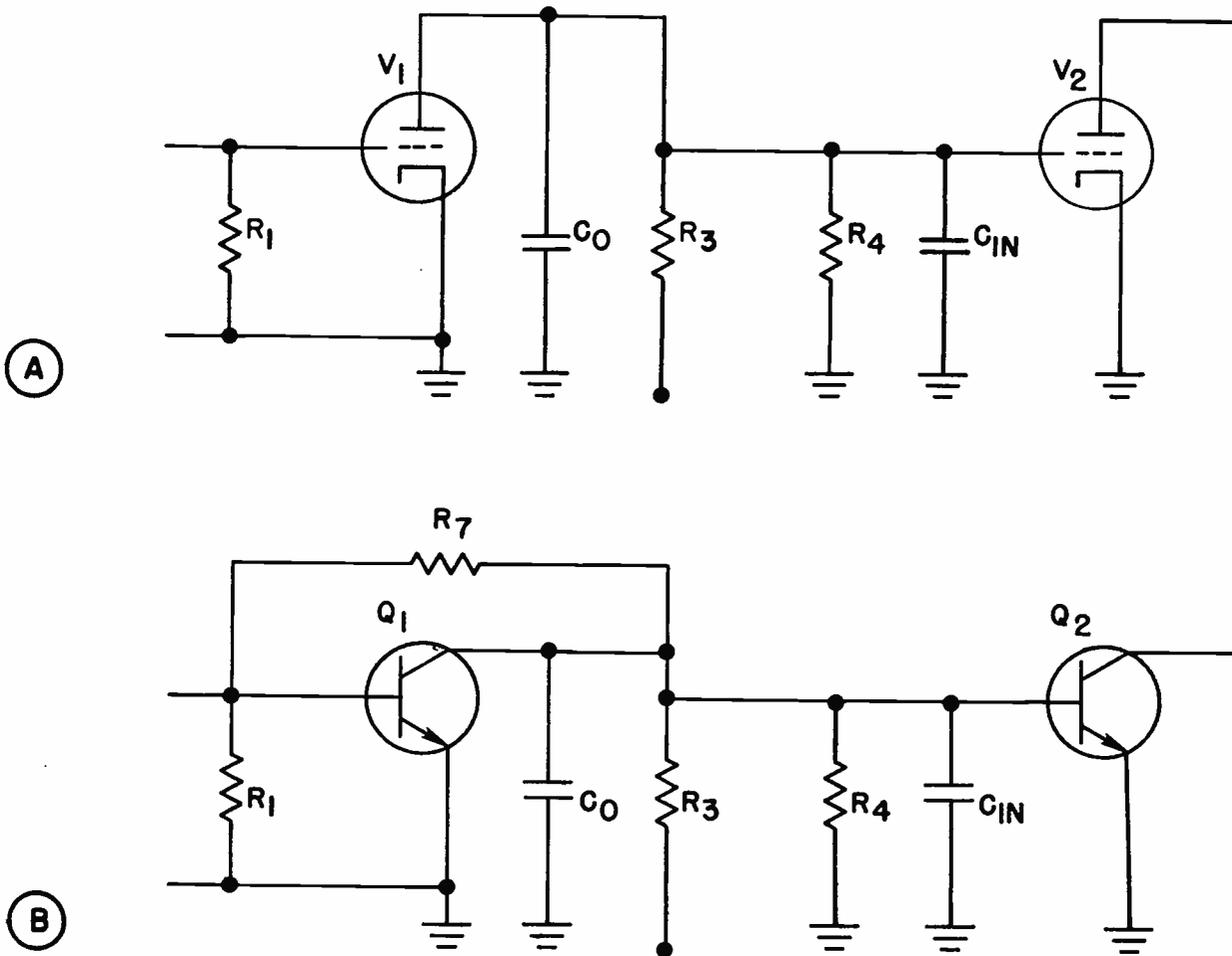
Fig. 8. High-frequency equivalents of circuits shown in Fig. 1.

Thus there is need of low-capacity tubes or transistors, low-capacity wiring, and small low-capacity components in a video amplifier stage.

In a video amplifier there are a number of capacities that shunt the signal path. The shunt capacity is made up of the output capacity of the first stage, the input capacity of the second stage, the wiring capacity between stages, the capacity of the individual parts to ground, and any other stray capacities. This capacity must be held to a minimum to obtain linear amplification of the wide range of video frequencies.

At high frequencies the problem that limits the response of the amplifier is the shunt capacities, as we mentioned earlier. In Fig. 8A, we've drawn the vacuum-tube amplifier shown in Fig. 1A as it appears at high frequencies. Notice we've left a coupling capacitor, C_2, out of the circuit completely. At high frequencies the capacitor has such a low reactance that it can be ignored. We've also omitted the cathode bias resistors and bypass capacitors on both stages because they act as short circuits and completely short-circuit the cathode of each tube to ground as far as the signal is concerned.

Thus in the vacuum-tube circuit we have the plate-load resistor R_3 effectively in parallel with the grid resistor R_4 as far as the signal is concerned. We also have the output capacity of V_1, which we have shown in the diagram and labelled C_0, and the input capacity

of V_2, which we've labelled C_{in}. These two capacities are in effect in parallel. At some frequencies the reactance of these capacitors will be low enough to effectively begin to short or reduce the value of the plate load on V_1, which consists of the parallel combination of R_3 and R_4. When the reactance of these capacities begins to reduce the size of the plate load, the output from V_1 will start to decrease and the gain of the amplifier will go down.

We have essentially the same situation in the transistor circuit shown in Fig. 1B. We've redrawn this circuit in Fig. 8B. Notice that we have once again omitted the coupling capacitor C_2 because its reactance is practically zero at high frequencies. We've also shown the emitter of each transistor connected directly to ground because the reactance of the emitter bypass capacitors will be so low at high frequencies that for all practical purposes the emitter is grounded.

Thus we see in this circuit we have R_3 in parallel with R_4. Actually, we must also remember that we have the input resistance of Q_2 to consider. Unless R_3 is a relatively small resistance, the chances are that the input resistance of Q_2 is actually lower than the value of R_3, and this in effect already reduces the value of the collector-load for Q_1.

At the output of the first transistor stage, Q_1, we've shown the output capacity, C_0. We've also shown the input capacity of the second transistor C_{in}. Notice

that these two capacities are effectively in parallel. Therefore when the reactance of these two parallel capacitors becomes lower than the effective collector load on Q_1, the capacities will begin to reduce the gain of the stage.

In transistor amplifiers we actually have to keep the value of R_3 comparatively low because there is no point in using a high value resistor. The collector load of Q_1 is limited by the input resistance of Q_2. Therefore, even if we did use a large value of R_3, the total collector load would still be equal to the parallel combination of R_3, R_4, and the input resistance of Q_2.

Using a large value of R_3 would reduce the collector voltage on Q_1; it would not result in any increase in the value of the collector-load, because the collector load would be controlled by the input resistance of Q_2. Therefore, due to the fact that we already have a relatively low resistance in the circuit, we need a higher value of capacitance to effectively reduce the resistance in the circuit than we do in a normal vacuum-tube amplifier circuit. Thus we are more likely to find that at high frequencies we can get close to the full gain from a transistor stage, whereas in a vacuum-tube amplifier we have to reduce the value of load resistor in order to reduce the shunting effect. This means that at low or medium frequencies we can get considerably more gain from a vacuum tube than we can at the high video frequencies.

We have another factor that improves the high-frequency response in the circuit in Fig. 8B. Notice that the forward bias across the emitter-base junction of Q_1 is provided by R_7 and R_1. Since R_7 is connected to the collector of Q_1, some of the output signal will be fed back to the base. Thus the signal voltage at the collector will be 180° out of phase with the input signal at the base of Q_1; the feedback is degenerative.

As the output of Q_1 begins to fall off at high frequencies, the amplitude of the feedback signal will go down. This will tend to allow the gain of Q_1 to increase and level off the output over a wide frequency range. The circuit shown in Fig. 9 shows how forward bias can be applied to Q_1 without introducing this type of degeneration.

Phase Distortion.

In studying the amplification of low frequencies, we pointed out that a phase shift will occur in any circuit containing both resistance and capacitance. This phase shift occurs at high video frequencies, with the result that the high-frequency video information will be displaced so that it does not fall at the proper place in the reproduced picture. This difficulty is even more troublesome than the attenuation of the signal. The phase shift is caused by a lag or time delay in the charge and discharge of a capacitor; in this case, the capacitor is the total distributed circuit capacity.

The total distributed capacity of the circuits is so small that at low and middle video frequencies it has a very high reactance. As a result, in the circuits shown in Fig. 8, which are simplified diagrams of the circuits shown in Fig. 1, all of the plate current in the circuit shown in A flows through the parallel combination of R_3 and R_4. Similarly, in the circuit shown at B, all of the collector current flows through the parallel combination of R_3, R_4 and the input resistance of Q_2.

As a result, the output voltage E_2 will be in phase with the signal current. This is shown in the vector diagram in Fig. 10A. The reactance of the distributed capacities is so high that all the current is flowing through the resistance elements in the circuit and the output voltage E_2 is at its maximum value and is in phase with the signal current.

However, at high video frequencies the filtering action of the shunt capacities becomes apparent. At some frequency, the reactance of the shunt capacities will be equal to the resistance of the load of the first amplifier. In other words, in the case of the vacuum-tube circuit the shunt capacities will be equal to the resistance of the parallel combination of R_3 and R_4 and in the case of a transistor circuit it will be equal to the parallel resistance of R_3, R_4 and the input resistance of Q_2.

When this happens, half the signal current will flow through the parallel resistance combination and the other half through the shunt capacity. This will result in the situation shown in Fig. 10B. Again, the voltage developed across the resistance load will be in phase with the current flowing through it. However, the current flowing through a capacitor leads the voltage by 90°. Therefore the voltage across the shunt capacitor
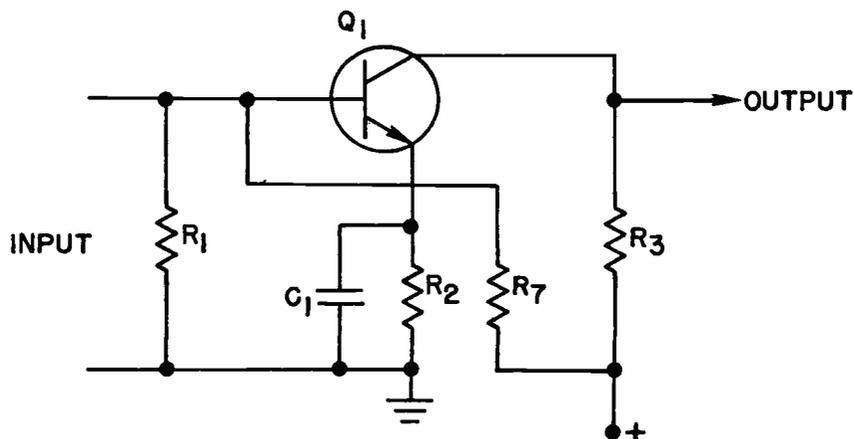
Fig. 9. Alternate method of providing forward bias across the emitter base junction.
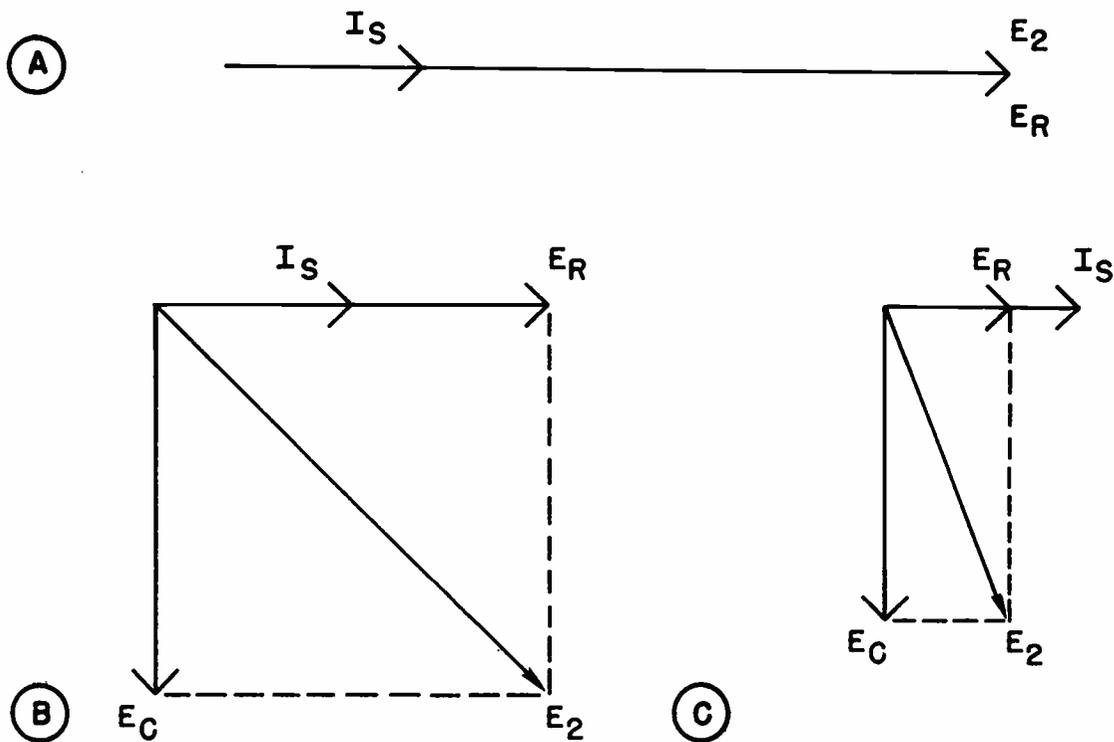
Fig. 10. Vector diagrams showing the phase shift and attenuation that occurs at high video frequencies.

will be 90° behind the voltage across the resistor, as shown in Fig. 10B.

The resulting output voltage, E_2, will be the vector sum of the two voltages E_r and E_c. The sum of these two voltages, E_2, will lag this signal current by 45°. This is the actual voltage that will be fed to the second stage, V_2, in the case of the vacuum-tube circuit, and Q_2 in the case of the transistor circuit. Therefore the signal voltage fed to these stages will be displaced by 45°. This will result in a misplaced high-frequency video signal.

When half the current flows through the resistive load and half through the capacitance, we reach a situation where the output voltage, E_2, which is the vector sum of these two voltages, will be .707 of its value at middle frequency. This is the so-called 3 db down-point at the high-frequency end of the video amplifier response. As in the case of low-frequency attenuation, this is about the maximum attenuation that can be tolerated.

If the frequency is increased still further, more than half the signal current will flow through the shunt capacity with the result shown in Fig. 10C. Notice that here the output voltage, E_2, which is the vector sum of the voltage developed across the resistive element, and the voltage developed across the shunt capacity lags the signal current by an even greater angle than in Fig. 10B. Also notice that the amplitude of the output voltage, E_2, is even less than it was in Fig. 10B.

The displacement of the high-frequency video component may cause smearing or a complete loss of the fine detail in the picture. The loss of picture detail is due to the inability of the video amplifier to follow rapid changes or high-frequency changes in brightness. You'll remember that both in monochrome and in color

television the picture detail is conveyed entirely in the brightness signal. Therefore it is important, whether the video amplifier is designed for a monochrome receiver or for a color television receiver, that it have sufficient high-frequency response to be able to follow rapid changes in brightness in order to reproduce the picture detail and to place it in the proper position.

It is important to the technician to recognize that both high-frequency and low-frequency losses are not confined to the video amplifier. Similar deficiencies in frequency response from the video i-f system, tuner, or antenna systems can result in the same degeneration in the picture. However, the most common cause of poor low-frequency or poor high-frequency response in a TV receiver is a defect in the video amplifier.

Now let us go ahead and see what steps can be taken to improve the high-frequency response of a typical amplifier so that adequate reproduction of the high-frequency video information will be obtained.

IMPROVING HIGH-FREQUENCY RESPONSE

In Fig. 10B we have shown, by means of vectors, what happens when the video frequency is high enough for the reactance of the capacities in the output of a video amplifier to equal the resistance of the load resistor. Notice that the net voltage developed across the load, E_2, and fed to the input of the second stage, lags the signal current by 45°. It so happens that the output voltage will be equal to .707 of the voltage obtained in the middle video frequency range.

If the video amplifier can be designed so that the highest video frequency to be handled receives no more attenuation and phase shift than this, the results will usually be satisfactory.
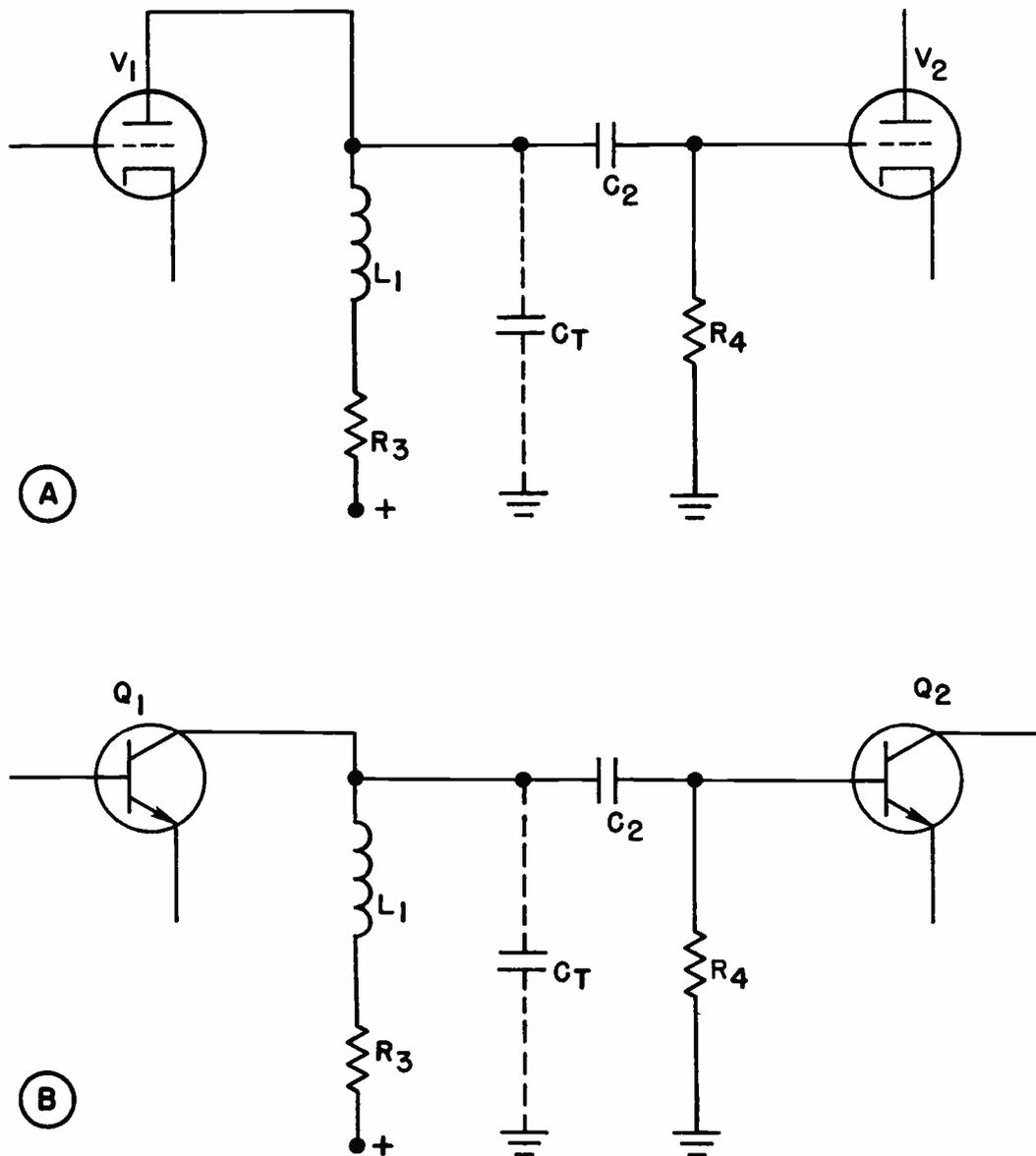
Fig. 11. Shunt peaking in tube and transistor video amplifiers.

For an amplifier using tubes with a fixed value of capacity in the circuit, the frequency at which the reactance will be equal to the load resistance depends primarily upon the value of the plate load resistor. In other words, if the plate load resistor is a 10,000-ohm resistor, and the reactance of the shunt capacities is equal to 10,000 ohms at a frequency of 1 megacycle, we could increase the frequency at which the reactance will be equal to the resistance simply by reducing the size of the plate load resistor to 5000 ohms.

Now the reactance of the shunt capacities will be equal to the resistance of the load resistor at a frequency of 2 megacycles. From this you can see that the frequency the video amplifier can handle can be increased by reducing the size of the plate load resistor. Of course, this reduces the gain of the video amplifier at low and middle frequencies, but gain must be sacrificed in order to gain a wide-band amplification. However, with the high Gm tubes that are available, a fairly high gain can be obtained even with

a low value plate resistor. For example, with a tube having a Gm of 20,000 micromhos, a gain of approximately 20 will be obtained with a plate load of only 1000 ohms.

The first step, therefore, in improving the response of the video amplifier using tubes, is to use a low value of plate load resistor. Let us look into some of the problems encountered at high frequencies in video amplifiers using transistors.

As we pointed out, in a transistor amplifier the actual load that the amplifier sees is influenced appreciably by the input resistance of the following stage. In the common emitter circuit frequently used in video amplifiers the input resistance will be somewhere between 1000 and 2000 ohms. Therefore the collector load resistor cannot be reduced appreciably to eliminate the effect of the shunting capacity. However, a low value of load resistor is used in order to avoid making the situation worse.

The method most widely used to help improve the

high-frequency response is the degenerative circuit shown in Fig. 1. The bias resistor R_7 is connected back to the collector instead of directly to the B supply, as shown in Fig. 9. With the bias resistor connected back to the collector there will be a certain amount of feedback at all frequencies. At middle frequencies, when the gain of the stage is highest, the degenerative feedback will be at a maximum and this tends to reduce the gain of the stage. On the other hand, at high frequencies when the gain begins to fall off because the shunting capacities enter into the circuit, the amount of feedback goes down so that the tendency is for the gain of Q_1 to come up and tend to level off the gain over a wider frequency range.

There are additional steps that can be taken in transistor circuits to improve the gain at high frequencies. In addition, you'll see that we also take steps to improve high-frequency response of vacuum-tube video amplifiers. Now let's look at some of the methods used to improve the high-frequency response.

High Frequency Peaking.

Special inductors called peaking coils, such as L_1 in Fig. 11 and L_2 in Fig. 12, can be used to boost and improve the gain of the video amplifier in the high-frequency range. The two basic methods of peaking are referred to as shunt peaking and series peaking. In Fig. 11, inductor L_1 is referred to as a "shunt peaking coil" because it is across the signal path. The peaking coil, which at the most has an inductance of just a few hundred microhenrys, has a very low reactance over the middle and low frequency range of the video spectrum. However, at high frequencies, the

inductive reactance increases, and adds, in series, with the load resistor R_3. Consequently, the impedance in the plate circuit of V_1 in Fig. 11A and in the collector circuit in Fig. 11B increases, and the gain of the video amplifier tends to rise to compensate for the drop due to the shunt capacity.

The peaking coil L_1, along with the distributed circuit capacity C_t, forms a circuit that is broadly resonant at the upper end of the video spectrum. This resonant circuit peaks the gain of the amplifier at the high-frequency end. As you have learned, the impedance of a parallel resonant circuit is largely resistive over its bandpass. As a result, the presence of the peaking coil not only adds to the load impedance to raise the gain of the stage at the high-frequency end, but also reduces the phase distortion introduced by the distributed circuit capacity.

When the peaking coil is inserted in series with the signal path, as in the two circuits shown in Fig. 12, it is called a "series peaking coil." A series peaking coil isolates the output capacity of one stage from the input capacity of the succeeding stage. Thus, the total distributed capacity is divided into input and output components, C_o and C_{in}. In fact, a low-pass filter results. This low-pass filter passes all frequency components up to a specific high-frequency limit.

To pass the high end of the video spectrum, inductor L_2 and the input capacity of the succeeding stage become series-resonant, and permit maximum transfer of signal energy over this spectrum. It might at first appear that the rising reactance of L_2 would act as a voltage divider and attenuate the high-fre-
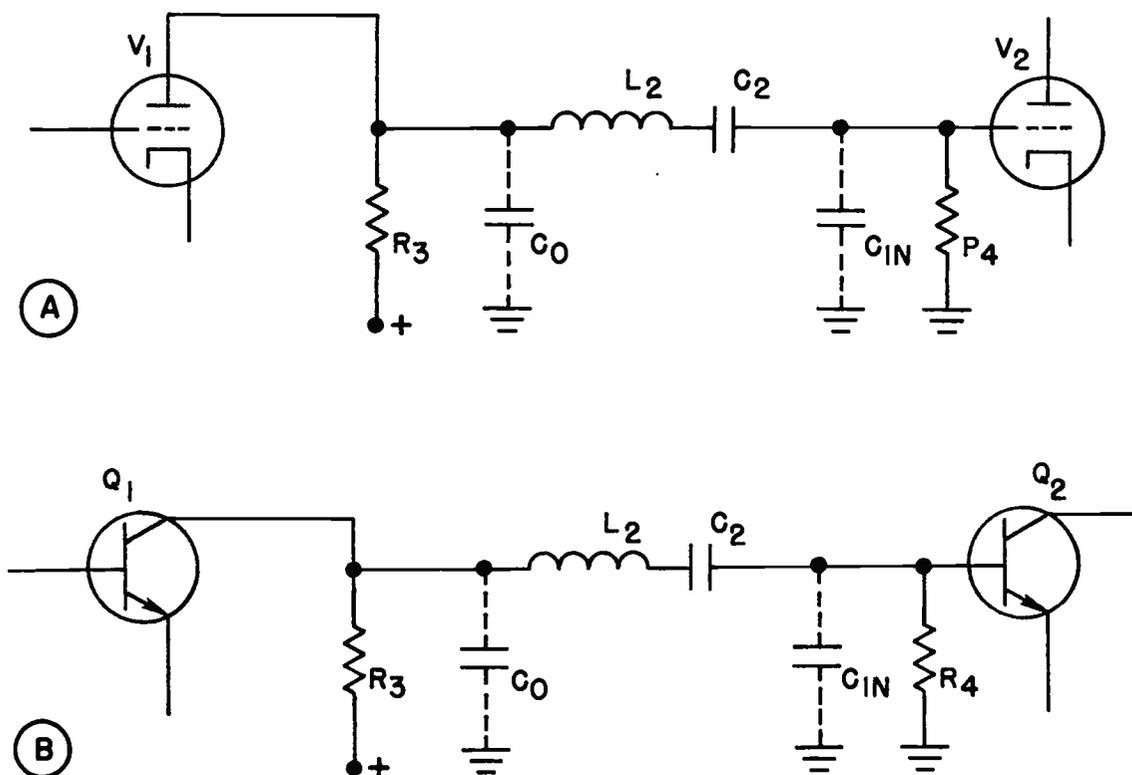
Fig. 12. Series peaking in tube and transistor circuits.
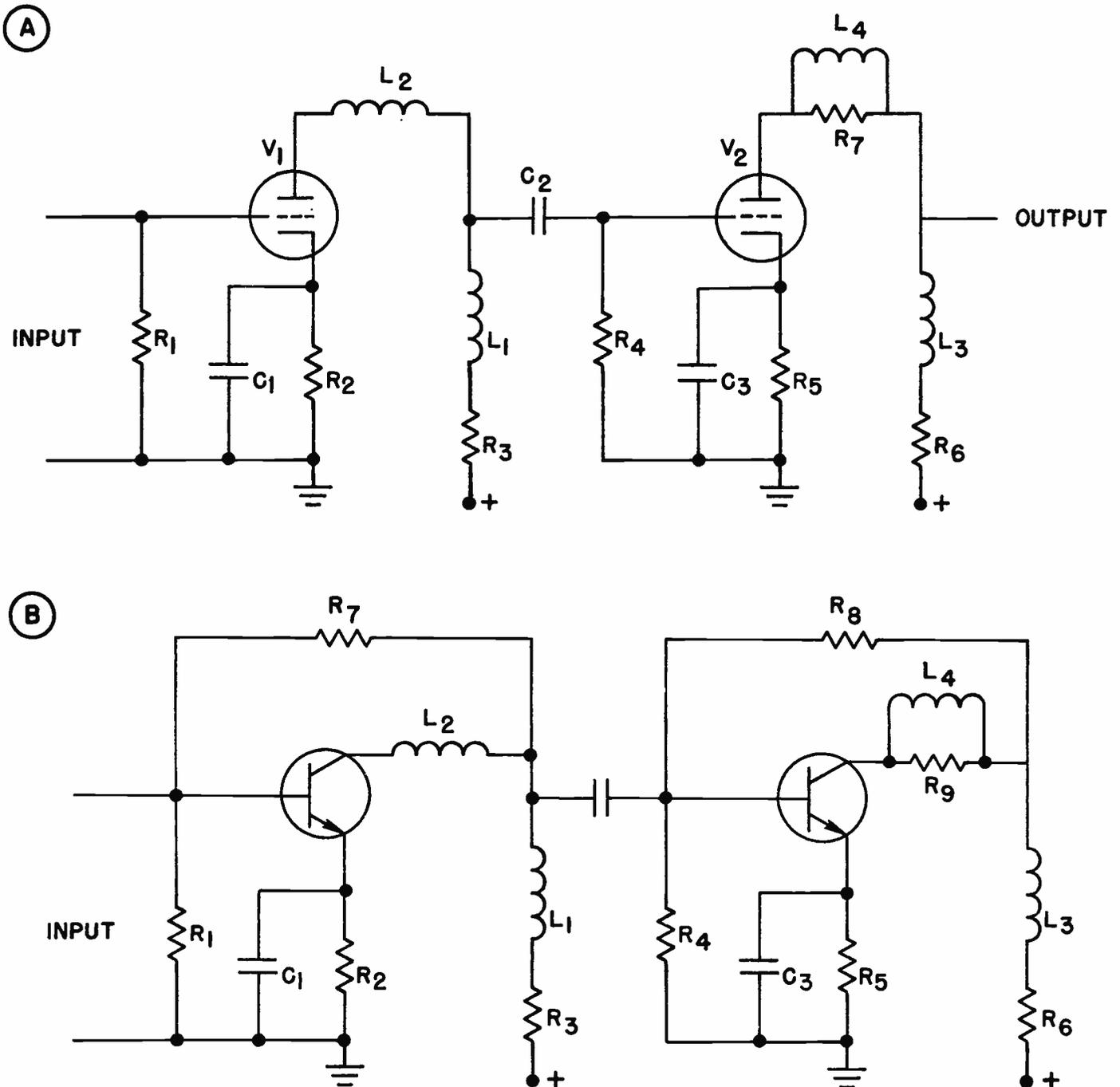
Fig. 13. Combination series and shunt peaking.

quency segments of the desired video spectrum. However, the series-resonant relationship between the inductor and the input capacity permits the voltage across C_{in} to rise as the frequency is increased, peaking the response over the necessary range to compensate for the presence of the output capacity.

In vacuum tube video amplifiers the effective isolation offered by the series peaking coil between input and output capacities permits the use of a higher value of load resistance for a given high-frequency limit than the shunt peaking coil arrangement. Consequently, series peaking not only peaks the video amplifier gain at the high-frequency end of the video spectrum, but

also permits an improvement in the overall gain of the video amplifier stage.

Series Shunt Peaking.

The most common form of peaking in commercial video amplifiers is combination series-shunt peaking. In vacuum tube video amplifiers, the combination of both types of peaking in a video amplifier, as shown in Fig. 13A, permits a higher value of plate load resistor for a given high-frequency limit, and provides best control of high-frequency response. The higher permissible value of plate resistor results in a higher gain per bandwidth than other types of peaking.

In the transistor circuit shown in Fig. 13B, the com-

bination of both types of peaking, plus the degenerative feedback through R_7 and R_8, usually gives the best overall combination of gain and bandwidth.

The series-peaking coil, inductor L_2, in both circuits of Fig. 13, is made series-resonant with the input capacity of the succeeding stage, at some frequency at the high end of the video spectrum. The shunt-peaking coil, inductor L_1, is made resonant with distributed circuit capacity at a somewhat lower frequency. The combination of both peaking coils gives a linear and extended high-frequency response with substantially higher gain than could be obtained with either of the two types of peaking alone.

The bandwidth and the flatness of the shunt-peaking depend on the loading of the parallel-resonant combination by the load in each stage. In Fig. 13A, the load for V_1 is primarily R_3. In Fig. 13B, the load for Q_1 is R_3 in parallel with R_4 and the input resistance of Q_2.

The load across the parallel-resonant circuit lowers its Q and extends its bandwidth over the high end of the video spectrum without causing a serious resonant peak. The series-peaking coil, however, is not loaded by the load resistor, because of its location in series with the signal path. It could have a very high Q, and therefore it is usually shunted with a resistor to lower its Q and prevent sharp resonant peaks in the video response curve. The loading of the peaking coil extends the bandwidth and keeps the response flat and linear over the high end of the video spectrum.

SELF-TEST QUESTIONS

(a) Would you expect to find a low Gm or a high Gm tube as the video amplifier in a modern TV receiver?

(b) Why is a bypass capacitor used across the resistor connected between the emitter and ground in a common emitter amplifier?

(c) What do we mean by the gain of the stage?

(d) What two purposes does the coupling capacitor serve in an R-C coupled circuit?

(e) What will happen to the picture on a TV receiver if the high-frequency response of the video amplifier is poor?

(f) What will happen to the TV picture if the low-frequency response of the video amplifier is poor?

(g) What two problems can the coupling capacitor in an R-C coupled amplifier introduce?

(h) What are the simplest ways of reducing the problems caused by the coupling capacitor in an R-C coupled vacuum-tube amplifier?

(i) What causes a drop in the high-frequency response of a video amplifier?

(j) What is the first step taken to get good high-frequency response in a video amplifier?

(k) What type of high-frequency peaking is most used in video amplifiers?

(l) Why is a resistor often connected in parallel with a series-peaking coil?

The Effect Of Time Constants On The Video Signal

One of the important factors that engineers must consider in designing video amplifiers is how the various R-C networks will affect the shape of the video signal. As a technician you need not go into the design of the these circuits, but you should have a general idea of how the video signal may be affected by these networks so that when a defect occurs, you will have a good idea of what type of trouble to look for.

We have already discussed the effect of the coupling capacitor on the low-frequency response of the video amplifier and also the effect of the shunt capacities on the high-frequency response of the amplifier. Now let us take another look at the video amplifier, and this time consider the time constants of the circuits involved, in order to get a better understanding of the factors that limit the response of a video amplifier.

THE VIDEO SIGNAL

In discussing audio amplifiers, we generally consider their response in terms of sine wave response. This is logical, because the electrical equivalent of a 400-cycle tone is a 400-cycle sine wave signal. More complex sounds are simply made up of combinations of sine wave signals.

Video signals are generally much more complex than audio signals. If the scene shown in Fig. 14A is televised, the video signal produced will be a square wave as shown in Fig. 14B. In Fig. 14A, the scene is simply divided into two parts, one black and the other white. To reproduce this scene, as the electron beam scans across the picture tube, we must have a signal that will turn the beam completely off during the first half of a line and then switch it to maximum brightness during the second half of the line. This will require a signal like Fig. 14B where the voltage rises almost immediately to a maximum, remains constant for the first half cycle, and switches polarity almost instantly, remaining constant for the second half and then dropping back to zero.

A signal of the type shown in Fig. 14B is usually re-ferred to as a square wave. By means of mathematics, we can show that a square wave actually consists of a fundamental sine wave plus an infinite number of odd harmonics. Therefore, in studying the response of a video amplifier to a wave of this type, we can study the response of the video amplifier to a sine wave and its odd harmonics. This greatly simplifies our study of video amplifiers.

The video signal consists of pulses similar to the pulse shown in Fig. 14B. Of course, the pulses may occur at a much faster rate. For example, if the video scene consisted of ten vertical bars, then we would have ten cycles during each line instead of one cycle. Similarly, if there were a hundred vertical lines, we would have a hundred cycles per line. You will remember there are 15,750 horizontal lines per second in a monochrome transmission and 15,734 in a color transmission. Therefore the square wave needed to produce a scene like Fig. 14A would have a frequency of approximately 15 kc. To produce ten vertical lines it must have a frequency of 150 kc and to produce 100 lines a frequency of 1500 kc.

A video amplifier cannot respond to instantaneous changes like those shown in Fig. 14B. It takes some time for the signal to go from zero to a maximum value. However, the shorter the time required, the better will be the quality of the reproduced picture.

Another important point to notice about the signal shown in Fig. 14B is that both the top and bottom of the signal are flat. In other words, the signal very closely resembles a dc voltage that has one polarity for the first half-cycle and the opposite polarity for the second half-cycle. To keep the flatness at the top and bottom of the signal, any coupling network used between video amplifier stages must have a good low-frequency response. If the low-frequency response is poor, both the top and the bottom of the square wave will slope. The reproduced picture, instead of being totally black on one side and totally white on the other will be shaded, going from total black on the left to a gray toward the center and then shifting to a white
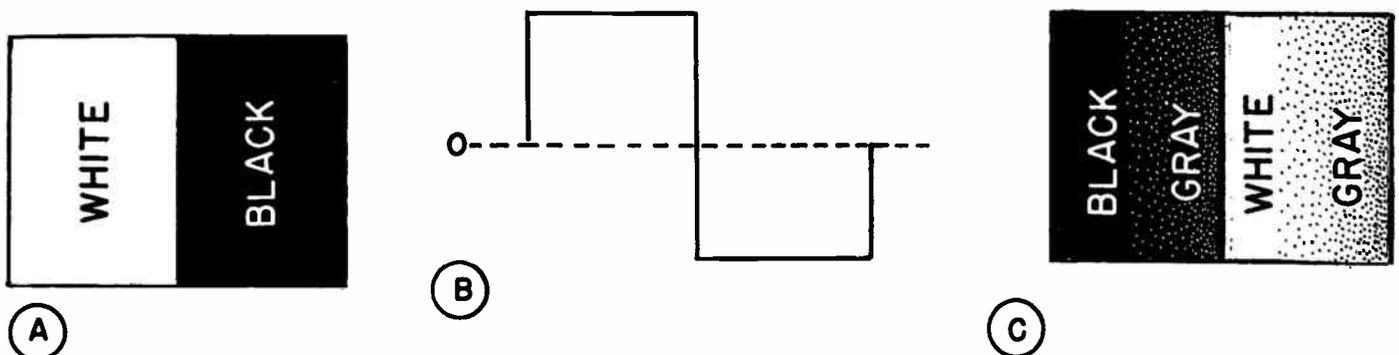
Fig. 14. Video signal resulting from the scene at A is shown at B; the effect of poor low frequency at C.
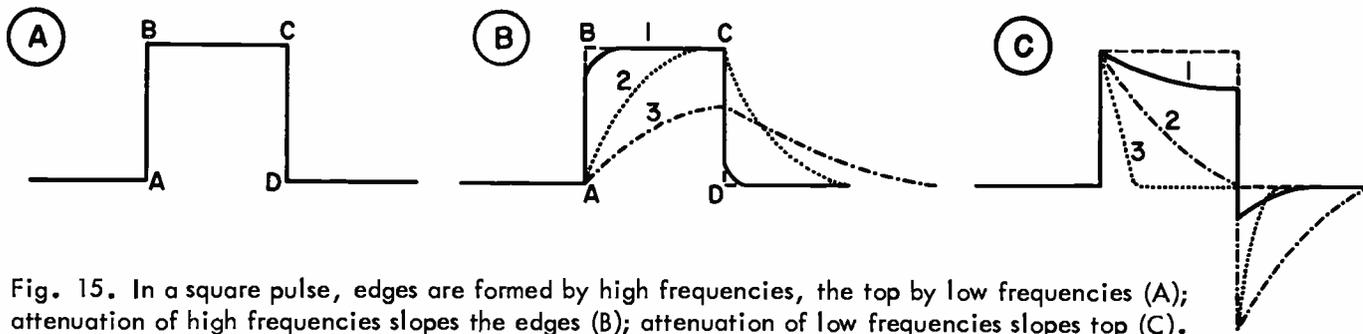
Fig. 15. In a square pulse, edges are formed by high frequencies, the top by low frequencies (A); attenuation of high frequencies slopes the edges (B); attenuation of low frequencies slopes top (C).

and then again drifting toward a gray at the right side as shown in Fig. 14C.

Of course, in addition to the video signal, the horizontal and vertical synchronizing pulses usually pass through one or more stages of the video amplifier. Again, in order to pass these pulses, the video amplifier must be capable of passing a wide band of frequencies.

Let us briefly review what we have learned about pulses and how the video amplifier can affect the shape of the pulse. The high-frequency components of the pulse must be passed to prevent misshaping of the leading and trailing edges of the pulse. The leading and trailing edges represent a fast change in voltage in a short period of time, and therefore constitute high-frequency voltage changes.

To prevent changing the shape of the tip or flat top of the pulse, the low-frequency components of the pulse must be passed, because the flat top of a pulse is formed mostly by the low-frequency sine wave. Consequently, as shown in Fig. 15A, the high-frequency response of an amplifier determines how well the sides A-B and C-D are passed, while the low-frequency response of the amplifier determines how well the pulse section B-C is passed.

If the high-frequency response of the amplifier passing the pulse is poor, the leading and trailing edges of the pulse are distorted as shown in Fig. 15B. A slight loss of high-frequency response results in a slight rounding of the pulse at points B and D as demonstrated by curve 1.

A more severe loss of high frequencies causes a greater distortion of the pulse as shown by curves 2 and 3. For example, in curve 3, the high-frequency response is so poor that the leading and trailing edges of the pulse have been lost almost completely. Note that not only is the pulse attenuated and its shape changed, but also it has been effectively extended and is now a longer signal (lasts longer) than the original pulse. This displacement of the information contained in the pulse is a result of phase shift and time delay. It follows that if a certain part of the video information were spread out as shown by curve 3 of illustration 15B, it would cause a blurred picture because of the presence of additional information to the right of the proper position for the information on the screen.

When the low-frequency response of the amplifier is poor, it is not possible to hold the constant voltage level represented by the flat top B-C of Fig. 15A. A slight loss of lows causes the flat top to tilt away

from point B as shown in curve 1, Fig. 15C, and also a drop of the trailing edge below point D, and then a return to the base line. A more severe loss of low frequency response causes a very decided drop off the flat top of the pulse as demonstrated in curves 2 and 3. The dotted curve 3 represents a severe loss at low frequencies and a very fast drop-off of voltage from point B of the original pulse. It is again to be noted that a loss of low frequencies not only changes the shape of the pulse for the duration of the pulse, but adds information following after the pulse as well. This information, which is again a result of phase shift and time displacement of the signals that make up the pulse, causes additional information and brightness variations following the actual signal.

THE TIME CONSTANT

The response of an amplifier to pulses can also be interpreted in terms of the time constants of various resistor-capacitor combinations within the amplifier circuit. Time constant is the time required by a capacitor to charge to a prescribed voltage.

You will recall that when a dc voltage is applied to a resistor-capacitor combination such as shown in Fig. 16, a certain time is required for the capacitor to charge through the resistor. The higher the capacity the longer the time required to charge the capacitor to full applied voltage because the larger the capacity, the more electrons can be stored. Likewise, the higher the value of the resistor, the longer the time required to charge the capacitor because the resistor retards movement of electrons into the capacitor. The product of the capacitance times the resistance is referred to as the time constant of the circuit because the time required to charge the capacitor depends on the values of the capacitor and the resistor. The product of the resistance in megohms
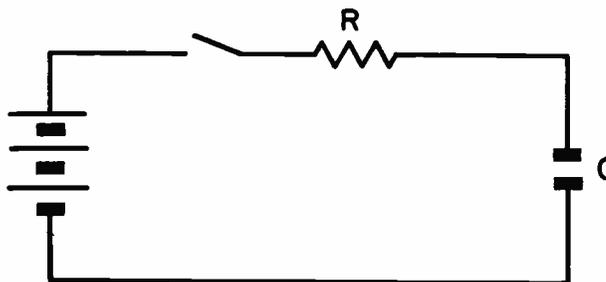
Fig. 16. A series R-C circuit.
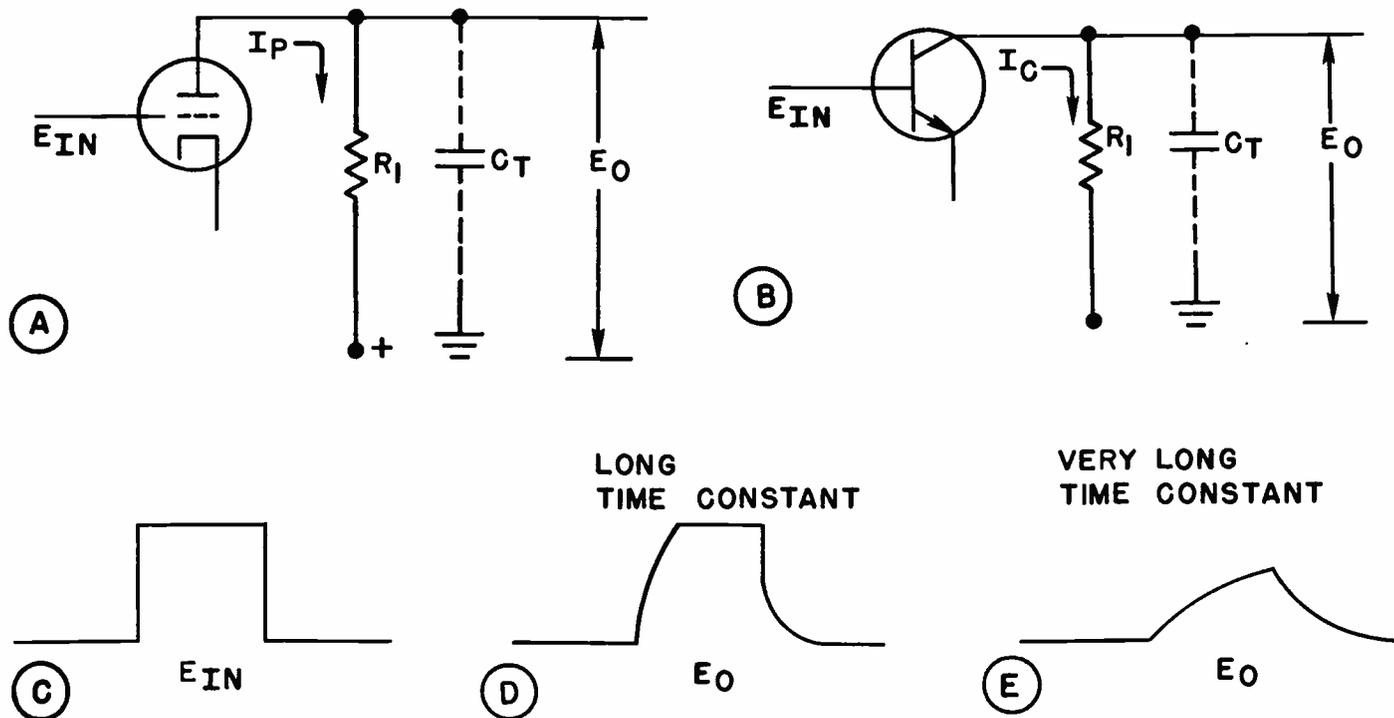
Fig. 17. The shunt capacities in the circuits A and B can distort a signal like the one in C, and produce the signals shown in D or E if the circuit time constant is too long.

times the capacity in microfarads gives the time constant in seconds. This is the time it will take the capacitor in an R-C circuit to charge to approximately 63% of the value of the applied voltage.

When the voltage is removed there is again a time lag before the voltage drops to zero across the capacitor. In other words, the capacitor voltage declines only as fast as the electrons can move through the resistor. Again, the higher the capacity and the higher the resistance, the longer the time of discharge.

An R-C product that is low (small capacitor and low value resistor) is referred to as a short time constant, because the capacitor charges and discharges quickly. If the product is high (large capacitor and high value resistor) it is called a long time constant because the capacitor charges and discharges slowly.

To better understand the action of these resistor-capacitor combinations on pulses, let us consider a pulse as a dc voltage that is applied to the circuit for only a short time. The leading edge of a pulse is the sudden closing of the switch and the application of the voltage; the trailing edge is the sudden opening of the switch and removal of the voltage. The pulse differs from a switched dc voltage only in the speed of the switching action--switching can occur a great many times in a second.

We have learned that the shunt capacity of a video circuit causes a loss of high frequencies. Another way to consider the same condition is that the presence of shunt capacity creates too long a time constant. Thus there is a lag between the change in plate voltage and the change in signal current because of the time required to charge C_t as shown in Fig. 17A. Similarly in the circuit shown in Fig. 17B, there is a lag between the change in collector voltage and the change in signal

current. The influence of this shunt capacity is more detrimental on the high frequencies, because of the very fast change in signal current that accompanies high-frequency variations. The leading and trailing edges of a pulse represent fast changes in signal or high frequencies. Thus the time of signal change is very short and the time constant of the output circuit must be very fast to follow this signal current change. If there is a lag introduced by the shunt capacity (too long a time constant) the output voltage will not follow the signal current, because the output voltage build-up will not be able to follow the fast rise time of the pulse. Also the fast drop-off of the pulse will not be followed faithfully because of the time required to discharge the shunt capacity. Consequently, the output voltage will lag behind the trailing edge of the pulse. The manner in which an input pulse, such as shown in Fig. 17C, may be distorted by a long time constant is shown in Fig. 17D. The distortion caused by a very long time constant is shown in Fig. 17E.

The time constant of a series combination of resistor and capacitor that must convey the pulse from one stage to another must be long enough to prevent distortion of the low-frequency components of that pulse. For example, in an interstage-coupling circuit such as the one shown in Fig. 18A and Fig. 18B the charge on the coupling capacitor, C_1, must not vary with signal voltage variations because this would represent a voltage across the coupling capacitor that did not reach the succeeding stage. Thus the time constant is made long enough to prevent the coupling capacitor from charging and discharging during the time of the pulse. If the time constant (t=RC) is made much longer than the duration of the pulse, the capacitor is not able to accumulate an appreciable charge during this interval. Consequently,

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Ⓐ

Ⓑ

Ⓒ E_{IN}

SHORT
TIME CONSTANT

Ⓓ

VERY SHORT
TIME CONSTANT

Ⓔ
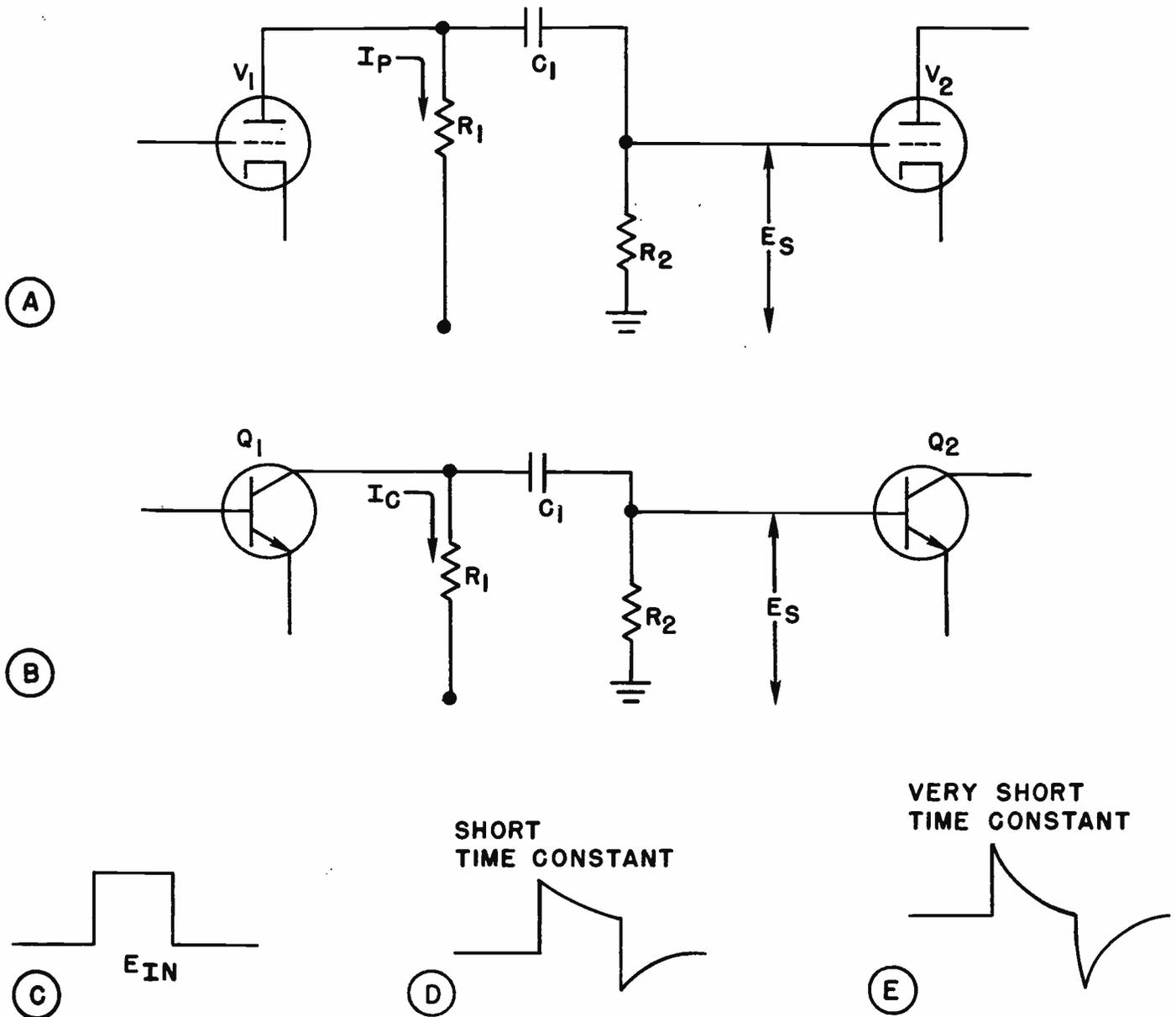
Fig. 18. The R-C coupling circuits in A and B can distort an input such as C if the time constant is too short, with the results shown in D and E.

the pulse will appear in its entirety across the resistor, R_2. If, however, the time constant of the coupling combination is too short, a charge does accumulate on the capacitor and subtracts from the pulse that should appear across the resistor. This subtraction is best shown in the curves of Fig. 18D, which show the drop-off of the curve as a charge builds up on the coupling capacitor. Fig. 18D shows the effect of a time constant that is slightly too short. Fig. 18E shows the effect of a very short time constant.

Up to this time we have been discussing the disadvantages and problems created by circuits that may change the shape of a pulse. However, there is another problem which must be dealt with in the video amplifier of color receivers. You will remember that the detail in the black-and-white or Y signal is greater than the color detail. The video amplifiers in color receivers are designed to amplify signals up to almost
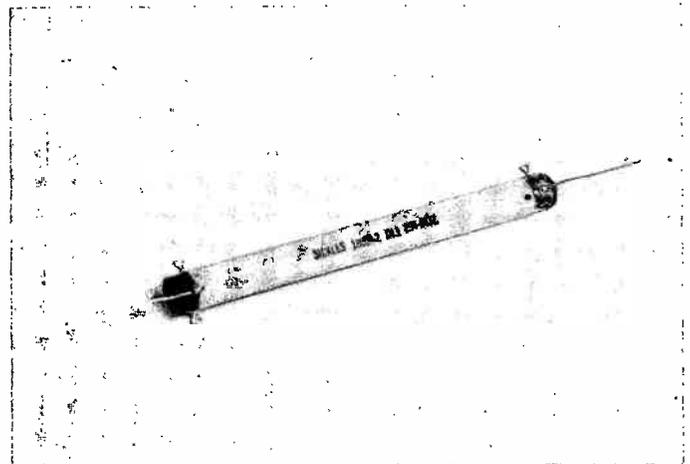
Fig. 19. Photo of a delay line used in a color TV.

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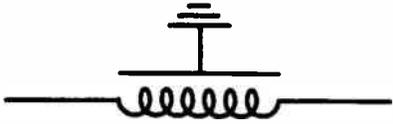
Fig. 20. Schematic symbol of a delay line.

3.5 mc. The color amplifiers, on the other hand, usually have a bandwidth of only 500 to 600 kc. Due to the longer shunt time constants found in an amplifier with a high-frequency limit of 600 kc compared to an amplifier with a high-frequency response up to 3.5 mc, a signal fed to both amplifiers will be delayed by the lower frequency amplifier.

In a color receiver, this delay would have the effect of displacing the color information on the picture tube to the right of the brightness information. This problem is overcome by introducing an equal delay into the video amplifier. This is done by means of a delay line such as shown in Fig. 19. The schematic symbol used to represent a delay line is shown in Fig. 20. As the symbol suggests, a delay line is made up of inductance and distributed capacity. The delay introduced into the video amplifier is usually in the order of about .7 microseconds.

SELF-TEST QUESTIONS

(m) What is the time constant of an R-C circuit made up of a 2 mfd capacitor and a 3-megohm resistor?

(n) Should the R-C coupling network in a video amplifier have a short or a long time constant? Why?

(o) Why is a delay line needed in the video amplifier of a color receiver?

The Signal Applied to the Picture Tube

The video amplifier is connected between the video detector and the picture tube. It amplifies the weak signal at the video detector output and feeds the amplified signal to the picture tube. The signal can be applied to either the grid or the cathode of the picture tube. However, the signal must be applied with the proper polarity. There are probably just as many monochrome receivers in use where the video signal is applied to the cathode as there are where it is applied to the grid. However, in most late model sets using high Gm tubes, you'll find the signal fed to the cathode. In monochrome transistor receivers, the signal is usually fed to the grid of the picture tube. In most color receivers, the luminance signal, as the video signal is called, is fed to the cathodes of the color tube leaving the grids available for the color information.

SIGNAL POLARITY

When the composite video signal is applied to the grid of the picture tube, the signal must be negative-going so that the blanking level drives the grid negative enough to cut off the electron beam. With negative-going sync pulses, the video information has what is called a positive picture phase. A video signal with a positive picture phase will drive the grid in a positive direction (less negative) for white portions of the scene and cause maximum beam current and illumination.

When the video signal is applied to the cathode of the picture tube the composite signal must be positive-going; this drives the grid circuit to cut-off during blanking, as it should. In other words, a positive-going sync signal on the cathode has the same effect as a negative-going sync signal has on the grid.

In the circuit shown in Fig. 21, the video signal is applied to the grid of the picture tube. Therefore the sync pulses must swing negative, as shown, to drive

the picture tube to cut-off during the blanking interval. Since each grounded cathode amplifier stage reverses the signal phase by $180°$, the sync pulse must have the opposite polarity at the input to V_2. Similarly, V_1 will reverse the signal phase $180°$, and therefore the input to V_1 must be $180°$ out-of-phase with the input of V_2 -- this means that the input of V_1 must have the same phase as the signal applied to the picture tube. Therefore, the video detector must be connected to develop a negative-going composite signal at its output for application to the grid of the first video amplifier stage, V_1. When there are two video stages, as there are here where each stage reverses the signal polarity, the polarity of the signal at the output of the video detector must be the same as that required at the grid of the picture tube.

In the circuit shown in Fig. 22, a two stage video amplifier is used but the signal is applied to the cathodes of a tri-color tube. At first glance you might think that this will produce the wrong signal polarity at the picture tube. However, notice that the first video amplifier stage is a cathode follower. This type of stage does not result in any phase reversal--in other words, the output signal taken from the cathode of the tube has the same polarity as the input signal fed to the grid. Thus we have negative-going sync pulses at the output of the video detector, negative-going sync pulses at the output of V_1 and then positive-going sync pulses at the output of V_2. This provides us with the correct polarity of video signal for the cathodes of the picture tube.

In some color receivers, the video amplifier will consist of three grounded cathode stages. Both the video and the 3.58 mc color subcarrier and its sidebands will be amplified by the first stage. At the output of the first video amplifier the 3.58 mc color signal is removed and fed to the color stages. The video signal is amplified by the following two stages. With
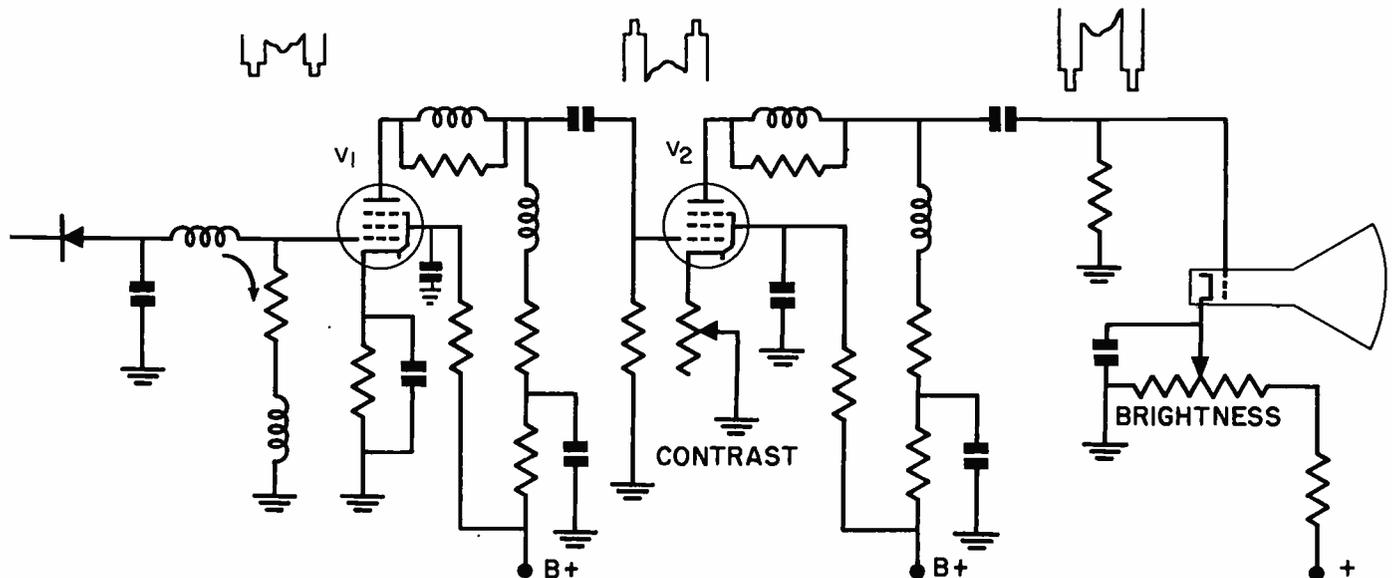
Fig. 21. Two-stage video amplifier connected between the video detector and the picture tube.
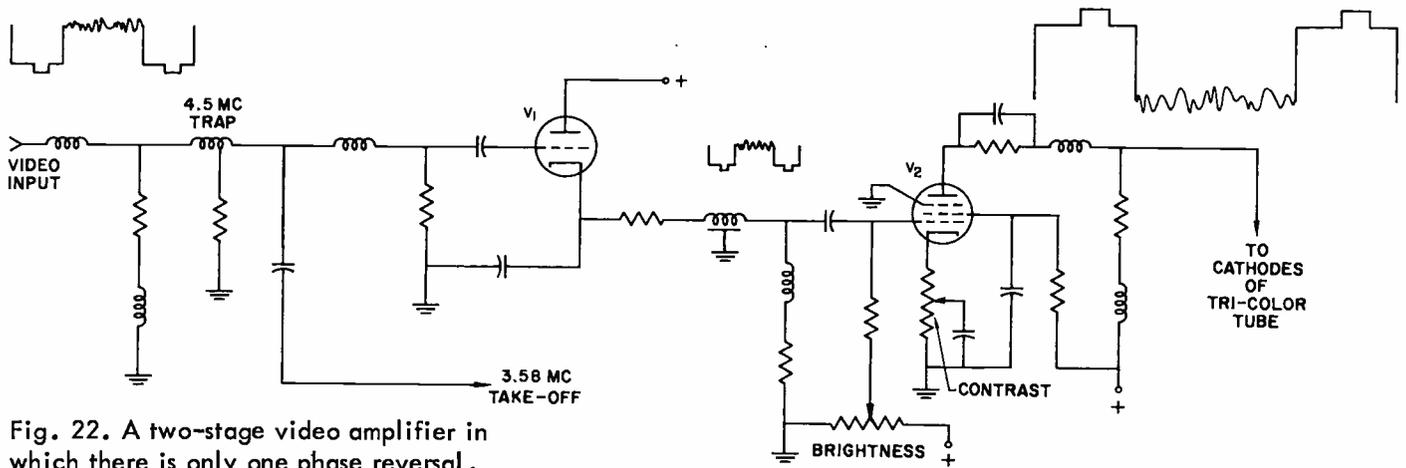
Fig. 22. A two-stage video amplifier in which there is only one phase reversal.

BRIGHTNESS AND CONTRAST CONTROLS

three grounded cathode stages, the signal phase will go through 180° phase reversals. Thus negative-going sync pulses at the video detector output will produce positive-going sync pulses at the output of a three-stage amplifier. As in other color sets, the signal is then fed to the cathode of the tri-color tube.

BRIGHTNESS AND CONTRAST CONTROLS

The brightness control is associated with the picture tube grid-cathode circuit. It sets the dc component of the bias between the grid and the cathode, and thus controls the overall brightness of the picture. The brightness control is adjusted to the level required by the room lighting. In a very bright room, the brightness must be set higher. In a darkened room, the brightness should be lower.

In the circuit shown in Fig. 22, the brightness control indirectly varies the positive potential on the cathode of the picture tube. The higher the positive potential, the lower the brightness. In this circuit, direct coupling is used between the second video stage V_2 and the cathodes of the tri-color tube. Increasing the positive voltage in the grid of V_2 will cause the tube to draw more plate current. This will cause a greater voltage drop across the plate load resistor and reduce the positive voltage on the cathode of the picture tube which in turn will cause increased brightness.

Still another requirement for proper picture tube operation is a means of controlling the amplitude of the video signal applied to the picture tube. The brightness control sets the overall brightness of the reproduced picture, but a second control, referred to as the "contrast control," regulates the peak amplitude of the video signal applied to the tube. The setting of the contrast control required for best picture will depend on the strength of the signal and on the setting of the brightness control.

If the peak amplitude of the video signal fed to the picture tube is not great enough, the picture will have an underexposed appearance, with an insufficient brightness range between the brightest part of a scene and the darkest part. If the peak amplitude of the video signal is too high, the picture will have an overexposed

look with excessive contrast. With too much signal, there is a lack of half-tone or gray-scale range in a monochrome picture and excessive color saturation in color pictures.

Two contrast control circuits are shown in Figs. 21 and 22. Fig. 21 shows the method of controlling the amplitude of the video signal by using a degenerative cathode resistance. In such an arrangement, the contrast control regulates the resistance between cathode and ground, and thus varies the bias on the tube. When there is a high cathode resistance, the bias is greatest and the stage gain is at a minimum. With low cathode resistance, the bias is minimized, and the video amplifier has maximum gain. Changing the cathode resistance also changes the amount of degeneration in the stage, but the primary control is by varying the amount of bias on the stage.

The contrast control system shown in Fig. 21 is exactly the same type of circuit, except in this case the resistance in the cathode circuit of V_2 remains constant; none, part, or all of the resistance may be bypassed by the capacitor connected between the variable arm on the contrast control and ground.

In the circuit shown in Fig. 21, the dc bias on the video amplifier is changed, and this causes the plate current to change. The change in plate current also changes the plate voltage on the video amplifier tube.

In an R-C coupled circuit, such as in Fig. 21, this is no problem, but in a direct-coupled circuit such as in Fig. 22, this would change the bias on the tube, and then the brightness as well as the contrast. The circuit shown in Fig. 22 is preferred where direct coupling is used. Changing the setting of the contrast control has no effect on brightness.

SELF-TEST QUESTIONS

(p) What picture polarity is required when the video signal is fed to the grid of a picture tube?

(q) What signal polarity is required when the video signal is fed to the cathode of a tri-color tube?

(r) Which voltage does the brightness control vary in order to control picture brightness?

(s) What is the purpose of a contrast control?

Retaining the DC Component
Of the Video Signal

The video signal at the output of the video detector is actually a pulsating dc voltage. That is, it consists of voltage variations either above or below a zero reference level, depending on whether the signal is negative or positive-going, but never on both sides of the zero reference level. Such a signal is shown at the left in Fig. 23. Note that the sync tips and the blanking pulses are always at the same voltage level, but the average brightness voltage for each line varies. This same type of video signal voltage must be applied to the picture tube for the best picture, although in some cases it may be reversed in polarity.

However, if an ordinary resistance-coupled amplifier is used, the signal must pass through coupling capacitors. You will recall that a capacitor, while it provides a path for ac, blocks dc. Therefore, only the ac component of the video signal is passed through a coupling capacitor. The dc components are blocked. The signal at the right in Fig. 23 shows what happens when the dc component is lost.

is tolerated, and the picture is entirely satisfactory. However, in color receivers, to get the best possible picture the dc component must be kept, or if it is lost in a capacity-coupled stage it must be restored.

DC AMPLIFIERS

The simplest way to keep the dc component of the video signal is to use direct coupling between the video detector and the picture tube. This is fairly simple in monochrome receivers. The schematic diagram for a single-stage direct-coupled video amplifier is shown in Fig. 24. Since there is no coupling capacitor at the input of V_1, both the ac and the dc components of the video signal will be applied across R_1, the grid resistor of V_1. The dc component of the signal will add to or subtract from the normal grid bias and faithfully reproduce the proper sync pulse, blanking pulse, and average brightness levels at the plate of V_1. The signal will, of course, undergo the usual 180° phase shift in the stage.

Fig. 23. The pulsating dc signal (left) changes to an ac signal when passed through a capacitor.

Note that the zero reference level becomes the average brightness level for all three lines shown. Also, the blanking and sync pulses no longer line up, but are at three different levels. Fortunately, the average brightness in most pictures does not change too much from one line to the next, so if we use coupling capacitors in the video amplifier and we lose the dc component, the resulting signal is usually not upset as much as it is in the example in Fig. 23. In many monochrome receivers, this loss of the dc component

In order to use direct coupling between the plate circuit of the video amplifier and the cathode circuit of the picture tube, it is necessary to set up a voltage-divider arrangement so that the proper negative dc voltage is applied between the grid and the cathode of the picture tube, and the proper positive voltage between the plate and the cathode of the video amplifier tube. A voltage divider network, consisting of resistors R_2 through R_6, connects two supply voltage points with each other and then to ground. A + 125-volt source
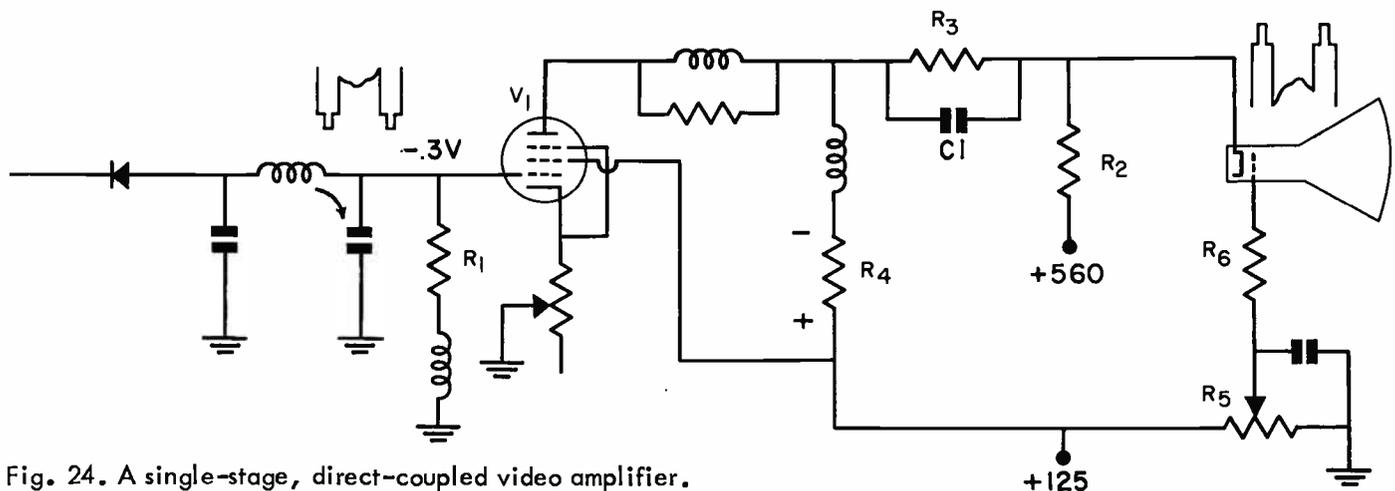
Fig. 24. A single-stage, direct-coupled video amplifier.

Fig. 25. A direct-coupled video amplifier using a high Gm tube.
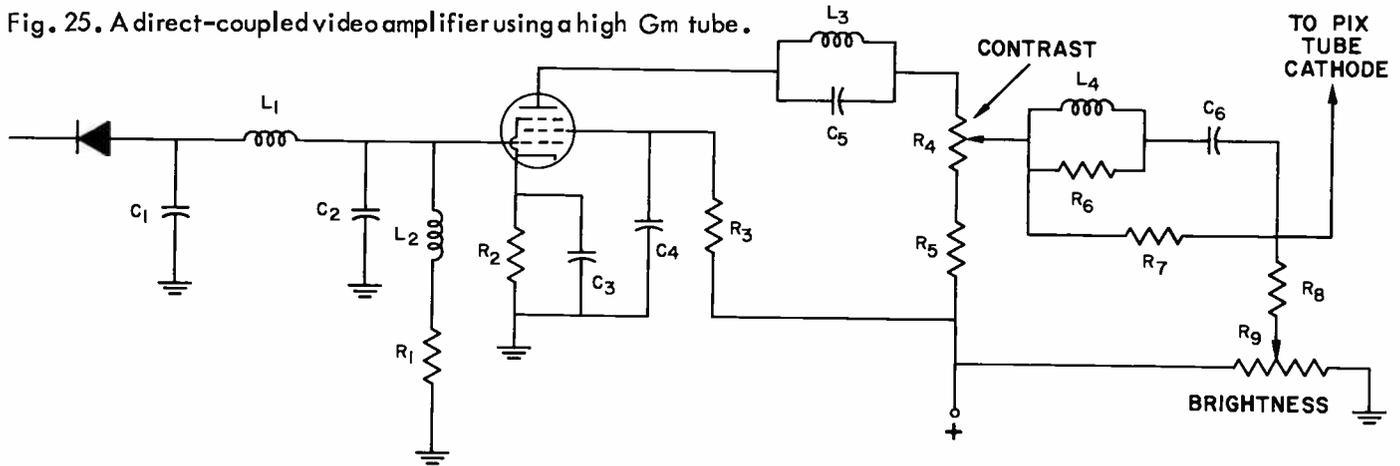
supplies voltage for the brightness control circuit through potentiometer R_5 to ground.

This arrangement permits proper biasing of the grid as well as a means of controlling brightness. The same + 125 volts is present on the screen of V_1 and is also connected through the voltage divider circuit consisting of resistors R_4, R_3, and R_2 to a + 560-volt source. This voltage-divider arrangement supplies a positive voltage to the cathode of the picture tube so that the cathode will be positive with respect to the grid, or in other words, the grid will be negative with respect to the cathode. In addition, the positive supply voltage, through divider action, is reduced to the correct value for the video amplifier stage. Capacitor C_1 serves as a low coupling reactance for the ac components of the video signal, permitting resistor R_3 to function simply as a dc divider resistor.

The presence of resistor R_4 in the plate circuit of the video amplifier, as well as in the voltage-divider circuit of the picture tube, presents the means of transferring the dc component of average brightness to the picture tube. Both the ac and the dc components of the amplified video signal at the output of V_1 are developed across R_4 and thereby add or subtract from the difference of potential existing between grid and cathode of the picture tube.

Another advantage of a system of direct-coupling is improvement in low-frequency response. If the low-frequency response is poor, as it is with the average resistor-capacitor coupling combination, slow changes in brightness that can occur in a sequence of scenes will not be faithfully reproduced.

A somewhat simpler arrangement is shown in Fig. 25. Here only the one voltage source is needed. L_3 and C_5 are the primary of the sound take-off transformer and are tuned to 4.5 mc. This parallel-resonant circuit is a high resistance to the 4.5 mc sound signal and keeps it from reaching the picture tube. The contrast control, R_4, is in the signal circuit and varies the amplitude of the signal fed to the picture tube. The ac component of the video signal reaches the tube through the L_4, R_6, C_6 combination, whereas changes in dc level reach the tube through R_7.

In some receivers, a two-stage direct-coupled amplifier is used between the video detector and the picture tube. The major problem in the planning of a two-stage, direct-coupled video amplifier is distribution of supply voltages so that the proper dc bias can be
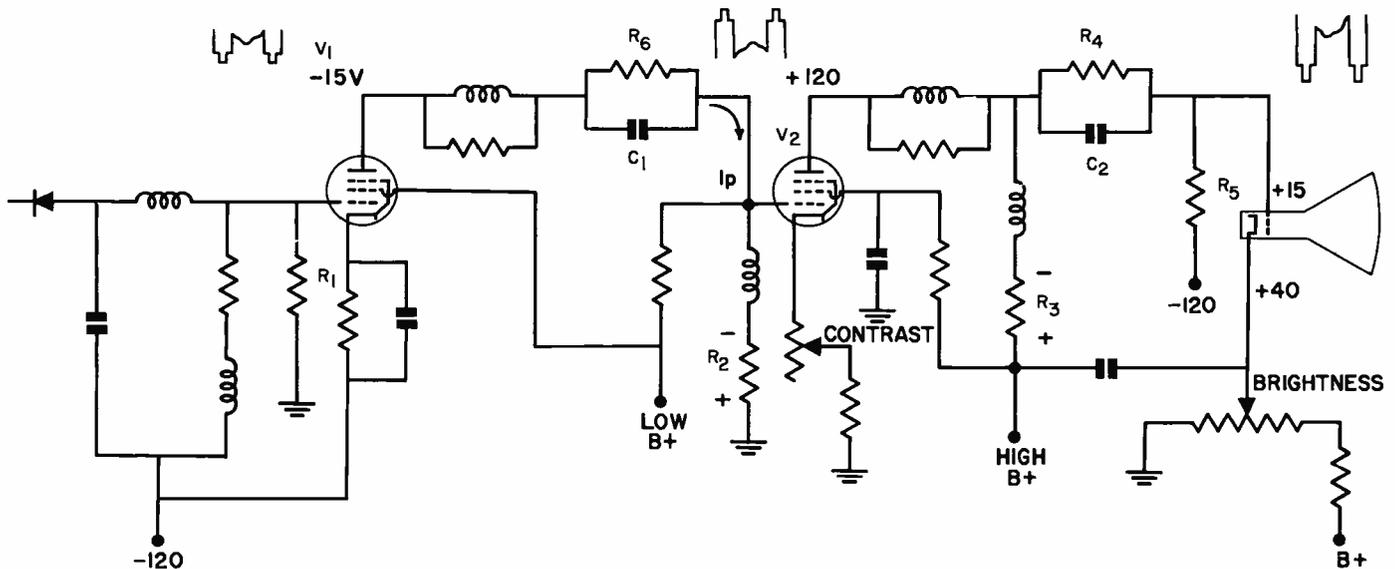
Fig. 26. The direct-coupled equivalent of the video amplifier shown in Fig. 21.

established between grid and cathode and so that sufficient plate and screen voltage is available for each tube. The video amplifier shown in Fig. 21 can be changed over to a direct-coupled version by making the changes shown in Fig. 26.

In the direct-coupled version shown in Fig. 26, the output of the video detector, instead of being returned to ground, is returned to a -120 volt source. Likewise the cathode of the first video stage is returned to -120 volts. Resistor R_1 has a very high value so that the dc voltage on the grid of V_1 is just slightly negative with respect to the dc voltage at the cathode. Consequently, the first video stage has the proper dc grid voltage. This dc voltage varies with the average brightness of the signal detected by the crystal diode, while the ac grid voltage also varies instantaneously with the ac components of the video signal.

Since the grid and cathode are at a high negative potential, only a very low supply voltage is needed for the screen and plate of V_1. In fact, the plate and screen voltages are slightly negative with respect to ground, because of the voltage-divider network that returns to a low B+ source, and the fact that tube plate current flows in a direction to develop a negative voltage drop across resistor R_2. Thus the actual plate voltage of the first video stage is slightly negative with respect to ground, but still more than 100 volts positive with respect to the cathode. At the same time the dc component of the grid voltage on V_2 is slightly negative.

The second tube is biased by the positive voltage developed across the cathode resistor and the negative dc voltage is applied to the grid. The second video stage operates almost as a conventional amplifier with a high B+ supplied to its screen and plate circuit and with the cathode near ground potential. A network of bleeder resistors, R_3 through R_5, direct-couple the plate circuit of the video amplifier to the grid of the picture tube. Notice that a negative voltage is supplied to the grid resistor R_5. This increases the dc current flow through R_3 and hence the voltage drop across it. It helps set the grid of the picture tube at a low positive potential. The cathode is then made more positive so that the grid of the picture tube will be negative with respect to the cathode. Capacitors C_1 and C_2, shunting resistors R_4 and R_6, permit the low reactance transfer of the ac components of the video signal, and the resistors act as dc voltage dividers.

Insofar as servicing a dc amplifier is concerned, it is somewhat more difficult than servicing a capacitor-coupled amplifier, because a defect does not confine itself to a single stage. If a defect that occurs in the grid circuit of the first video amplifier causes a change in the dc voltage at the grid of the first stage, the voltages throughout the entire amplifier will be affected.

DC amplifiers such as shown in Fig. 26 were widely used at one time in monochrome TV receivers and you are likely to run into such an amplifier sooner or later. However, in late model sets, most often a single high gain video stage, such as the one shown in Fig. 25, is used. In transistor monochrome receivers, ac coupling is used, due to problems of maintaining correct operating voltages with dc-coupled transistor amplifiers. As a result, the dc component of the video signal is
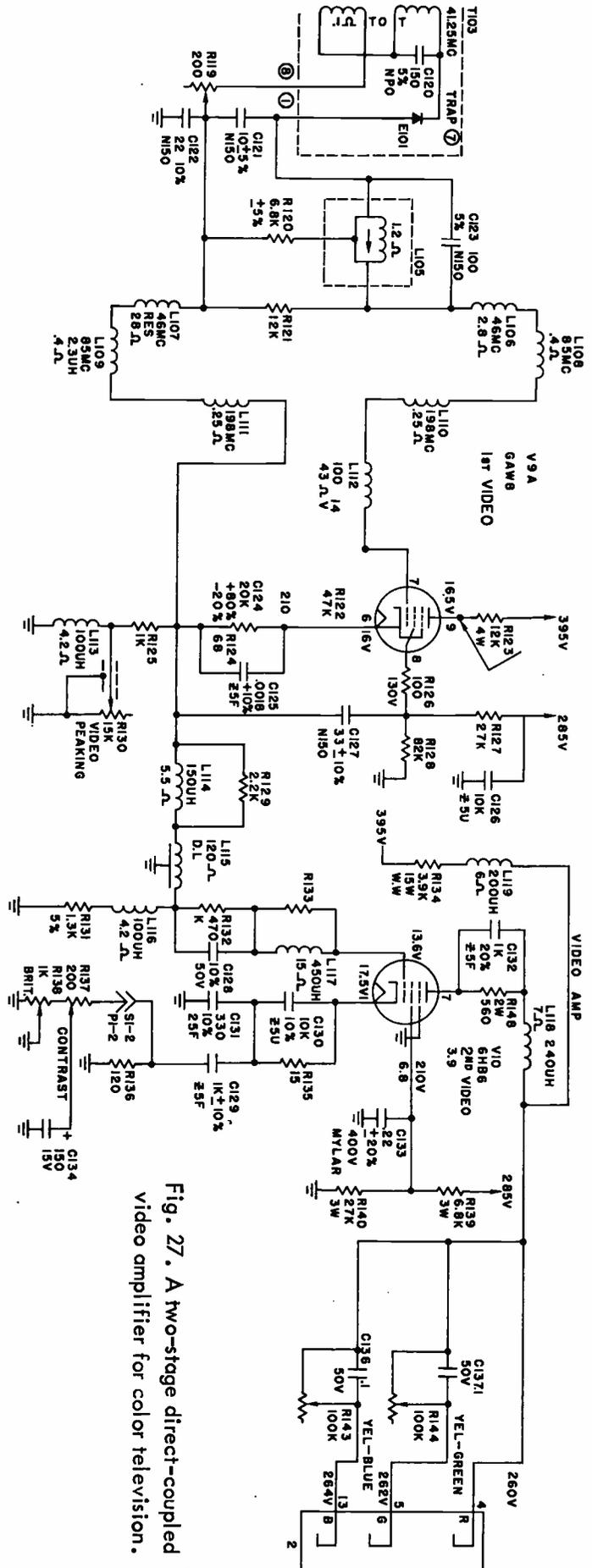
Fig. 27. A two-stage direct-coupled video amplifier for color television.

lost. This results in some degrading of picture quality, but usually it is not too noticeable.

As we mentioned earlier, the loss of the dc component of the video signal causes more degradation in a color picture than it does in a monochrome receiver. As a result, provisions are made in color receivers for retaining the dc component.

In the circuit shown in Fig. 27, the video detector is coupled directly to the first video amplifier. In the video amplifier a split load is used. Part of the load, R123, is in the plate circuit and part, R125, L113 and R130, are in the cathode. Notice that one side of the detector circuit is not grounded, but is fed to the junction of R124 and R125. Thus the stage is not degenerative, and there is gain developed across the cathode part of the load.

The video signal is taken from the cathode of the first video stage and fed through the combination of R129 and L114 to the delay line, through the line and then through the combinations of R132, C128, and R133 and L117 to the grid of the second video amplifier. From the plate of the second video amplifier, the signal is fed through the combination of C132 and R148, through L118 to the cathodes of the tri-color tube. Thus paths are provided for both the ac and the dc component of the video signal from the detector to the picture tube. The circuit of Fig. 27 has been simplified somewhat by removing the sync and color take-off points as well as blanking circuits.

Notice how the brightness and contrast are controlled in the amplifier. The controls of both are located in the cathode circuit of the second video amplifier. The brightness control varies the bias on the tube, which in turn will vary the plate and screen currents. This will vary the plate voltage, and hence the voltage applied to the three cathodes of the tri-gun tube. The contrast control varies the amount of degeneration in the cathode circuit, hence the amplitude of the signal fed to the picture tube.

If the dc component of the video signal is lost, due to the fact that the video signal is amplified by R-C coupled amplifiers, we can use dc restoration to replace the dc component.

The process of dc restoration permits reinsertion of dc brightness after it has been lost. A technique that was often used in video amplifiers in the early days of TV was to increase the amplitude of the ac portion of the composite video signal, using conventional amplifiers with capacitive coupling between stages. In such a case after the signal has been amplified to a sufficient level, it is applied to a circuit that contains a diode dc restorer, which evaluates and re-establishes the dc brightness component. It does so by causing the sync tip and blanking levels to line up again. If this is done, the average signal again varies with changes in average brightness, while the blanking and sync tips remain constant.

Since dc restorers have not been used for many years, we will not study this circuit. We mention it here only so you will know that the dc component can be restored if it is bad. You may at some time run across a very old TV receiver using a dc restorer.

SELF-TEST QUESTIONS

(t) What happens to the video signal when the dc component is lost?

(u) What is the simplest way of preventing the loss of the dc component of the video signal in a video amplifier?

(v) Why does direct coupling in a video amplifier result in good low-frequency response?

(w) Why is a direct-coupled amplifier often more difficult to service than an R-C coupled amplifier?

(x) Is the first video amplifier in Fig. 27 a cathode follower?

(y) What is meant by dc restoration?

Typical Video Amplifier Systems

There are two basic types of video amplifiers, direct-coupled and capacity-coupled. You may find either type in monochrome receivers, but you can expect to find some form of direct coupling in color receivers. We will now look at several typical video amplifiers taken from commercial TV receivers.

SINGLE-STAGE, DIRECT-COUPLED AMPLIFIERS

One of the most common types of video amplifiers used in black-and-white TV receivers is shown in Fig. 28. It is a single-stage, direct-coupled video amplifier that supplies a positive-going composite signal to the cathode of the picture tube. The video detector supplies a negative-going signal to the grid of the video amplifier stage which uses a high mutual conductance tube. This type of amplifier tube has a very high gain and can build up the weak signal output of the video detector to a peak-to-peak amplitude of 100 volts or more.

The output of the video detector is developed across the diode load made up of L_2 and R_2. The signal is fed through L_3 and the parallel combination of L_4 and R_3 to the grid of the video amplifier tube. The 45.75 mc video i-f signal beats with the 41.25 mc sound i-f signal in the video detector to produce a 4.5 mc sound signal. This signal is also fed to the grid of the video amplifier.

Both the composite video signal and the 4.5 mc sound signal are amplified by the video amplifier. The parallel combination of L_5 and C_4 in the plate circuit of the video amplifier is a parallel-resonant circuit resonant at 4.5 mc. This parallel-resonant circuit is a very high impedance at 4.5 mc. It is in series with the contrast control, R_6, and R_7, but almost all the 4.5 mc signal voltage will be dropped across the resonant circuit; very little of it will be across R_6 and R_7. The 4.5 mc signal is coupled through C_2 to the 4.5 mc sound i-f amplifier.

At the same time the L_5-C_4 parallel combination is not resonant to the video frequencies and therefore does not appear as a high impedance to these frequencies. The composite video signal is fed to the sync circuits through an isolating network from the point shown, and from the contrast control to the cathode of the picture tube.

Notice there are two paths from the contrast control to the cathode of the picture tube. One path is through L_6 in parallel with R_8 and through C_6 to the picture tube. The ac component of the video signal will take this path. The dc component reaches the picture tube through R_9.

TWO-STAGE VIDEO AMPLIFIERS

You will find two-stage video amplifiers in many of the older monochrome TV receivers and in many color TV receivers. Here the picture phase goes through two 180° phase reversals. The video signal is fed to the grid of the picture tube in receivers of this type. Figs. 21 and 26 are examples of this type of video amplifier.

Another two-stage video amplifier is shown in Fig. 29. This is typical of the video amplifiers found in many color TV receivers. The sound is taken off before the video detector. The last video i-f transformer contains a 41.25 mc sound absorption trap to keep this signal at as low a level as possible. Any 4.5 mc sound that is developed in the video detector is trapped by the 4.5 mc trap consisting of L_3 and C_3.

The diode load is L_1, R_2 and L_2. The ac component of the video signal developed across R_2 and L_2 is fed through L_3, through L_4 and R_4 and through C_4 to the grid of V_1. V_1 is a cathode follower; the signal taken from the cathode of the tube will have the same picture phase as the signal on the grid and will be somewhat reduced in amplitude. The signal is fed through R_8 and the delay line, through C_7 to the grid of V_2.
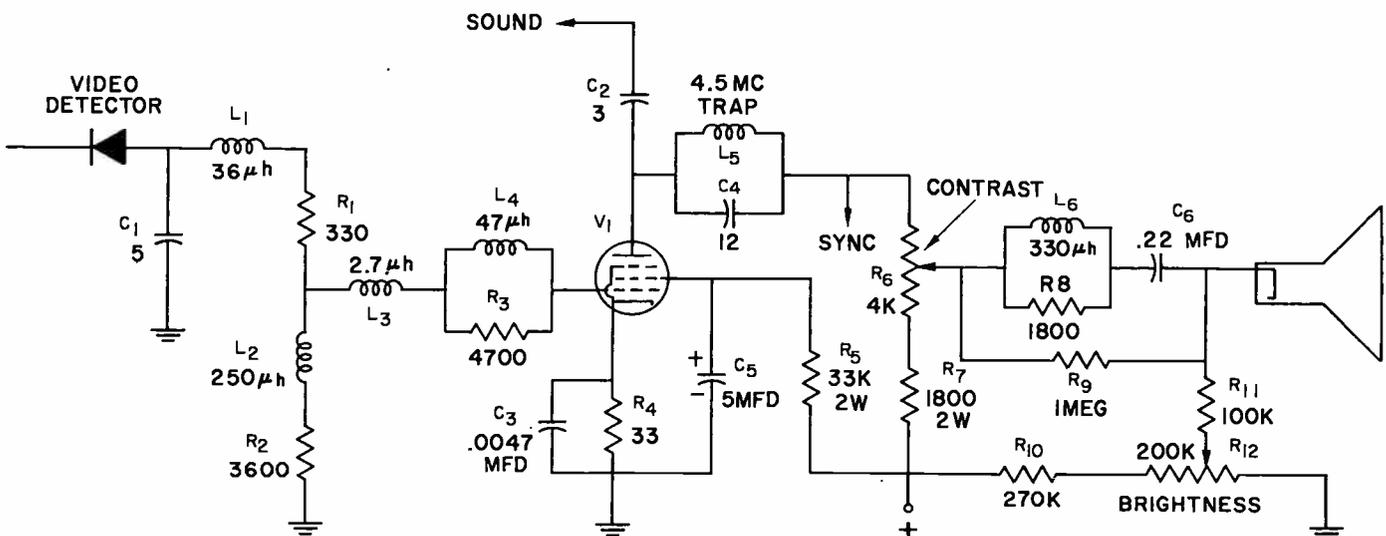
Fig. 28. A typical single-stage, high-gain video amplifier.
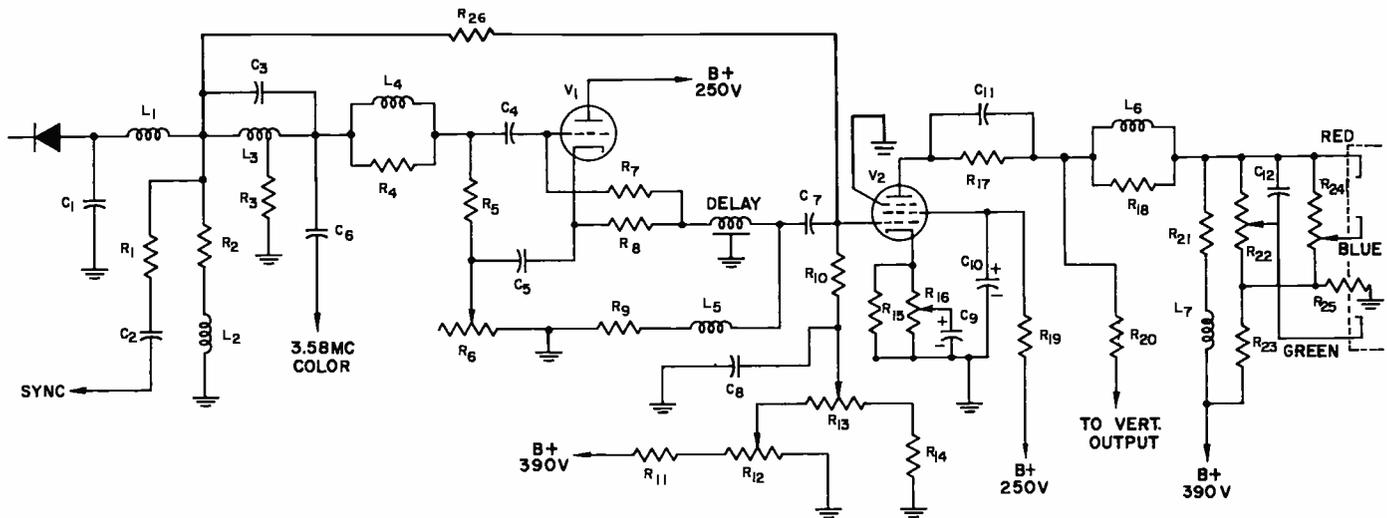
Fig. 29. A two-stage video amplifier from a color TV receiver.

The dc component of the video signal is fed directly from across the diode detector load through R_{26} to the grid of V_2.

V_2 is a high mutual-conductance tube so there is considerable gain in the stage despite a comparatively low value of plate load. The signal developed across the load consisting of R_{21} and L_7 is normally fed directly to the cathode of the red gun of the picture tube. The amplitude of the signals fed to the cathodes of the blue and green guns is usually somewhat less than that fed to the cathode of the red gun and can be controlled by R_{24} and R_{22} respectively. The higher amplitude signal is fed to the red gun, because the red phosphor on the picture tube is usually less sensitive than the blue and green phosphors. However, sometimes when installing a replacement tube, you may find that either the blue or the green phosphor is less efficient than the red phosphor and you cannot get a satisfactory black-and-white picture during the set-up procedure. In this case you'll have to change the connections to the cathodes of the tri-color tube to connect the less efficient phosphor to the connection originally set up for the red gun.

Most sets have provisions for changing the cathode connections by means of slip connectors. The direct connection is usually marked R and the other two B and G. If the black-and-white picture appears yellow, connect the blue gun cathode to the direct connection. If the picture appears magenta, connect the green gun cathode to the direct connection. The other two cathode leads should be connected to the remaining terminals.

Fig. 29 shows where the 3.58 mc color signal is taken off through C_6. The 3.58 mc color signal is fed from C_6 to the color amplifier stages. Notice the connection to the vertical sweep output through R_{20}. This is to provide a positive pulse from the vertical output tube which is fed to the cathodes of the picture tube during vertical retrace to give vertical retrace blanking.

In this video amplifier the brightness is controlled by means of the two potentiometers R_{12} and R_{13}. R_{12} is called a brightness-range control. It is an adjustment located on the rear of the chassis and is set so the brightness control R_{13}, which is located on the front of the set, can be used to control the brightness of the picture. The brightness is controlled by varying the positive voltage on the grid of the second video amplifier, V_2. This causes the plate current flowing through the tube to change and hence the voltage drop across the load resistor will change. This will change the voltage applied to the cathodes of the tri-color picture tube.

The contrast is controlled by means of the potentiometer R_{16} located in the cathode circuit of the tube. The adjustment of this control adjusts the amount of degeneration in the cathode circuit by either placing C_9 across the entire cathode resistor so that there is no degeneration or completely removing it from the circuit so that the entire cathode resistance is unbypassed, in which case there will be maximum degeneration in the cathode circuit.

Notice also the potentiometer R_6 that can be found in the cathode circuit of V_1, the first video amplifier. This is called a video peaking control, and can be used to get maximum high-frequency response from the video amplifier. With the control set for maximum high-frequency response you'll get the sharpest possible picture. With the control in the other extreme the high-frequency detail is reduced and there may be some smear introduced in the picture. Normally the control is set for best high-frequency response, but on occasion when viewing old motion pictures, for example, where there is considerable noise in the picture it may be advantageous to alter the setting of this control to reduce the high-frequency response to some extent to cut down on the snow in the picture produced by the surface noise.

You might wonder why the manufacturer used a cathode follower for the first video amplifier stage
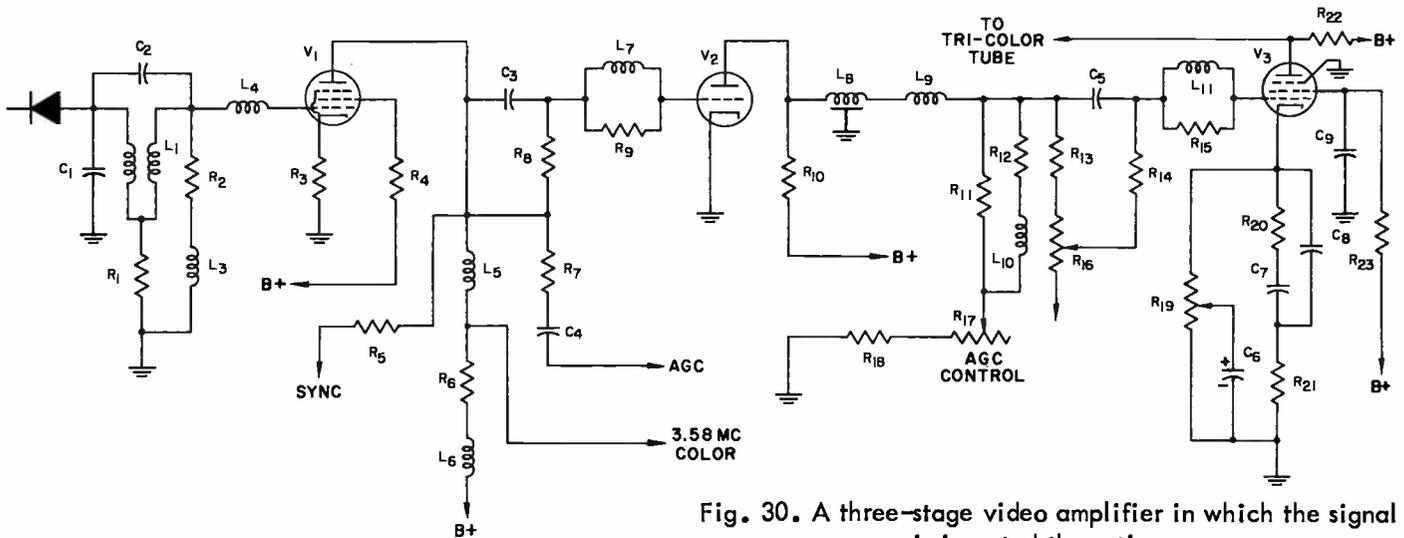
Fig. 30. A three-stage video amplifier in which the signal is inverted three times.

since this stage does not provide any gain. The reason lies in the problem of matching the amplifier to the delay line. The delay line is a low-impedance device and by means of a cathode follower we can prevent the delay line from loading the video detector. The input impedance of the cathode follower is high, so it does not load the detector. The output impedance is low, so it readily matches the low impedance of the delay line.

THREE-STAGE VIDEO AMPLIFIERS

A three-stage video amplifier in which the picture phase is inverted is shown in Fig. 30. The circuit is straightforward and you should have no difficulty tracing the various signals through it.

The output from the video detector is fed through the 4.5 mc sound trap consisting of L_1, L_2 and C_2 to the grid of V_1 through L_4. The signal is amplified by V_1 and the picture phase inverted for the first time. The video signal developed across the plate load consisting of L_5, R_6 and L_6 is fed through the parallel combination C_3 and R_8 and through L_7 and R_9 to the grid of V_2. Meanwhile the sync signal is fed from the plate of V_1 through R_5 to the sync separator and the 3.58-mc color signal is fed from the junction of L_5 and R_6 to the 3.58 mc color amplifier.

The video signal reaching the grid of V_2 is amplified and inverted by this stage and then fed from the plate of the tube through the delay line L_8, through L_9, C_5, L_{11} and R_{15} to the grid of V_3. The signal is amplified and inverted by V_3 and the signal developed
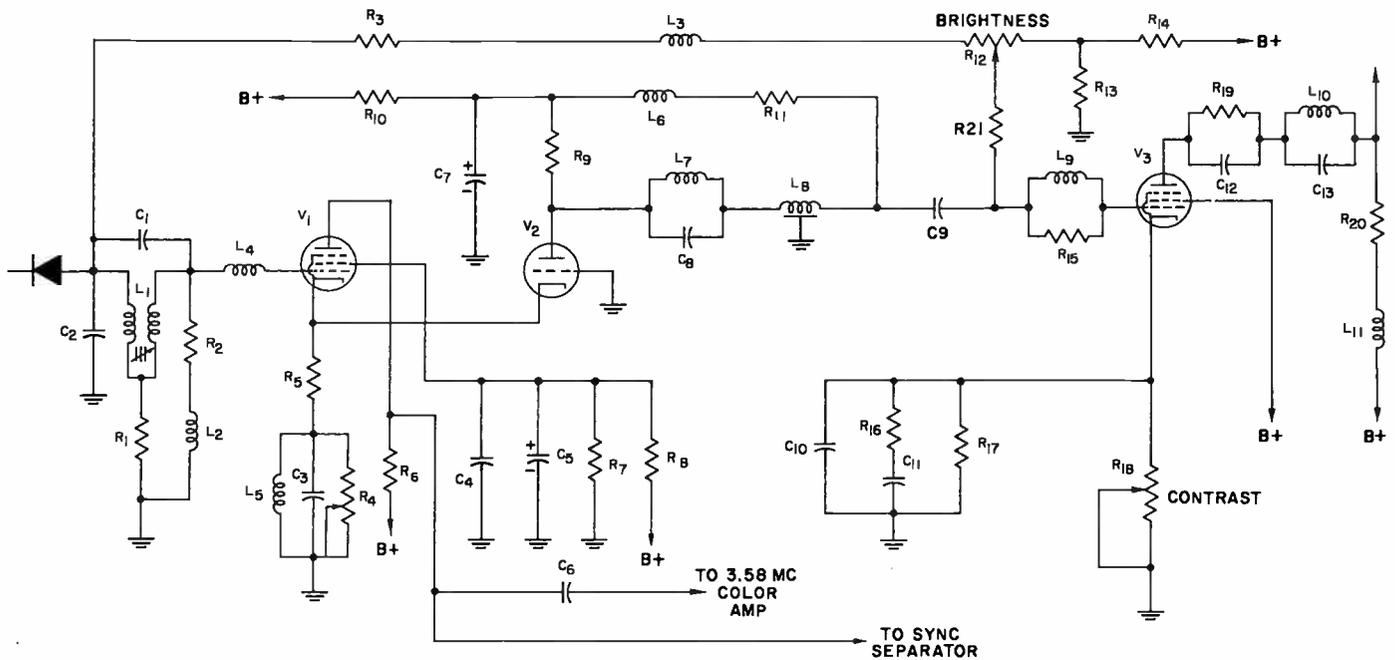
Fig. 31. A three-stage video amplifier that uses a cathode follower and a grounded-grid amplifier.

Fig. 32. A two-stage capacity-coupled video amplifier.
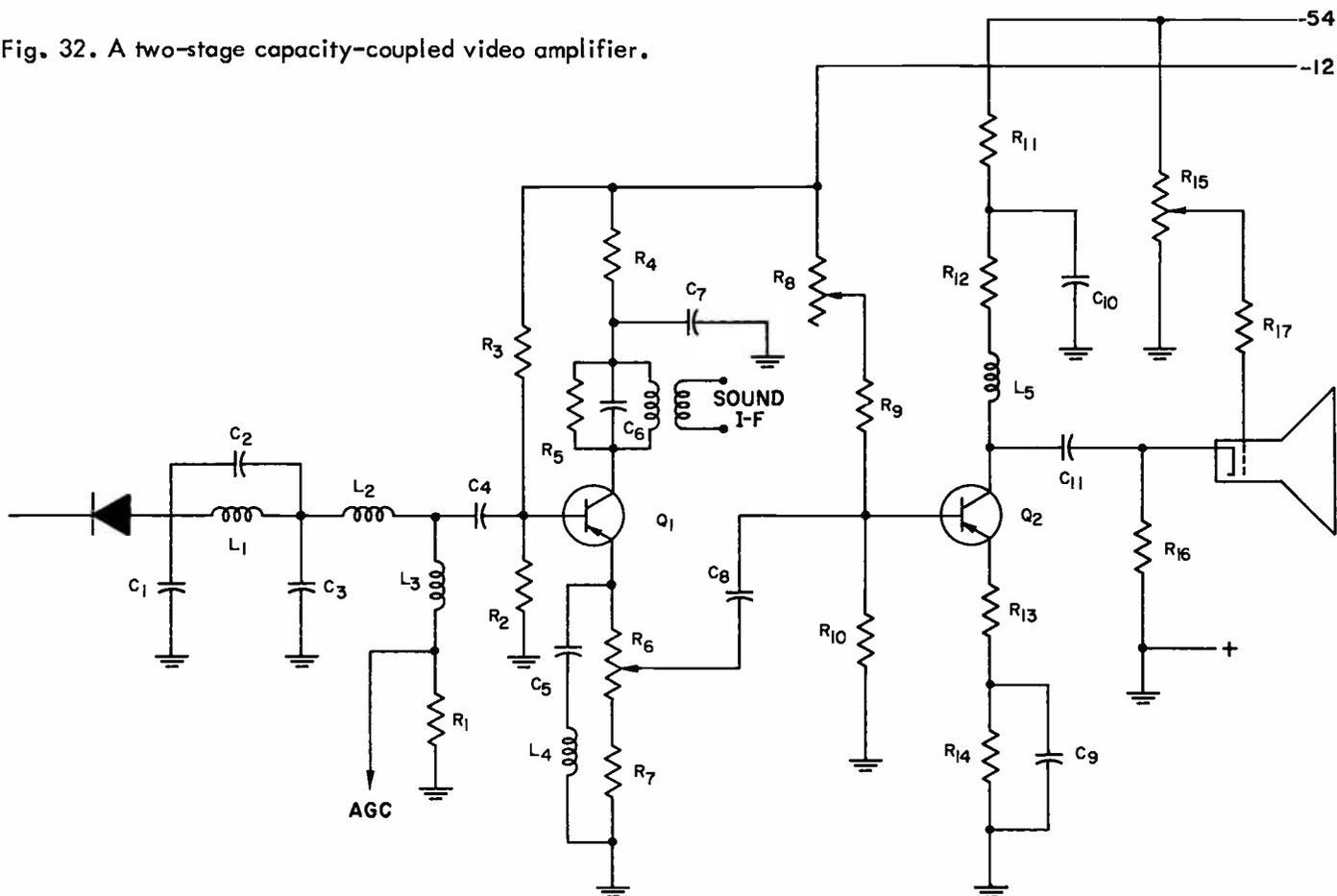
in the plate circuit fed to the cathodes of the tri-color tube through a circuit similar to the one described in Fig. 29.

Another three-stage video amplifier is shown in Fig. 31. This amplifier is quite different from the one shown in Fig. 30. In this amplifier, the picture phase is inverted in only one stage; in the other two stages we have the same picture phase in the output as in the input. Let's examine the circuit in detail.

The output from the video detector is fed through the 4.5 mc trap L_1, and through L_4 to the grid of the first video amplifier, V_1. In this stage we have a load in both the plate circuit and in the cathode circuit. The 3.58 mc color subcarrier is taken from the plate circuit and fed through C_6 to the 3.58 mc color i-f amplifier. At the same time an amplified and inverted video signal is taken from the plate circuit and fed to the sync separator where the sync pulses will be separated from the video signal.

Meanwhile, a composite video signal is also developed in the cathode circuit across R_5 and the parallel combination of L_5, C_3 and R_4. As far as this signal is concerned, V_1 is a cathode follower. The signal developed in the cathode circuit will be smaller than the input signal, but the same phase as the input signal.

The signal from the cathode of V_1 is fed to the cathode of V_2. Notice that the grid of this tube is grounded; this stage is a grounded-grid amplifier. The amplified signal developed in the plate circuit will be in phase with the input signal applied to the cathode. So

far this signal has passed through two stages without phase inversion.

The signal from the plate of V_2 is fed through the parallel combination of L_7 and C_8, through the delay line, L_8, through C_9 and then the parallel combination of L_9 and R_{15} to the grid of V_3. Meanwhile the dc component of the video signal reaches the grid of V_3 from the detector through R_3, L_3, R_{12} and R_{21}. In this stage the signal is amplified and its phase inverted and then fed through the parallel combinations of R_{19}, C_{12} and L_{10}, C_{13} to the cathodes of the tri-color tube. There are provisions for varying the signals fed to the various cathodes similar to those in Fig. 29.

This circuit is interesting inasmuch as it used three tubes in the three possible amplifier configurations; grounded plate (cathode follower), V_1; grounded grid, V_2; grounded cathode, V_3.

TRANSISTOR VIDEO AMPLIFIERS

The problems encountered with transistor video amplifiers are basically the same as those found in tube amplifiers.

When we discussed R-C coupling networks earlier in this lesson, we pointed out that when the reactance of the capacity equalled the resistance of the resistor, there would be a 3 db loss in the coupling network. In a tube amplifier, we can use a large value of grid resistor in most cases, and by doing so keep the value of the coupling capacitor needed for good low frequency

response to a reasonable value. However, unlike the tube amplifier which has a high input impedance, the transistor amplifier has a low input resistance. Therefore in an R-C coupling network, the resistor is in parallel with the low input resistance of the transistor. This means that if we are to avoid excessive losses at low frequencies, we must use a large value of coupling capacitor.

A two-stage monochrome video amplifier is shown in Fig. 32. The circuit is not too different from those used in tube amplifiers. We have a signal with a positive picture phase developed across the video detector load which consists of L_3 and R_1. With a positive picture phase, the bright elements of the picture swing in a positive direction and the sync pulses swing negative. Coupling from the detector load to the base of Q_1 is through C_4, which is a 20 mfd capacitor. The first video amplifier Q_1 acts as a common emitter to the 4.5 mc sound signal and the amplified sound is taken off by means of the sound i-f transformer in the collector circuit. At the same time Q_1 acts as a common collector amplifier to the composite video signal. The signal is taken from the contrast control R_6 in the emitter circuit of Q_1 and fed through C_8, a 10 mfd capacitor, to the base of Q_2. Since Q_1 is used in a common-collector circuit for the video signal, there will be no phase reversal in the stage so the signal at the base of Q_2 will have a positive picture phase.

The signal applied between the base and emitter of Q_2 is amplified by the stage and the picture phase is inverted (Q_2 is used in a common-emitter circuit.) The signal with a negative picture phase (positive-going sync pulses) is fed to the cathode of the picture tube through C_{11}. The picture brightness is controlled by varying the negative voltage applied to the grid of the picture tube.

It is interesting to note that while coupling capacitors C_4 and C_8 must be large because of the comparatively low input resistance of the transistors, C_{11} need not be nearly so large, because in the R-C coupled circuit made up of C_{11} and R_{16}, R_{16} governs the resistance in the circuit and not the input resistance of the tube.

At the same time, notice the shunt-peaking coil L_5 is in the collector circuit of the output transistor Q_2. We pointed out previously that the shunt-peaking coil did not do much good in transistor video amplifiers, because of the low input resistance of the following stage. However, this applied to a situation where the following stage was another transistor amplifier. Here the signal is fed to a vacuum tube, the picture tube, which has a high input resistance. Therefore, a higher value of load resistor can be used, and the shunt-peaking coil will be effective at high frequencies in keeping the collector load at a reasonably high value.

Also notice the low-frequency compensating network consisting of R_{11} and C_{10}. Again, this type of network is particularly effective in the output video amplifier stage where the stage following the last transistor amplifier is the picture tube.

This arrangement of Q_1 in a common-collector circuit and Q_2 in a common-emitter circuit is an ideal arrangement for video amplification. The common-collector circuit has the highest input resistance of all transistor circuits and therefore presents little or no loading on the detector circuit. At the same time, its low output resistance is ideally suited to drive Q_2. Q_2 on the other hand has a low input resistance, hence is easily driven by Q_1 and at the same time has a reasonable output resistance and so is able to drive the picture tube.

Another two-stage video amplifier used in a black-and-white TV is shown in Fig. 33. Notice that this

Fig. 33. A two-stage video amplifier using NPN transistors.

amplifier uses NPN transistors whereas the one shown in Fig. 32 uses PNP transistors. Also notice that the diode detector polarity is reversed so that the signal developed across the diode load resistor R_1 has a negative picture phase. R_2 and R_3 are part of the bias network. R_2 is bypassed by C_3 so the lower end of R_1 is at signal ground potential.

The first transistor Q_1 is connected in a common-collector circuit. As mentioned before this type of circuit has a reasonably high input resistance and a low output resistance. The sound signal is taken off through T_1. The sync and agc signals are taken from the emitter of Q_1.

The composite video signal from the emitter of Q_1 is fed through C_6 to the base of Q_2. Since the common-collector circuit does not invert the picture phase, the signal will have a negative picture phase at the base of Q_2.

Q_2 is used in a common-emitter circuit. This stage will amplify the signal and invert it so that we will have a positive picture phase at the collector. The signal from the collector is fed through L_3 and C_9 to the grid of the picture tube. With the positive picture phase, the bright picture elements drive the grid in a positive direction and the sync pulses drive it in a negative direction.

The collector of Q_2 is fed through R_7 by a supply voltage of about 90 volts, whereas Q_1 is fed by a supply voltage of only 12 volts. The higher voltage is needed for Q_2 because we must develop a signal voltage of approximately 70 volts peak-to-peak to drive the picture tube. We could not do this with only 12 volts on the collector. Since we need such a high signal voltage to drive the picture tube, you'll find fairly high-voltage transistors used in the video output stage.

THREE-STAGE COLOR VIDEO AMPLIFIER

Perhaps the most interesting and usual video amplifier is the one shown in Fig. 34. This is a three-stage video amplifier from a color TV receiver. Notice that two of the transistors used in the circuit are NPN transistors while the third is a PNP transistor. Let's go through the circuit in detail.

The secondary winding of the transformer T_1 is shown; this is the secondary winding of the output video i-f transformer. The transformer secondary feeds to the video detector D_1 and also to a trap made up of L_1 and C_2. This trap is tuned to 41.25 mc to keep the sound signal out of the video detector.

The signal developed by the video detector will contain a certain amount of 4.5 mc signal because in spite of the trap made up of L_1 and C_2 some of the sound signal will get through to the detector. The 4.5 mc signal is further trapped by the parallel-resonant circuit consisting of L_4 and C_5 which is tuned to 4.5 mc. The video signal is fed through R_5 to the base of Q_1. The manufacturer calls this stage the video detector output amplifier. Actually, the transistor is connected in the common collector circuit which is also called an emitter follower. You will remember that the characteristic of this type of circuit is a high input impedance so the transistor does not load the detector. At the same time, the transistor has a low output imped-

Fig. 34. A three-stage transistor video amplifier from a color TV receiver.

ance so it is ideally suited to drive the following transistor Q_2. The manufacturer calls this the first video amplifier. Actually, it is the second transistor in the video amplifier circuit, but is the first one that will contribute voltage gain insofar as the signal is concerned because the emitter-follower circuit has an output less than the input.

The video signal is amplified by Q_2 which is connected in the common-emitter circuit and then fed through L_5, the delay line L_6 and then the peaking coils L_7 and L_8 to the base of Q_3, which is referred to as the second video amplifier.

Notice that Q_3 is connected as an emitter follower and that the signal is taken from across the contrast control R_{19} and fed to a line called the black-and-white video line. This is the terminology used on the schematic diagram by the manufacturer. In the color TV receivers we have described previously the signal at the output of the video amplifier has been fed to the three cathodes of the tri-color tube. However, in this particular receiver, the amplified brightness signal is fed to the three color demodulators. The brightness signal swings the demodulators so that the signal at the output of each of the color demodulators is a signal produced as a result of the color signal fed to the demodulator and also the brightness signal. When the receiver is receiving a black-and-white transmission, there is no color signal fed to the demodulators and the brightness signal simply goes through the demodulators and through the color amplifiers to the cathode of the picture and produces a black-and-white picture. In later lessons we'll study the color circuit used in this receiver and then you will see how the video signal is fed through the color detectors and color amplifiers.

For the present all you have to remember is that the black-and-white or brightness signal is not fed to the cathode of the tri-color tube as in the other video amplifiers we have described.

Also notice that there is a noise take-off circuit at the junction of R_{11} and R_{12}. The signal taken off at this point is fed to the sync and agc circuits to prevent noise impulses from producing a signal that might cause instability in the sync circuits. Also notice that the sync and agc signals are taken off directly from the emitter of the second video amplifier Q_3.

SELF-TEST QUESTIONS

(z) What is the polarity of the sync pulses fed to the grid of V_1 in Fig. 28?

(aa) What is the purpose of L_5 and C_4 in Fig. 28?

(ab) In the video amplifier shown in Fig. 29, what is the picture phase at the input to V_1 and at the picture tube?

(ac) What is the approximate gain of V_1 in Fig. 29?

(ad) In the circuit shown in Fig 29, which gun receives the maximum drive?

(ae) How many times is the picture phase inverted in the amplifier shown in Fig. 30?

(af) What type of circuit is used in each stage of the amplifier shown in Fig. 31?

(ag) In which stages is the video signal amplified in the amplifier shown in Fig. 31?

(ah) What is the picture phase at the input of Q_2 in Fig. 32?

(ai) What is the advantage of using an emitter follower after the video detector such as in the circuit shown in Fig. 34?

Answers to Self-Test Questions

(a) High Gm -- 20,000 or more micromhos.

(b) To prevent the varying signal current which flows through the resistor from developing a voltage which would oppose the input signal voltage fed to the base and reduce the gain of the stage.

(c) The ratio of the output voltage to the input voltage.

(d) Couples the signal from the output of one stage to the input of the next, and keeps the dc voltage on the first stage from upsetting the bias on the following stage.

(e) The fine detail in the picture will be missing.

(f) Large objects will be smeared and the picture may roll vertically.

(g) Attenuation of the signal and phase shift.

(h) By using as large a grid resistor as practical in the following stage and by using a large value coupling capacitor.

(i) Shunt capacities, usually the tube or transistor capacities and distributed wiring capacities.

(j) Using a low value of load resistor.

(k) Series-shunt peaking.

(l) To lower the Q of the coil and prevent any sharp peaks in the response of the video amplifier.

(m) 6 seconds. 2 mfd × 3 megs = 6 seconds.

(n) Long time constant. To prevent the capacitor from charging and losing low frequency signals.

(o) To compensate for a delay introduced in the color amplifiers due to the fact that the bandpass of the color amplifiers is less than that of the video amplifiers.

(p) Positive -- the bright picture elements must drive the grid in a positive direction; the sync pulses will drive it in a negative direction.

(q) Positive-going. This means the sync pulses, which represent maximum signal amplitude, will drive the cathode in a positive direction. The bright elements in the picture will drive the cathode in a negative direction.

(r) The voltage between the grid and cathode of the picture tube. If the negative voltage on the grid, or the positive voltage on the cathode is increased, the brightness will be reduced. If the grid is made less negative or the cathode less positive, the brightness will increase.

(s) To control the amplitude of the video signal fed to the picture tube.

(t) The sync pulses and blanking levels no longer line up because the signal becomes an ac signal whose amplitude varies with the average brightness level, instead of a pulsating dc signal with the sync tips and blanking pulses all of equal amplitude.

(u) The use of dc coupling in the amplifier.

(v) Poor low-frequency response is usually due to voltage division between the coupling capacitor and resistor in R-C coupled amplifiers. This becomes a problem at low frequencies where the reactance of the capacitor becomes appreciable. In direct coupling either the coupling capacitors are removed completely or a dc path is provided around them so this problem is eliminated.

(w) A defect in one circuit may upset the operating voltages throughout the entire amplifier so it is sometimes difficult to pinpoint the circuit in which the defect actually exists.

(x) No. In a cathode follower the input signal is applied between grid and ground and the output taken from the cathode. The entire cathode signal subtracts from the input signal; there is 100% degeneration and the output is always less than the input. In Fig. 27, the output is taken across R125 and L113 in the cathode circuit. However, the input signal is applied between the grid and the cathode through R124. The output signal does not subtract from the input signal; the circuit is not degenerative. With loads in the cathode circuit and the plate circuit, this amplifier is known as a split load amplifier.

(y) Restoring the dc component of the video signal which had been lost in R-C coupled stages.

(z) The sync pulses will be negative-going. The polarity will be reversed by V_1 and positive-going sync pulses will be fed to the cathode of the picture tube.

(aa) They are a sound trap. The parallel circuit is resonant at 4.5 mc. This keeps the 4.5 mc signal from the picture tube because the parallel resonant circuit is a high impedance at 4.5 mc.

(ab) The picture phase is positive at the input of V_1 and negative at the picture tube. The diode detector is connected so that the sync pulses developed across the diode load resistor will have a negative polarity. This means they will point in a negative direction and be the most negative part of the video signal. Therefore the brightest parts of the video signal will be the least negative or the most positive part of the video signal. Thus the video signal has a positive picture polarity at the input of V_1. Since V_1 is a cathode follower it does not invert the signal phase and therefore the signal fed to V_2 also has a positive picture polarity. The signal polarity is inverted by V_2 so that we have a negative picture polarity fed to the cathode of the tri-gun tube. This means that the brightest parts of the picture will be the most negative part of the video signal and the sync pulses will point in a positive direction. This is the type of video signal we need if we are to feed it to the cathode of the picture tube.

(ac) Something less than one. V_1 is a cathode follower so the output will be less than the input.

(ad) The red gun to compensate for the usually lower efficiency of the red phosphor in the tri-color tube.

(ae) Three times.

(af) V_1 – cathode follower; V_2 – grounded-grid amplifier; V_3 – grounded-cathode amplifier.

(ag) V_2 and V_3.

(ah) Positive picture phase. The picture phase at the diode detector is positive. Q_1 is used in a common-collector circuit which does not invert the picture phase; therefore the picture phase at the output of Q_1 and the input to Q_2 must be positive. Q_2 inverts the picture phase to provide the required negative picture phase for cathode drive.

(ai) One of the characteristics of the emitter-follower circuit is that it has the highest input resistance or impedance of any of the transistor circuits. Therefore this type of circuit will load the video detector the least. The emitter-follower circuit is used for this reason in the video amplifier shown in Fig. 34. It also has a low output impedance and therefore it is readily able to drive the following transistor. This is the second reason for using a circuit of this type after the video detector.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. What two capacitors in a resistance-coupled amplifier cause attenuation of the low frequency signals?

2. What capacity limits the high-frequency response of a resistance-coupled amplifier?

3. What disturbance does phase distortion cause in the picture?

4. How does high-frequency attenuation affect the picture?

5. What effect does reducing the value of the plate resistor of a vacuum-tube video amplifier have on the high-frequency response?

6. What information does the dc component of the video signal carry?

7. Why is a delay line used in the video amplifier of a color receiver?

8. How many times is the picture phase reversed in the video amplifier shown in Fig. 31?

9. What is the advantage of using a common-collector circuit in the first video stage in an amplifier such as in Fig. 32?

10. What is L_5 in Fig. 32 and why is it particularly effective in this circuit?

AT THE END OF THE RAINBOW

The only pot of gold you'll find at the end of the rainbow is the one which you put there yourself.

Now, when your best earning years are still ahead, is the time for you to fill that pot of gold. You're an NRI student -- you're carrying the ball down the field right now for a touchdown -- and everything favors you to make the goal you have in mind.

Will you falter now and be thrown for a loss, or will you keep right on going? Will you complete your training Course just as steadily as you started it, with no losses, no set-backs, preparing yourself for that rainbow trail to success -- or will you let minor successes now lure you from your planned path to a sound future?

There is no royal road to anything. Steady progress step by step will get you anywhere and bring you a success which endures. The only failure you need to fear now is failure to stick to the goal you know is best.

J. M. Smith

COLOR TELEVISION SERVICING

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SWEEP AND CONVERGENCE CIRCUITS
B510

TV SYNC AND AGC CIRCUITS
B511

SOUND SYSTEMS AND POWER SUPPLIES
B512

B510

TV SWEEP AND CONVERGENCE CIRCUITS

●

STUDY SCHEDULE

> For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

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TV SWEEP AND CONVERGENCE CIRCUITS

The sweep, or deflection, system of the television receiver generates the current waveforms that move the scanning beam across and down the fluorescent screen of the picture tube. In the case of a black-and-white tube, there is a single scanning beam to be swept across and down the face of the picture tube, but in a three-gun color tube there are three electron beams to be swept.

When no signal is being received, the sweep system forms a "raster" of almost 500 individual lines from top to bottom of the screen. The individual lines that form this raster glow with a uniform brightness. When a video signal is applied to the grid or cathode of a monochrome picture tube or to the three cathodes of a three-gun tube, it varies the number of electrons in the beam, and as the scanning beam is moved across each line by the sweep system, the brightness along the line changes.

Each variation in the applied signal represents a brightness change in the scene being picked up by the camera tube. This signal change causes brightness variations on the fluorescent screen in the particular section toward which the beam is directed at that instant.

When the color signal is processed and added to the brightness signal, either in the color picture tube or in a preceding circuit, the signal, along with the brightness signal, causes the number of electrons in the individual beams to vary. This not only produces changes in brightness, but also changes in color.

The sweep system in the television receiver must generate the series of lines that form the scanning raster. The process of synchronization, which will be discussed in detail in another lesson, locks in the sweep voltages so that the position of the scanning beam on the picture tube is in exactly the same position as the camera tube beam scanning the televised scene at the station. Thus, if the camera tube scanning beam is covering a particular spot at the top right side of the image, the scanning beam in the picture tube will also be directed to the equivalent spot at the top right part of the receiver picture tube.

In a receiver that uses a three-gun color tube, in addition to moving the electron beam across and down the face of the tube, provisions must be made to be sure that each electron beam approaches the face of the picture tube at the correct angle. You'll remember that the three-gun tube uses a shadow mask and color phosphors arranged in groups of three dots. If the electron beams from the three guns approach the face of the tube at the correct angle, the beam from the blue gun will go through a hole in the shadow mask and strike the center of a blue phosphor dot. At the same time, the beam from the green gun will go through the same hole in the shadow mask and strike the center of the green phosphor dot in the same group, and the beam from the red gun will go through the same hole and strike the center of the red phosphor dot in the same cluster.

When the three beams are adjusted in this way over the face of the tube, we say they are converged. The operation of adjusting the beams to do this is called convergence. The circuits are called convergence circuits. Provisions must be made in sets using three-gun color tubes to provide the best possible convergence over the face of the tube. The convergence adjustment of color TV receivers is probably the most time-consuming of all TV adjustments. If they are not made correctly, colored objects in at least part of the picture will be fringed by one of the other colors -- for example a red object may have a green border on one side of it. Also color outlining or fringing will result on black-and-white reception.

Besides studying sweep circuits such as those used
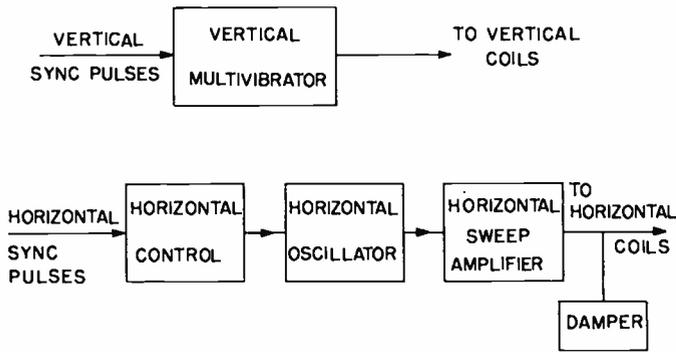
Fig. 1. Block diagram of a sweep system.

in both black-and-white receivers and in color receivers, you will study convergence circuits used for three-gun color tubes in this lesson. You will study the sweep circuits first, since the requirements are basically the same in both monochrome and color TV receivers.

A block diagram of a sweep system is shown in Fig. 1. The sweep system is responsible only for the motion of the scanning beam and the formation of a raster. The synchronization of the raster, so that the electron beam (or beams) in the picture tube is synchronized with the electron beam in the camera, is the responsibility of the sync circuit. The brightness variations and the color variations along the individual lines of the raster are caused by the video and color signals applied to the grid-cathode circuit of the picture tube. An understanding of this relationship is necessary in rapidly locating troubles in the television receiver.

SCANNING RASTER FORMATION

The formation of a scanning raster can best be understood by observing how a moving beam of electrons behaves under the influence of a magnetic field. If a beam of electrons is moving from a source behind this page and through the page towards you, there will be a magnetic field around each electron, as shown in Fig. 2A. A magnetic field is between the north and south poles of a magnet, as shown in Fig. 2B. If the beam of electrons is travelling through the field, the magnetic lines of force will bunch up on the top and spread out on the bottom. This bunching of the magnetic lines of force on the top of the electron will push the electron down. The amount the electron will be deflected will depend on the strength of the magnet and on the speed of the electrons in the electron beam. The stronger the magnet, the greater the deflection. The faster the electrons are moving, the more difficult it will be to deflect them.
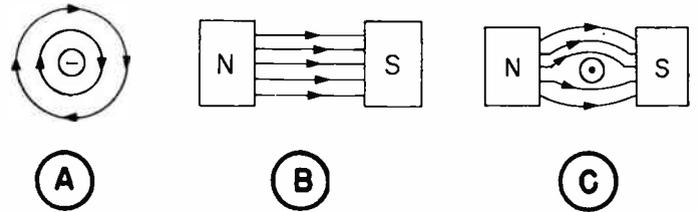
Fig. 2. (A), Magnetic field about electron moving out of page; (B), magnetic field between two poles of a magnet; (C), buildup of strong magnetic field on top of electron, weak field on bottom, with electron beam deflected down.

If instead of a permanent magnet, as shown in Fig. 2, an electromagnet is placed at the sides of the neck of the picture, the amount the electron beam will be deflected will depend on the strength of the magnetic field, which in turn will depend on the current through the coils of the magnet and the number of turns of wire on the coils.

To produce the scanning raster on the face of modern picture tubes, deflection yokes like those shown in Fig. 3 are used. The yoke shown at the left is for a modern short neck monochrome picture tube. The one at the right is for a rectangular three-gun color tube. The yoke is placed over the neck of the tube and pushed up against the bell of the tube as in Fig. 4.

The deflection yoke is made up two separate sets
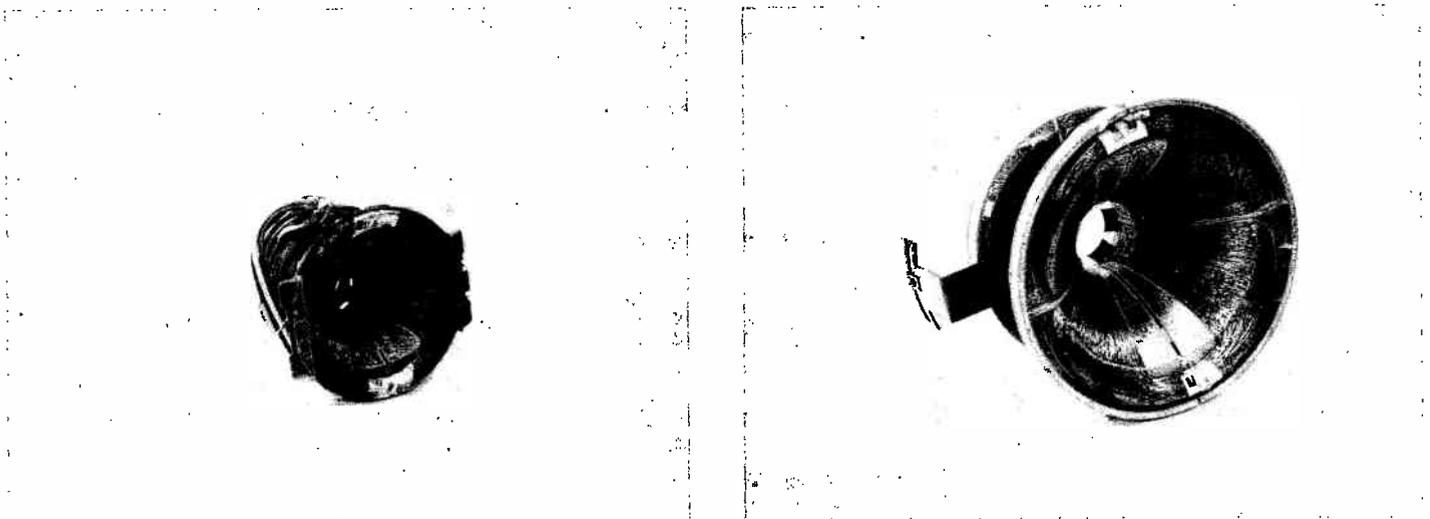
Fig. 3. Deflection yokes for modern picture tubes. At left, yoke for a monochrome tube; right, for a color tube.
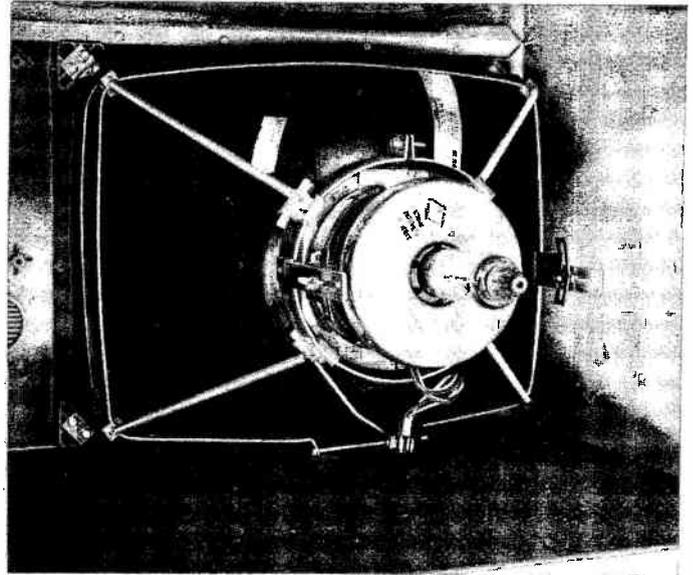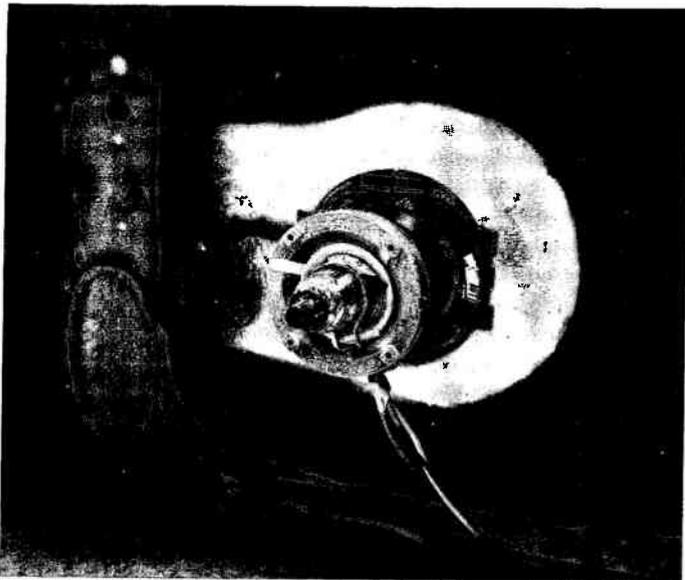
Fig. 4. The deflection yoke is placed over the neck of the tube and up against the bell, as in the monochrome tube on the left and the color tube on the right.

of coils which are positioned around the neck of the tube, as shown in Fig. 5. The two horizontal coils produce a horizontal field, which will cause the electron beam to move up or down depending on the direction the current flows through the coils. Since these coils produce vertical motion of the electron beam, they are called the vertical deflection coils. The coils above and below the neck of the tube will produce a vertical magnetic field which will cause the beam to move to the left or to the right, depending again on the direction the current flows through the coils. Since these coils cause horizontal movement of the electron beam, they are called the horizontal deflection coils.

To see how the electron beam can be deflected horizontally refer to Fig. 6. Here we have shown the horizontal deflection coils which are above and below the neck of the tube. If the electron beam, represented by the dot in the center of the diagram, is moving out of the paper towards you, there will be a magnetic field around the beam with the lines of force in a clockwise direction as shown. If the negative terminal of a voltage source is applied to terminal 1 and the positive terminal to terminal 2, the coils will be magnetized as shown in Fig. 6A.

This will cause the magnetic lines of force between the upper and lower coils to bunch on the right side of the electron beam. The stronger magnetic field on the right side will push the electron beam to the left. In the case of the electron beam in a picture tube, if the current is strong enough, the beam can be pushed far enough to the left so that it will strike the face of the picture tube on the left edge.

Now if the current through the deflection yoke is decreased linearly, the electron beam will move back towards the center at a linear rate, and when the cur-

Fig. 5. Diagram showing arrangement of deflection coils around neck of tube and field about electron beam if the direction of the beam is out of the paper towards you.
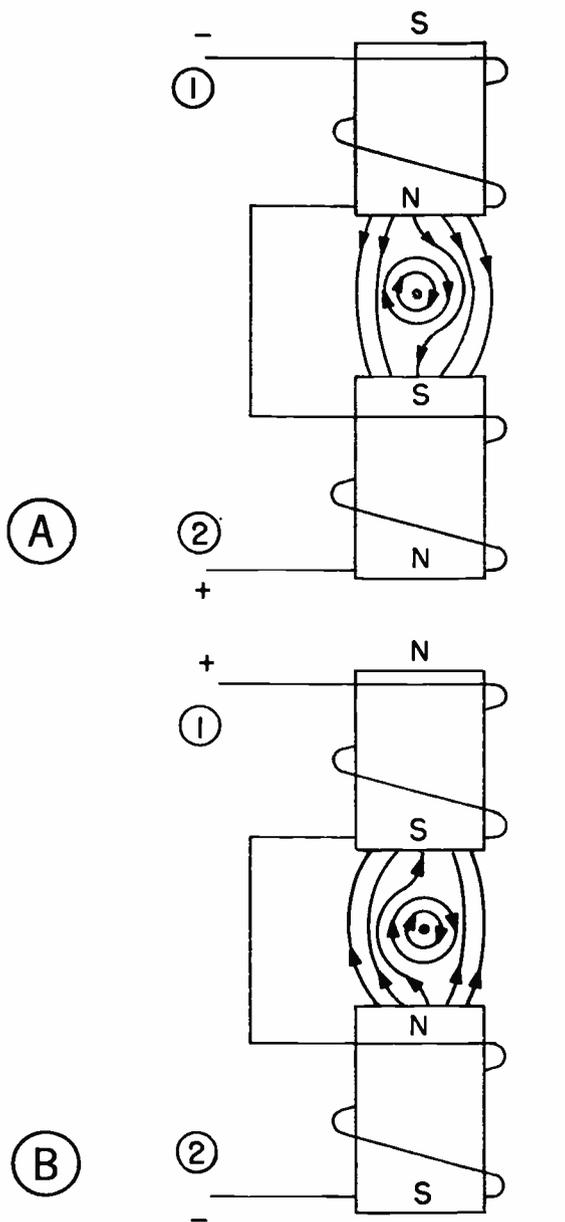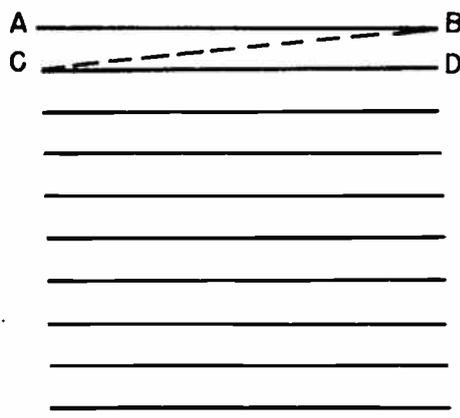
versed and the current built up at a linear rate in the opposite direction, the magnetic lines of force will build up on the left side of the electron beam, as shown in Fig. 6B. This will push the electron beam towards the right. If the current is made strong enough, the electron beam will be pushed far enough to the right so that it will strike the face of the picture tube at the right edge.

It would be possible to deflect the electron beam across the face of the tube by a fixed voltage source and a variable resistance. This would let us vary the current through the coils as we just described. Of course this would be too slow for use in TV. Sawtooth currents must be generated electronically to perform this fast sweeping of the electron beam across the face of the tube. The current waveform that must flow through the deflection coils is shown in Fig. 7.
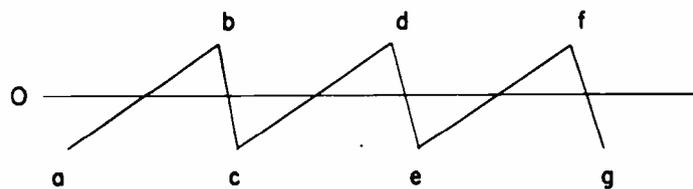
Fig. 7. Sawtooth current needed to produce scanning lines.

The portion from a to b moves the beam linearly across the face of the tube from left to right. The part from b to c is called the retrace. During this interval, the beam is moved rapidly from the right edge of the tube back to the left edge to start the next line of the picture. The waveform from c to d and e to f produces the next two lines and d to e and f to g the next two retrace periods. During the retrace periods, the electron beam is cut off to blank the face of the picture tube, so that only during the periods a to b, c to d and e to f does the beam strike the face of the picture tube.

So far we have been discussing horizontal movement of the electron beam across the face of the picture tube. If a sawtooth current is applied to the horizontal deflection coils to produce horizontal movement and at the same time a sawtooth current is applied to the vertical deflection coils, we will get both horizontal and vertical movement. If a sawtooth current having a

Fig. 6. Diagram showing bunching of magnetic lines, which produces horizontal deflection.

rent through the deflection coils reaches zero, the electron beam will strike the face of the picture tube in the center. If when the current reaches zero, the polarity of the voltage applied to the coils can be re-
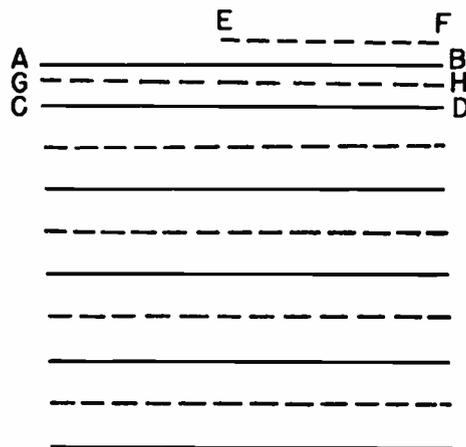
Fig. 8. Simplified diagram showing how scanning lines produce interlaced fields.

frequency of 15,750 cycles per second is applied to the horizontal coils and a sawtooth current having a frequency of 60 cycles is applied to the vertical coils, the horizontal coils will cause the beam to move across the face of the tube 262-1/2 times during each cycle of the vertical sawtooth.

This means that as the vertical coils move the electron beam from top to bottom and back to the top, the horizontal sawtooth will move the electron beam back and forth across the face of the tube 262-1/2 times. Due to the fact that the vertical coils are slowly moving the beam down the face of the tube, the horizontal coils will cause the electron beams to trace out a series of lines, one below the other, as shown in Fig. 8A.

Horizontal Sawtooth.

If both the vertical and horizontal cycles start at A, the horizontal sawtooth moves the beam from A to B. During this interval the vertical sawtooth will move the beam slightly down the face of the tube so that B is lower than A. The horizontal retrace then rapidly moves the beam across from B to C. C is below A, so the next line, C-D, is traced out slightly below line A-B. This action continues for almost one-sixtieth of a second. Shortly before one-sixtieth of a second, which will be the end of one vertical cycle, the vertical retrace starts. This moves the electron beam back to the top of the picture tube, level with point A.

During the period of one vertical cycle, while the vertical sweep has moved the electron beam from the top of the face of the picture tube slowly down the face of the tube to the bottom of the face of the picture tube and then the retrace has moved the electron beam rapidly back to the top of the face of the tube, one-sixtieth of a second will have elapsed. During this period, the horizontal sweep, which is operating at a frequency of 15,750 cycles per second will have traced out 262-1/2 lines. (15,750 ÷ 60 = 262-1/2.)

This means that when the electron beam is returned to the top of the face of the picture tube at the end of the first field, it will arrive at point E in Fig. 8B. Point E will be level with point A, so the beam will trace out a half line, E-F slightly above line A-B. Point F will be lower than point A, but higher than point C so when the electron beam is moved to the left edge of the picture tube to point G, line G-H, which falls between lines A-B and C-D, will be traced out. The dotted lines in Fig. 8B show how the lines of the second field are interlaced between those of the first field.

If there are 262-1/2 lines in each field, since the first line of the second field is only a half-line, the last line will be a full line, so the next field will start at point A again to produce another field like the first field shown in Fig. 8A.

Actually Fig. 8 is a simplification of what happens. Even though the vertical retrace returns the electron beam from the bottom to the top as rapidly as practical, the horizontal sweep is operating at a frequency that is so much higher than the frequency of the vertical that it actually takes several horizontal lines to move the beam from the bottom back to the top. The
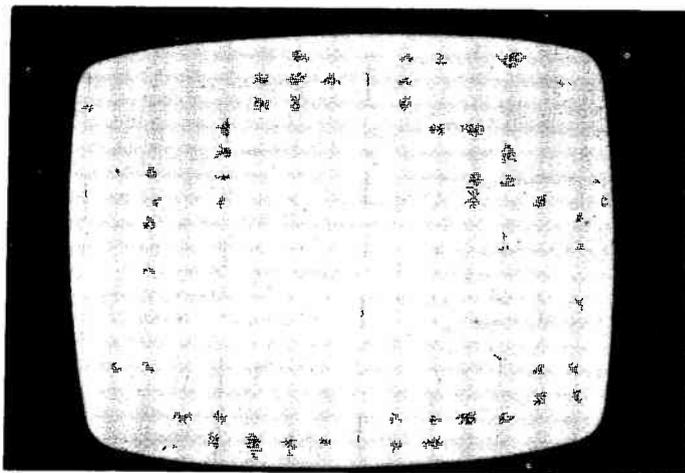
Fig. 9. Photo showing retrace lines.

number of horizontal lines traced out depends on the speed of the vertical retrace.

Because the vertical retrace may not be equal to an exact multiple of half lines, the odd and even fields may not start exactly at points A and E as shown. This is not important; the important thing is that they start exactly 262-1/2 lines apart in order to provide interlaced scanning. It is often possible to see these retrace lines on the face of many TV receivers if the brightness and contrast controls are not adjusted correctly.

Fig. 9 is a photo showing the retrace lines. This effect was very prevalent in older TV sets but is seldom seen in modern receivers. In modern TV receivers, a pulse is derived from the vertical sweep circuit during the vertical retrace period and fed to the grid cathode circuit of the picture tube to blank the tube during the vertical retrace period.

The horizontal sweep rate of 15,750 lines per second and the vertical sweep rate of 60 fields per second are the rates that were set up for monochrome television. In color television we actually use slightly different standards. However, they are so close to the monochrome standards that we usually refer to the monochrome line and field rates because they are easier to remember.

In color television, the number of horizontal lines transmitted per second is 15,734.264. With this number of horizontal lines per second, if we used a vertical field rate of 60 fields per second the picture would have somewhat less than 525 lines. Therefore the vertical field rate is altered to 59.94 fields per second in color TV.

Interference Pattern.

You might wonder why this change is made in horizontal and vertical field rates for color TV. The answer lies in the 920 kc interference pattern that may be produced in the video detector. You will remember that the difference between the video i-f and sound i-f signals is 4.5 mc. If both the video i-f and sound i-f signals beat together in the video detector a 4.5 mc signal will be produced. The color subcarrier when it is demodulated will have a frequency of 3.58 mc. If the 3.58 mc color subcarrier beats with the 4.5 mc signal, we'll have a 920 kc signal produced, and this will produce interference. Also, if the 41.25 mc sound

signal gets through the trap in the last i-f stage and reaches the video detector, it will beat directly with the 42.17 color i-f subcarrier and produce the 920 kc interference signal. It was discovered that if this 920 kc signal were made an odd harmonic of half the line scanning rate, the interference pattern became less objectionable. Therefore, to accomplish this, the horizontal sweep rate or line rate was changed to 15,734.264. Once the horizontal line rate is changed to this value, if we want to maintain 525 lines in a complete picture or 262.5 lines in each field then we have to slow down the vertical field rate slightly to accomplish this. This explains why the field rate is reduced to 59.94 fields per second.

When a TV station is broadcasting a color program it uses color line and field rates. However, if a station is broadcasting both color and monochrome programs, in almost every case the sweep generators are set up to produce the color line and field rates. Then when the station goes to monochrome broadcasting, it continues to broadcast using the color standards for line and field rates. Both black-and-white and color TV receivers are capable of synchronizing on either the monochrome or color line and field rates; when a station is transmitting a black-and-white program, it is impossible to tell from the reproduced picture whether the station is using the monochrome or color line and field rate.

You should keep in the back of your mind that the color line and field rates are slightly below the original monochrome standards. However, you don't have to remember the exact line or field rate. Remembering the monochrome standards which end in round numbers are close enough, and then simply remember that in a color broadcast there are a few less lines transmitted per second and a fraction of a field less than 60 fields per second.
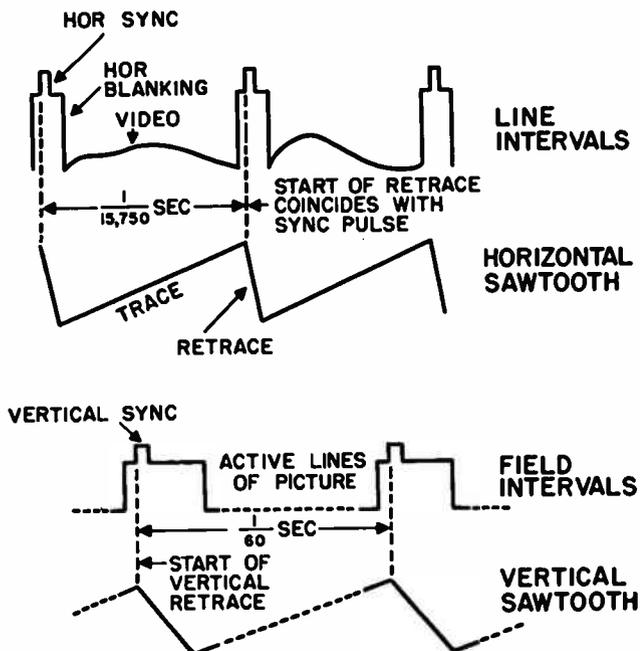
Fig. 10. Comparison of horizontal and vertical sawtooth pulses with respect to received pulses.

SYNCHRONIZATION

In the television receiver the video and blanking pulses are used at the grid circuit of the picture tube to modulate the intensity of the scanning beam. The synchronizing pulses are also used to synchronize the deflection system. The deflection sawtooth waves are generated continuously, whether the signal is being received or not. Consequently, when the television set is turned on, a scanning raster should always appear, indicating that the horizontal and vertical deflection systems (or sweep systems, as they are usually called) are operating.

The arrival of the horizontal and vertical synchronizing pulses at the input of the deflection system locks in the generation of the vertical and horizontal sawtooth components so that they operate in phase with, and at the same frequency as, the horizontal and vertical oscillators at the camera tube. The horizontal sync pulse occurs at the start of the horizontal retrace portion of the sawtooth wave, as shown in Fig. 10. In fact, the horizontal sync pulse is responsible for the start of the horizontal retrace period. Thus, the horizontal sawtooth has the same frequency as the arriving sync pulse and also has the proper phase relationship.

The vertical sync pulse coincides with the vertical retrace interval and is responsible for the proper cycling of the vertical deflection system. Note that the sync pulses ride on top of the blanking pulses. The vertical sync pulse shown in Fig. 10 is simplified to show how it is related to the start of the vertical retrace period. Remember that the pulse is serrated so we can continue transmitting horizontal sync pulses during the vertical sync interval. Also remember the vertical sync pulse is preceded and followed by six equalizing pulses.

The blanking pulse starts just ahead of the sync pulse, and continues on for a period of time after the sync pulse. The blanking pulse arrives at the grid of the picture tube and shuts off the scanning beam just before the start of the retrace period.

We generally speak of beam retrace in discussing the scanning process. However, if the receiver is working properly, the actual beam does not retrace, because the blanking pulse has biased the tube beyond cut-off so that there is no beam. What actually takes place is that the deflection magnetic fields are reshaped during the retrace times. As a result, when the beam is turned on once again, at the end of the blanking pulse, it will immediately be deflected to the proper position to start a new trace.

To understand the relationship between the deflection sawtooth waves and the arriving pulses, let us consider how the picture is reproduced on the picture tube. During the horizontal trace period, the scanning beam is moved from left to right across the screen. At the same time, the video signal is applied to the grid of the picture tube and modulates the scanning beam in accordance with the brightness variations along this single line of picture information.

The blanking pulse arrives just before the synchronizing pulse, and shuts off the scanning beam at the

right-hand side of the raster. Next, the horizontal sync pulse arrives, at which time the horizontal deflection field is reshaped to start the next horizontal line. Reshaping the deflection field involves changing the field from a maximum value of one polarity to a maximum value of the opposite polarity.

If the scanning beam were turned on, the reshaping of the field would cause it to return rapidly to the left side of the screen, and it would produce a visible line from right to left across the screen, and cause a deterioration in the quality of the picture.

The blanking pulse continues after the synchronizing pulse to allow sufficient time for complete reshaping of the deflection field. At the end of the horizontal blanking pulse, the scanning beam is turned on again, and starts its motion across (left to right) to form the next line.

The second horizontal line appears below the preceding one, because of the action of the much slower vertical sweep, which is slowly pulling the beam down the screen. The vertical sweep causes the beam to move from top to bottom of the screen at a 60-cycle rate so that approximately 250 visible horizontal lines are traced down the screen during the vertical trace period. Just before the arrival of the vertical sync pulse, a vertical blanking pulse arrives at the grid circuit of the picture tube and cuts off the scanning beam as it reaches the last line at the bottom of the raster.

During the vertical retrace period the vertical sync pulse arrives. During the vertical retrace interval, the vertical fields are reshaped so that, at the conclusion of the vertical blanking pulse, the scanning beam will start a new field beginning at the top of the raster. The vertical blanking period is approximately equal to the time required to transmit 20 lines, and there are two vertical retrace periods for each complete picture. Consequently, the actual reproduced television picture contains about 485 lines instead of 525.

The vertical blanking pulse continues after the vertical sync pulse to allow time for reshaping the vertical deflection field. At the conclusion of the vertical blanking pulse, the beam is turned on once again and appears at the top of the raster, ready to begin a new field. The equalizing pulses that appear before and after the vertical sync pulses insure precise timing

and stable interlace. They will be discussed in more detail in the lesson on synchronizing systems.

An understanding of what occurs in the deflection system, and the relationship between the generated sawtooth waves and the received pulses is very helpful in isolating receiver defects. For example, even if no signal is being received, it should still be possible to obtain a normal raster on the picture tube screen, because the sync pulses influence the timing of the deflection waveform only, and do not actually generate the deflection energy.

If the raster is normal, but it is not possible to lock it in with the sync pulses, you know there is a sync defect in the receiver. If the raster locks in normally, but the picture information does not appear or is very weak, there is some defect that prevents the arrival of the full amplitude video signal to the grid circuit of the picture tube. Knowing where each signal goes and what it is supposed to do is a great help in rapid isolation of receiver defects.

SELF-TEST QUESTIONS

(a) What is the name given to the (approximately) 500 lines traced across the face of the picture tube?

(b) How many electron beams must the deflection system of a three-gun color tube move?

(c) What do we call the circuits in a color set that adjust the electron beams to fall on the correct color phosphors?

(d) If an electron beam is moving out of the paper towards you, what is the direction of the magnetic field around the beam?

(e) If two magnets are placed on the sides of the neck of a picture tube to produce a horizontal field, which way will the electron beam be deflected, horizontally or vertically?

(f) What type of current wave must flow through the deflection coils in the yoke to produce a linear sweep?

(g) How many horizontal lines will be traced out during one cycle of the vertical oscillator?

(h) Should you see a scanning raster on the face of the picture tube in a TV receiver when the set is tuned to a channel on which there is no station operating?

Formation of a Sawtooth Wave

The sawtooth voltage is the basic deflection waveform. After shaping and amplification, the sawtooth voltages are used to excite the deflection output stages. These form the sawtooth current waves in the two pairs of deflection coils, to produce horizontal and vertical motion of the scanning beam.

A sawtooth voltage can be formed by using the simple arrangement shown in Fig. 11. The gradual rise of voltage across a capacitor charging through a resistor can be used to form the long side of a sawtooth trace. Thus, in the circuit shown, a capacitor, C, is between the plate and cathode of a special tube. This capacitor attempts to charge to the supply voltage (B+) through resistor R. The rate of charge decreases as the total charge increases, making the charging curve "fall off," forming an exponential curve as shown by the dotted lines in Fig. 11. If all of this curve were used, the scanning would not be linear. Therefore, only the lower portion, which is almost a straight line, is used.

The tube is of a special gas-filled type. The gas becomes ionized (becomes conductive) at a certain critical voltage. At this point it provides a low-resistance shunt through which the capacitor can discharge very rapidly, forming the retrace portion of the sawtooth. When the voltage drops sufficiently, the tube again becomes non-conductive, and another charging cycle is started. The time required for charging is controlled by the time constant of the resistor and capacitor combination. This is made long as compared to the period of the trace so that only the initial linear part need be used.

The sync pulse arriving at the grid of the tube supplies a trigger action. By suddenly increasing the voltage, it "trips" the tube, making it conductive at the proper scanning frequency.

The vertical trace is much longer than the horizontal trace, so the time constant required is also much longer. Fig. 11 shows typical values for using the circuit as a horizontal sawtooth generator and as a vertical sawtooth generator.
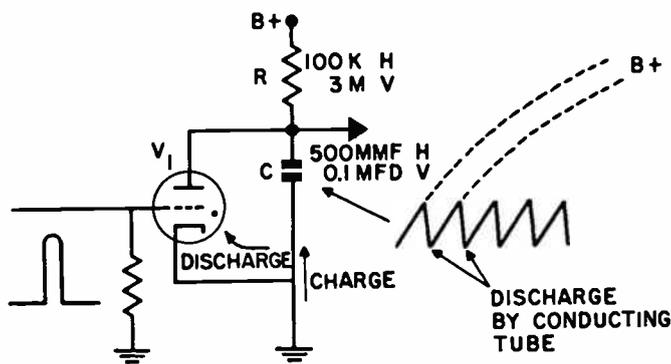
Fig. 11. A simple sawtooth generator.
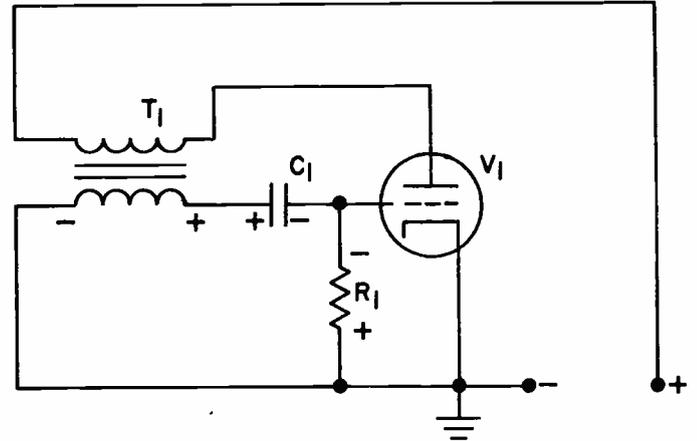
Fig. 12. A basic vacuum-tube blocking oscillator.

BLOCKING OSCILLATORS

Although the circuit shown in Fig. 11 represents one of the simplest methods of producing synchronized sawtooth voltages, there are other circuits that operate on similar principles that are more stable and more economical.

The basic sawtooth oscillators used in television are the blocking oscillator and the multivibrator. The more complex oscillators used in modern TV receivers are modifications of these two basic types. While the multivibrator has replaced the blocking oscillator almost completely in modern TV receivers that use vacuum tubes, there are many older tube-type sets in use that use blocking oscillators. In addition, many of the new all-transistor television receivers use blocking oscillators. Therefore it is important that you know how both the blocking oscillator and the multivibrator work. In this section of the lesson you will study both tube and transistor type blocking oscillators, and then later you will study the multivibrators.

A simplified diagram of the basic vacuum-tube blocking oscillator is shown in Fig. 12. The transformer T_1 is a special transformer designed for use in this type of circuit.

The operation of the blocking oscillator is relatively simple. When the tube V_1 heats and current begins to flow from the cathode of the tube to the plate of the tube, the current will start to build up through the tube and through the primary winding of T_1. The primary winding is the winding connected between the plate of the tube and B+. The changing current in the primary winding of T_1 will induce a voltage in the secondary winding having the polarity shown across the secondary winding. The positive potential at the grid of the secondary winding will be coupled to the grid of V_1 through the coupling capacitor C_1. The positive potential on the grid of the tube will cause the current flowing through the tube to increase substantially very rapidly.

This changing current through the primary winding
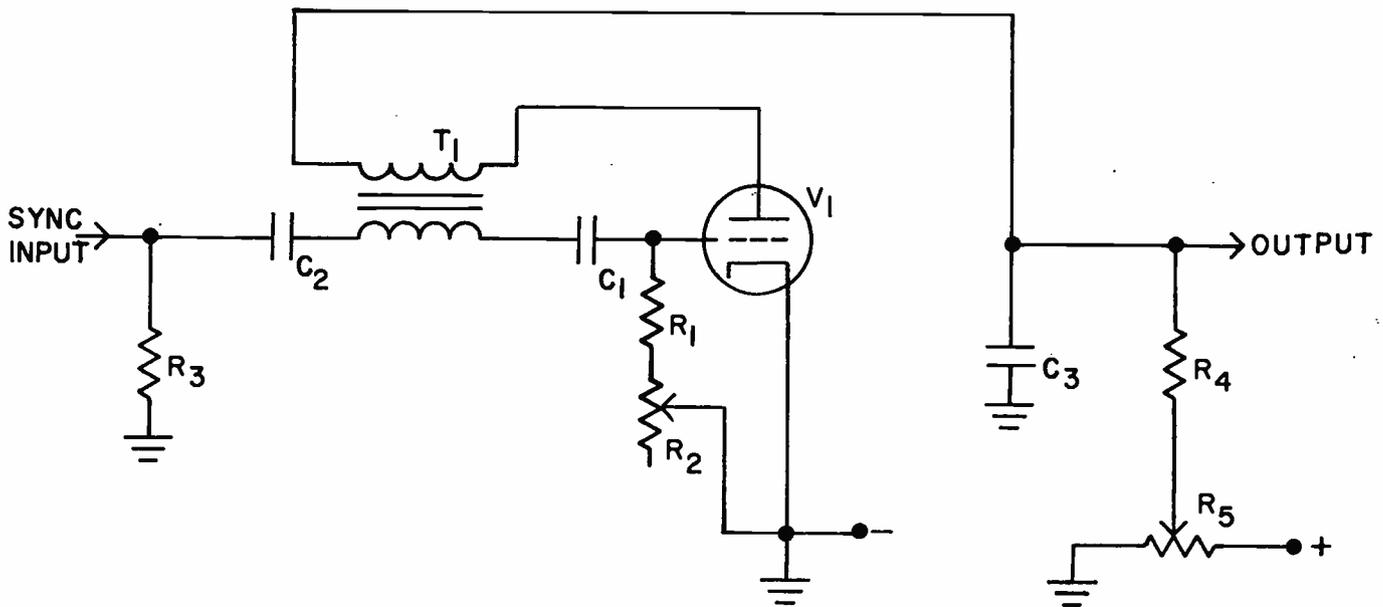
Fig. 13. Blocking oscillator modified for use as a vertical sweep oscillator.

of T_1 builds up the voltage across the secondary with the polarity shown to an even higher value. Eventually, the grid voltage reaches a value when any further increase in the positive potential applied to it will not cause a further increase in plate current. We say that the tube is saturated. Once this happens and the plate current remains the same, the current through the primary winding of T_1 will no longer be changing and there will no longer be a voltage induced in the secondary of T_1.

Drawing Grid Current.

Meanwhile, while the grid of the tube has been made positive by the voltage across the secondary of T_1, the grid will be drawing grid current. This will cause the capacitor C_1 to charge with the polarity shown on it. Once the voltage across the secondary of T_1 disappears because the current through the primary winding is no longer increasing, the voltage across the capacitor C_1 will be built up to a high enough value to cut off the flow of plate current instantly.

The capacitor C_1 then begins to discharge through the grid resistor R_1. The flow of plate current will be cut off as long as the voltage drop across R_1 is high enough to bias the tube beyond cutoff. Once the grid voltage drops below the cutoff value, current will start to flow through the tube from the cathode to the plate. A small change in current through the primary of T_1 will induce a voltage in the secondary having the polarity shown; this drives the grid in a positive direction, causing the plate current to build up to a very high value almost instantly. Thus the cycle repeats itself.

It is easy to see where the circuit gets its name; the tube is blocked by the high potential developed across the capacitor in the grid circuit. The tube is held at cutoff as long as it takes the capacitor to discharge through R_1 to a value low enough to permit the tube to start conducting again. Actually, in the blocking oscillator, plate current flows in relatively short bursts and the tube is cut off for the majority of the cycle.

As we mentioned, the blocking oscillator shown in Fig. 12 is a basic blocking-oscillator circuit. The modified form of the blocking oscillator shown in Fig. 13 is the type you will find in vertical-oscillator circuits of many television receivers. The operation of this circuit is essentially the same as the operation of the blocking oscillator shown in Fig. 12; however, there have been some refinements added.

Notice, for example, the potentiometer R_2 located in the grid circuit of the oscillator tube. The purpose of this potentiometer is to permit you to vary the time constant of the RC network in the grid circuit. This will enable you to vary the time the tube is cut off and hence control the frequency. Notice also the sync input circuit. Positive-going sync pulses are fed into this circuit. The purpose of these sync pulses is to drive the tube into conduction. If the RC time constant in the grid circuit is made long enough so that the time it takes it to discharge to the point where the tube would start conducting is slightly longer then the time between sync pulses, the tube will be held cut off until the sync pulse arrives. It will take a little longer for the capacitor C_1 to discharge to a low enough value to let the tube start to conduct. However, the positive pulse from the sync circuit arrives and drives the grid into the conduction region so that the tube will go through its cycle. Thus the frequency at which the oscillator operates is controlled by the sync pulses and not by the RC time constant in the grid circuit.

The network consisting of C_3, R_4 and R_5 is used in the plate circuit to develop a sawtooth voltage in the plate circuit. When the tube begins to conduct, the voltage across C_3 will drop almost instantly. It will not drop all the way to zero because there will be some voltage drop across the tube. When the tube stops conducting, the charge on C_3 will start to build up through R_4 and part of R_5. The voltage to which this charge is building will depend upon the setting of R_5. Thus R_5 acts as an amplitude control (which in television is called the height control).

Fig. 14. The exponential waveform at (A) is cut off to produce the sawtooth waveform shown at (B).

no sync pulse applied. Here the frequency of the oscillator is controlled primarily by the RC time constant in the grid circuit. Notice that when the voltage on the grid circuit reaches the conduction level the tube starts to conduct and the grid is driven positive for a brief instant while the tube passes a very high current. The curve shown in Fig. 15B illustrates the effect of the positive-going sync pulse. Notice that the sync pulse arrives slightly ahead of where the tube would reach the conduction level and the sync pulse triggers the grid voltage in the conduction region so that the tube starts to conduct. The action in the blocking-oscillator circuit itself causes the grid voltage to swing further in a positive direction.

A Transistor Blocking Oscillator.

Transistor blocking oscillators in their basic form look very much like the circuit shown in Fig. 12, with the exception that a transistor is substituted for a vacuum tube. Actually, the big difference in the circuits is due to the addition of several parts in the transistor circuit that are needed to protect the transistor from high surge voltages.

A transistor blocking oscillator that is used as the vertical sweep oscillator in a typical commercial TV receiver is shown in Fig. 16. The transformer connecting the output signal back to the input is connected in essentially the same way as in the vacuum-tube circuits. In this oscillator circuit notice that you can trace from the base of the transistor Q_1 through the diodes D_1 and D_2, through R_3, R_4 and R_5 to the +12 volts terminal. Therefore, a positive voltage is applied to the base of the transistor through these components so there is a forward bias across the emitter-base junction.

When the oscillator is turned on, current begins to flow through the transistor from the emitter to the collector and then through the primary winding of the blocking-oscillator transformer T_1. The primary winding is the winding connected in the collector circuit. As the current starts to build up in this winding of the transformer it induces a voltage in the secondary winding having the polarity shown. This voltage induced in the secondary is in effect in series with the supply voltage so it increases the positive potential on the base of the transistor. This increases the forward bias across the emitter-base junction and causes the current flowing through the transistor to increase. The increased current through the transistor increases the current flowing through the primary winding of the

The time constant of this network in the plate circuit of the tube is deliberately made quite long. If the charge on C3 reached an appreciable percentage of the power supply voltage the charge would be an exponential curve, as shown in Fig. 14A. This would be unsuitable for use as a sawtooth wave in television. However, by using a long time constant, then we use only a small part of this charging curve and obtain a relatively linear sawtooth, as shown in Fig. 14B.

Notice the rapid drop in voltage that occurs across the capacitor when the tube starts to conduct. This is due to the fact that the tube goes from zero current to saturation in almost an instant and the very high current flowing through the tube will discharge the capacitor quite rapidly. On the other hand, the charging action is governed by the time constant of the RC network and this is relatively slow.

In Fig. 15A we have shown the waveform in the grid circuit of the blocking-oscillator tube when there is

Fig. 15. Blocking oscillator grid circuit waveform showing arrival of sync pulse, and how sync pulses drive the grid into the conduction regions.

Fig. 16. A transistor blocking oscillator used as the vertical sweep oscillator.

transformer, which builds up the induced voltage still further. This action continues until current saturation is reached, and then there is no longer a change in the current in the primary winding of the transformer; thus, no voltage will be induced in the secondary winding. All this current build-up, from the time the transistor begins conducting until it reaches saturation, occurs almost instantaneously.

While the transistor is conducting, the high positive bias applied to the base of the transistor causes current to flow out of the base through D_1 and T_1 and through R_3 into the .22 mf capacitor C_2, charging this capacitor with the polarity shown. The two diodes, D_1 and D_2, are connected so the current flow from the base through these diodes will encounter little or no opposition. The capacitor charges quickly through the 8.2K-ohm resistor R_3. When the voltage across T_1 disappears, the negative voltage on C_2 immediately places a negative voltage on the base of the transistor. This voltage is applied through R_3, the secondary of T_1 and R_2 to the base of Q_1. This places a reverse bias across the emitter-base junction of the transistor and causes the current flow through the transistor to stop. When the current flow through the transistor stops, the field built up in the primary of T_1 reverses and causes current to flow through D_3 to dissipate this field.

Similarly, the field in the secondary of the transformer reverses and the voltage will cause a current to flow through D_2 and dissipate the energy in this field. Meanwhile, the transistor is held at cutoff until the surplus of electrons on C_2 can dissipate through R_4 and R_5. Eventually, since these resistors connect to the positive side of the power supply, the negative plate of the capacitor will become positive; when this happens, a positive voltage will once more be applied to the base of the transistor and the cycle will repeat itself.

Notice that the 100K-ohm resistor R_5 in the discharge circuit of C_2 is variable. By varying the resistance in this circuit the length of time the transistor is cut off can be changed and hence the frequency of the oscillation is controlled. The RC time constant of C_2 and resistors R_4 and R_5 should be slightly longer than the time between sync pulses. Then, the base of the transistor Q_1 will still be slightly negative when the positive-going sync pulse arrives at the input and is fed through C_1 and R_1 to the base of the transistor. The positive pulse will drive the transistor into conduction and start the oscillation cycle. In this way, the frequency of the oscillation will be controlled by the sync pulse rather than by the RC time constant of the resistor-capacitor network.

The RC time constant may vary as temperature changes, and it also may be subject to variations due to power supply voltage fluctuations. However, as long as the time constant is adjusted close enough so that when the sync pulse arrives, the base is almost ready to go positive, then the sync pulse will be able to drive the base positive. This will start the transistor conducting and initiate the oscillator cycle.

As we pointed out, D_2 and D_3 are used to dissipate the current produced when the transformer fields reverse. You might wonder what the purpose of D_1 is. This diode is used to provide a low resistance connection between the voltage induced in the secondary winding of T_1 and the base of the transistor. We want this positive voltage applied to the base so that the forward bias across the emitter-base junction will reach a high value almost instantly to cause the current flow through the transistor to go to saturation as rapidly as possible. If we simply used a direct connection to the transformer, this would load or short out the incoming positive sync pulse. However, with a diode connected as shown, when a positive sync pulse strikes the cathode of the diode D_1,

the diode acts as a high resistance so the sync pulse is not attenuated but rather fed directly to the base of the transistor. The resistor R_2 provides a circuit for the negative voltage across C_2 to cut off the transistor and this voltage is applied to the base of the transistor.

Sawtooth Frequency and Amplitude.

The frequency of the blocking oscillator is controlled by the time constant of an RC network. In the vacuum-tube blocking oscillator circuit shown in Fig. 13, the time constant of C_1, R_1 and R_2 controls the frequency of the blocking oscillator. This is why R_2 is made adjustable, so that the frequency of the oscillator can be varied. In the transistor blocking oscillator circuit shown in Fig. 16, the frequency of the blocking oscillator is controlled by C_2, R_4 and R_5. Once again, R_5 is made variable, to control the frequency of the oscillator. Both of these circuits are used as the vertical sweep oscillators in modern television receivers and hence the variable controls are usually referred to as the vertical hold control.

The amplitude of the output signal is governed by the time constant of the sawtooth waveforming circuit. In the vacuum-tube circuit in Fig. 13, this consists of C_3, R_4 and R_5. R_5 is made variable in order that the amplitude of the signal can be adjusted. This control is usually referred to as the height control or the vertical size control.

In the transistor blocking oscillator shown in Fig. 16, the capacitors C_3 and C_4 are in the sawtooth forming circuit. They are part of an RC circuit which includes a resistor, not shown in the diagram, and the two capacitors. The resistor is adjustable so that the RC time constant of the network, and hence the amplitude to which the capacitors will charge, can be varied. Again, this control will be called the height control in this circuit. In cases where a blocking oscillator is used as the horizontal sweep oscillator, the control then is usually referred to as the width control, size control, or drive control. The name "drive control" comes from the fact that the amplitude of the signal will determine how hard you drive the horizontal output stage.

The amplitude to which the RC sawtooth network charges is affected to some extent by the frequency adjustment. Normally the hold control will adjust the frequency of the oscillator over a relatively limited range, but this is sufficient to affect the amplitude to which the capacitor in the sawtooth-forming circuit charges. Therefore, if it is necessary to make any appreciable adjustment of the hold control, it is usually also necessary to adjust the height or size control in order to obtain an adequate size picture. In fact, in most vertical sweep circuits there will be a third control referred to as the vertical linearity control. If you adjust the vertical hold control appreciably then you usually have to adjust both the height and the vertical linearity controls in order to obtain the correct size picture with a reasonable linearity.

Be sure you remember that in both of the circuits shown in Fig. 13 and Fig. 16 (where we have examples of vertical sweep oscillators), the frequency of the oscillator is controlled primarily by the sync pulse.

The RC time constant of the frequency determining network is made so that the tube (Fig. 13) and the transistor (Fig. 16) will be cut off and just about to go into conduction when the sync pulse arrives. The sync pulse will drive the tube or transistor into conduction and thus control its frequency.

Thus the RC time constant of the network is somewhat longer than the period between sync pulses. Remember that to speed up the oscillator the RC time constant is reduced, and to slow down the oscillator the RC time constant is increased. Remembering whether you increase or decrease the RC time constant to change the frequency in a certain way will be helpful to you in service work.

MULTIVIBRATORS

Another widely used sweep oscillator is the multivibrator. There are two types of vacuum-tube multivibrators used in TV receivers: the plate-coupled multivibrator and the cathode-coupled multivibrator. The plate-coupled circuit is widely used in the vertical sweep of modern TV receivers, whereas the cathode-coupled circuit is used as the horizontal sweep oscillator. You will study both of these types of multivibrators as well as transistor multivibrators in this section of this lesson.
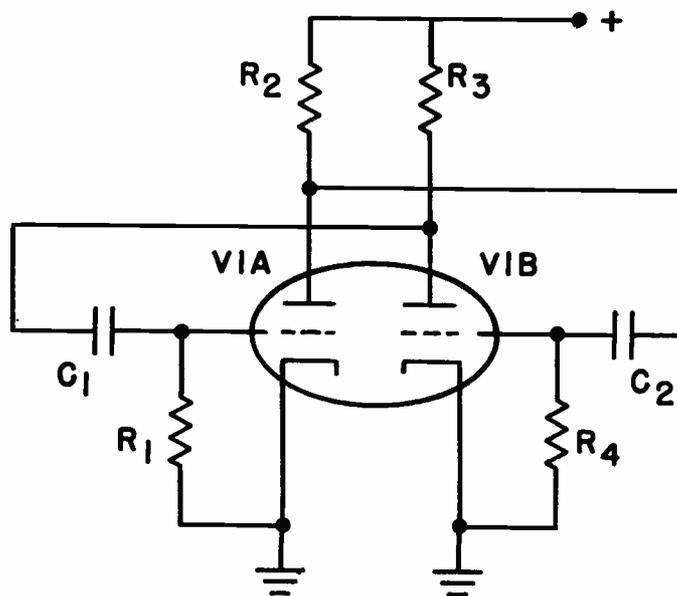
Fig. 17. A plate-coupled multivibrator.

Plate-Coupled Multivibrators.

The circuit of a plate-coupled multivibrator is shown in Fig. 17. In this circuit, the frequency of the multivibrator is determined primarily by the values of C_1, R_1, C_2, and R_4. The output from the multivibrator can be taken from either plate. With the circuit as shown, the output at either plate will be almost a square wave. If $C_1 = C_2$ and $R_1 = R_4$, the output of the multivibrator will be symmetrical; that is, the two halves of the square wave will be equal. If we

take the output from the plate of V_{1B}, we will obtain a signal similar to the square wave shown in Fig. 18A. If the value of C_1 or R_1 is made smaller than the value of C_2 or R_4, V_{1A} will be cut off for a shorter period than V_{1B}. The output from V_{1B} will look like Fig. 18B. If C_2 or R_4 are made smaller than C_1 or R_1, the output at the plate of V_{1B} will look like Fig. 18C.

The operation of the plate-coupled multivibrator shown in Fig. 17 is as follows: With the plate voltages applied to the two triodes, as the tubes warm up one will conduct slightly more than the other. Let's assume that V_{1A} conducts more heavily than V_{1B}. When V_{1A} conducts, the plate voltage on V_{1A} will drop. C_2, which will be charged to or almost to the supply voltage, must now discharge to the lower voltage. This will cause a current flow through R_4 which will cut off V_{1B} completely, and the plate voltage will rise to a value equal to the supply voltage.

As soon as C_2 has discharged, the negative voltage across R_4 will disappear and V_{1B} will start to conduct. This means there will be a voltage drop across R_3, so the plate voltage on V_{1B} will drop. C_1, which has charged to the full supply voltage, must now discharge through R_1. In doing so it develops a negative voltage on the grid of V_{1A} which cuts off this triode. Once the tube is cut off, the plate voltage on V_{1A} rises to the full value of the supply voltage. C_2 must now charge to this value. It does so by starting to draw current through R_4, which biases the grid of V_{1B} positive. This causes current to flow from the cathode to the grid of V_{1B} into the one plate of the capacitor.

At the same time the positive grid voltage causes a very high plate current to flow through V_{1B} and through R_3, dropping the plate voltage on this tube to a very low value. This causes C_1 to discharge still further, keeping V_{1A} cut off. In the charging action of C_2, the electrons flow into the grid side of C_2 and out the other side through R_2 to the positive side of the power supply.

V_{1A} will remain cut off until C_1 discharges through R_1 to a point where the voltage across R_1 drops to a value that can no longer hold V_{1A} cutoff. As soon as V_{1A} starts to conduct, the plate voltage on V_{1A} starts to drop due to the voltage drop across R_2. When this happens, C_2 must discharge through R_4; this cuts off V_{1B}, its plate voltage rises to the full value of the power supply, and C_1 charges through the cathode-grid circuit of V_{1A} and R_3.

This action of one triode and then the other conducting continues. The length of time the tube is cut off depends on the time constant of the capacitor and resistor connected to the grid. In Fig. 18A a sym-

Fig. 19. A cathode-coupled multivibrator.

metrical output is obtained because the time constants of C_1, R_1 and C_2, R_4 are equal. In Fig. 18B, V_{1B} is cut off longer than V_{1A} because the time constant of C_2 and R_4 is longer than the time constant of C_1 and R_1. In Fig. 18C, V_{1B} is cut off for a shorter time than V_{1A} because the time constant of C_2 and R_4 is less than the time constant of C_1 and R_1.

The waveshape at the output of the multivibrator can be changed from a square wave to a sawtooth wave simply by connecting a capacitor from the plate of the tube to ground. In other words, a capacitor of the correct size connected from the plate of V_{1B} to ground will give you a sawtooth output at the plate of V_{1B}. We'll go into this in more detail later.

Cathode-Coupled Multivibrators.

Another basic sawtooth-generating circuit is the cathode-coupled multivibrator illustrated in Fig. 19. In this circuit the sawtooth voltage is developed across capacitor C_1, and the frequency of the multivibrator is determined mainly by capacitor C_2 and resistor R_2. The two sections conduct and are cut off more or less in the same way as the two sections of the plate-coupled multivibrator. In many respects, the second section of the triode functions very much the same as the blocking tube, because the sawtooth trace is formed on capacitor C_1 when the tube is non-conducting, and the retrace is formed when the tube conducts and discharges capacitor C_1. The cut-off time of the tube is controlled by the time constant of the grid capacitor C_2 and grid resistor R_2, just as in a blocking oscillator and a plate-coupled multivibrator. In fact, the first

Fig. 18. Waveforms from symmetrical and nonsymmetrical multivibrators.

section of the cathode-coupled multivibrator has the same purpose as the transformer of the blocking tube oscillator--mainly to initiate a feedback cycle. This is also true of the plate-coupled multivibrator; you'll see an example of this when you study typical vertical sweep circuits.

The cycle for the cathode-coupled multivibrator is as follows: Let us assume that capacitor C_2 is discharging and the grid voltage has reached the level at which the second section of the tube begins to conduct.

The rise in plate current, when the second section of the tube conducts, develops a more positive voltage across cathode resistor R_3. The higher cathode voltage results in an increase in negative bias on the first section. The plate current of the first section decreases, and its plate voltage increases.

The plate circuit of the first section is coupled through capacitor C_2 to the grid of the second section. Therefore, the rise of plate voltage on the first section causes a further increase in positive grid voltage on the second section.

This feedback arrangement causes the grid voltage of the second section to rise rapidly and almost instantaneously, driving the grid of the first section toward cutoff and the grid of the second section positive to the level where a further increase in grid voltage causes no further increase in the plate current of the second section. At this instant, no further feedback occurs, because there is no change in plate current in the second section. With no feedback to support it,

the grid voltage of the second section begins to slide back and reverses the feedback cycle.

This time the grid voltage of the second section decreases, causing a decrease in plate current and a less positive voltage across the cathode resistor R_3. Thus, the bias on the first section of the tube begins to decrease and there is an increase in the plate current of the first section. The resultant decline in the plate voltage of the first section drives the grid of the second section further in the negative direction. In fact, feedback operation, assisted by the amplification by the first section, drives the second section beyond cutoff. As a result, the second section is held at cutoff by the high negative charge placed on capacitor C_2, just as the negative charge placed on the grid capacitor of a blocking tube holds it at cutoff. The second section remains cut off until capacitor C_2 discharges through resistor R_2 to the bias level at which the second section of the tube begins to conduct again. As soon as the second section begins to conduct, a new feedback cycle is originated.

During the interval that the second section is held at cutoff by the charge on capacitor C_2, capacitor C_1 charges toward the B+ voltage through resistor R_1. At the instant the second section conducts, this same capacitor is discharged through the tube, forming the sawtooth retrace interval. The frequency of the generated sawtooth is controlled by the grid time constant (capacitor C_2 and resistor R_2), which determines the rate of discharge of capacitor C_2, as shown in the
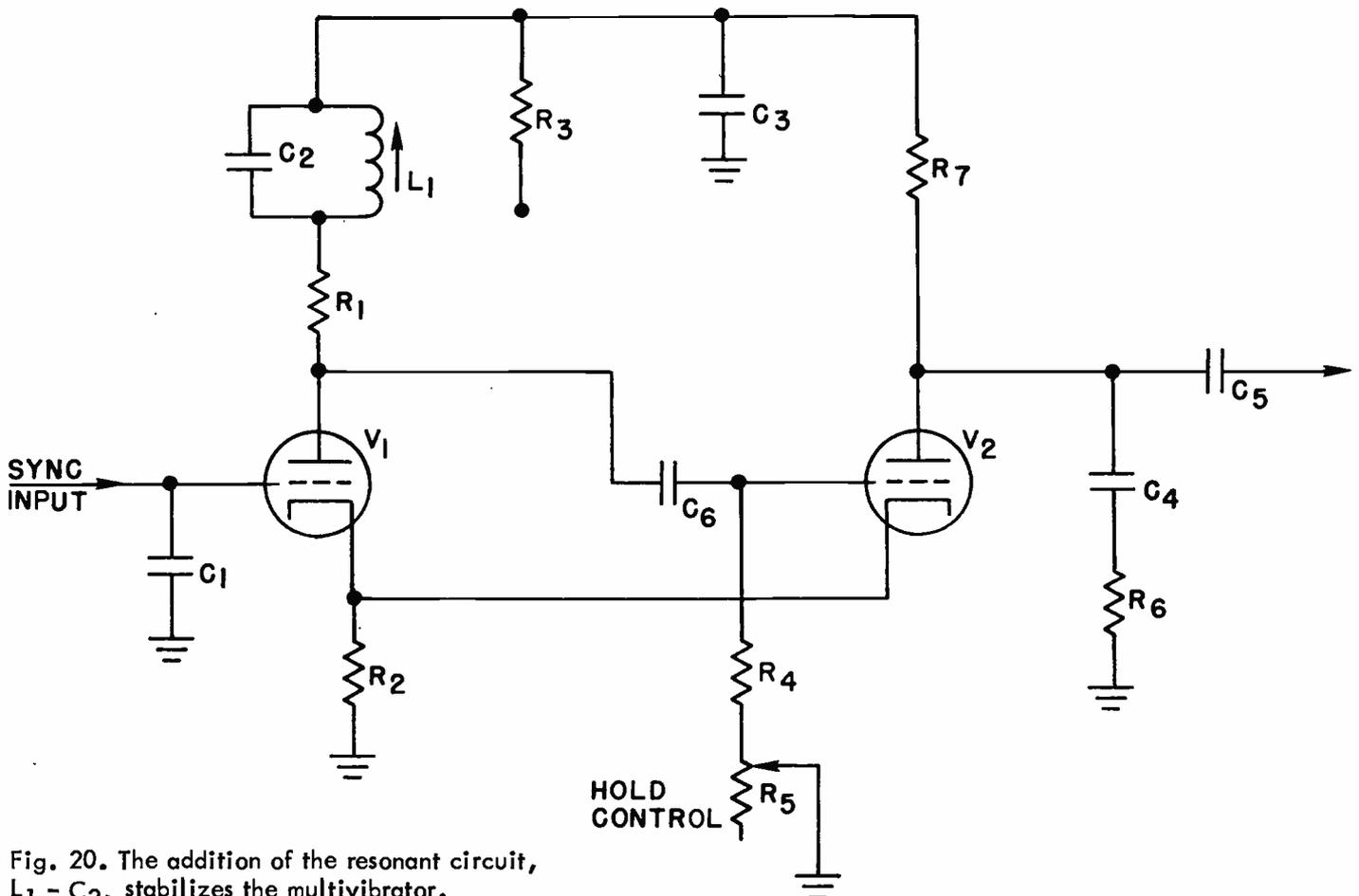
Fig. 20. The addition of the resonant circuit, $L_1 - C_2$, stabilizes the multivibrator.

CONDUCTION LEVEL — REGULAR GRID WAVEFORM

NOISE

DISCHARGE OF C_6

CONDUCTION LEVEL — GRID #2 WAVEFORM
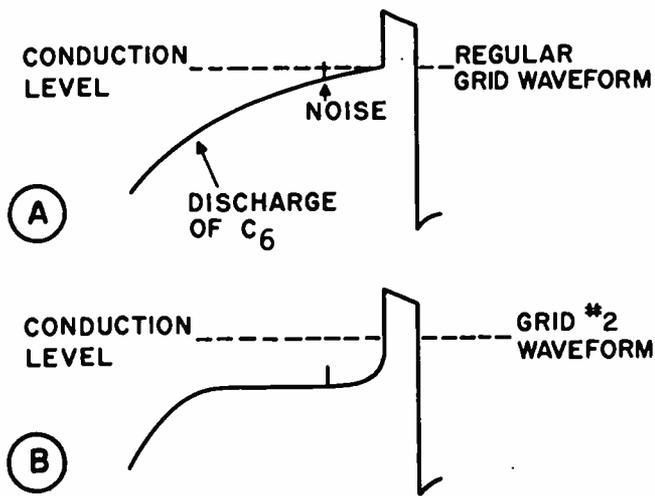
Fig. 21. The sine wave voltage developed across the resonant circuit combines with the regular multivibrator grid waveform (A) to produce the modified form at (B).

grid 2 waveform. The faster the time constant, the higher the frequency of the sawtooth generated, as explained in the discussion of blocking tube oscillators. The amplitude of the sawtooth wave is again controlled by the plate-circuit time constant (resistor R_1 and capacitor C_1), and the supply voltage toward which capacitor C_1 charges.

The feedback characteristic of the first section of the triode is illustrated by the cathode waveform. This cathode waveform is developed by the plate current changes in the second section. An amplified version of this same waveform appears at the plate of the first section, and therefore serves as the strong feedback pulse that is fed to the grid of the second section. Thus, the first section of the multivibrator has the same task as the blocking tube transformer, namely, to supply the necessary feedback pulse that triggers the sawtooth-forming second section.

Stabilized Multivibrators.

It is possible to improve the frequency stability of a cathode-coupled multivibrator by inserting a tuned circuit in the plate circuit of the feedback tube, as shown in Fig. 20. The resonant circuit, consisting of inductor L_1 and capacitor C_2, is tuned to a frequency near the synchronized frequency of the multivibrator. Except for the resonant circuit, the multivibrator is basically the same as the one shown in Fig. 19. Circuits such as shown in Fig. 20 are widely used as the horizontal oscillator in a TV receiver.

The frequency of a multivibrator is controlled by the time constant in the grid circuit of the second tube. Resistor R_5 is variable and acts as a horizontal hold control to adjust the multivibrator frequency as close as possible to that of the incoming horizontal sync pulses. The drive for the horizontal sweep output stage is developed across the series combination of C_4 and R_6. C_4 charges through R_6 and R_7 to produce the drive signal. The retrace portion of the sawtooth is formed when the second tube conducts.

The resonant circuit, C_2 and L_1, improves stability by adding a sine wave to the regular grid waveform of the multivibrator. The sine wave voltage is developed across the resonant circuit by the sharp change in plate current of the first tube, V_1, and is coupled through capacitor C_6 to the grid of the second section. Also present on the grid of the second section is the standard multivibrator waveform that results from the discharge of capacitor C_6. The two waveforms combine to form the resultant waveform B of Fig. 21. The advantage of this type of grid waveform is that the discharge cycle of capacitor C_6 near conduction time is separated by a substantial voltage from the conduction level of the second tube.

For example, if a small burst of noise reaches the grid of the second section, as shown in Fig. 21A, it may reach the conduction level and start the second tube conducting before the true synchronization time. This will start the retrace portion of the sawtooth too soon, and the next line of video information will be displaced on the scanning raster. However, with the discharge portion of the waveform substantially below the conduction level, as shown in waveform B, the same burst of noise does not reach the conduction level and trigger the multivibrator incorrectly. Thus, the resonant circuit improves the stability of the multivibrator by preventing stray noises and circuit variations from causing a shift in frequency and phase of the sawtooth output of the multivibrator.

Transistor Multivibrators.

Transistor multivibrators are used both for the comparatively low-frequency vertical sweep and the high-frequency horizontal sweep circuits in modern transistor television receivers. We'll study one of each so you'll be familiar with the operation of these circuits when you encounter them.

A transistor multivibrator that is used as the vertical sweep oscillator in a modern TV receiver is shown in Fig. 22. In addition to forming part of the multivibrator circuit the transistor Q_2 is also the output transistor; in other words, it is the transistor that feeds directly to the vertical deflection coils. However, we will not be concerned with that part of the circuit now; we will concern ourselves only with the multivibrator action.

At the instant the vertical sync pulse arrives, the transistor Q_2 will be conducting heavily and Q_1 will be cut off. The incoming sync pulse will be a negative pulse and when it is applied through R_1 and C_2 to the base of Q_1, it will drive Q_1 into conduction. Notice that the transistors are PNP transistors and therefore the holes in the emitter will be attracted by the negative pulse arriving at the base of the transistor. When the transistor Q_1 conducts, electrons will flow from ground or B- through R_{11} and R_{10} to the collector of Q_1, where they will fill holes arriving at the collector.

Meanwhile, the transistor will conduct so heavily that electrons will be pulled from the plate of capacitor C_3 to the collector of Q_1 to fill holes arriving at the collector. As a result, C_3 and C_4 will be charged with the polarity shown. Two capacitors are used in this circuit instead of one, along with the network consisting of R_8 and R_9 in order to shape the discharge of this network to get the correct shape waveform to drive the vertical output stage, Q_2. Since R_8 is adjust-
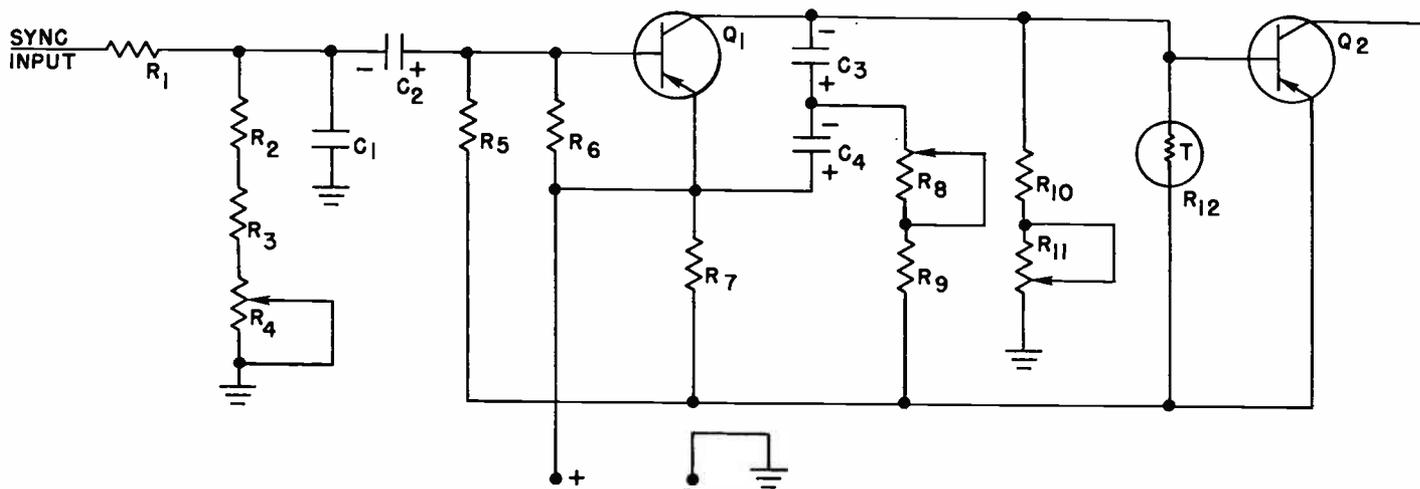
Fig. 22. A transistor multivibrator.

able, it is referred to as the vertical linearity control.

The current flowing through R_{11} and R_{10} will develop a high voltage drop across this resistor combination having the polarity such that the end that connects to the base of Q_2 is positive with respect to ground. This will place a positive potential on the base of Q_2 with respect to the emitter of Q_2 so that the transistor will not conduct.

Meanwhile, with Q_1 conducting heavily, electrons will be pulled from the one plate of C_2 to fill some of the holes arriving from the emitter and crossing the emitter-base junction and flowing to the base of Q_1. This flow of holes across the junction and pulling of the electrons out of the capacitor will place a charge on the capacitor C_2 having the polarity shown.

As soon as the sync pulse has disappeared, the charge on C_2 will bias the base of Q_1 positive with respect to the emitter. This means that we'll have a reverse bias across the emitter-base junction and therefore Q_1 will stop conducting. As soon as this happens the capacitors C_3 and C_4 will begin to discharge. C_3 will discharge through R_{10} and R_{11}, to the power supply and then through C_4. There will also be another path through R_7, R_8 and R_9. At the same time C_4 will be discharging through R_8, R_9 and R_7. The important thing is that in discharging across R_{10} and R_{11}, C_3 will develop a voltage drop across these resistors, having a polarity such that the base of Q_2 will be made negative with respect to the emitter. Once this happens we have a forward bias across the emitter-base junction of Q_2 and the transistor will begin to conduct heavily.

The time constant of the network consisting of C_2 and resistors R_2, R_3 and R_4 is made long enough so that Q_1 will be held cut off until the next sync pulse arrives. At the time the sync pulse arrives, C_2 should have discharged to the point where Q_1 is just about ready to go into conduction. Then the sync pulse will drive the transistor into conduction, cutting off the output transistor as before, and the cycle will repeat itself.

In this circuit, R_4 is adjustable and is in the circuit with C_2; this control is therefore the vertical hold control. It is adjusted so that the time constant of the network, as we mentioned previously, is such that the

transistor will be almost ready to go into conduction when the next sync pulse arrives. As we also mentioned previously, R_8 is a linearity control and R_{11}, in the sawtooth forming circuit, is the height control.

Transistor Multivibrator Circuit.

In Fig. 23 we have shown a stabilized transistor-multivibrator circuit. This circuit is used as the horizontal sweep oscillator in a modern television receiver. Notice how similar it is to the stabilized vacuum-tube multivibrator circuit in Fig. 20. In the vacuum-tube circuit the two tubes are cathode-coupled, whereas in this circuit the transistors are emitter-coupled. Notice that in the vacuum-tube circuit the resonant circuit is placed in the plate circuit of one of the tubes, whereas in the circuit in Fig. 23 the resonant circuit is placed in the collector circuit of one of the transistors.

The operation of the transistor oscillator shown in Fig. 23 is quite similar to the operation of the vacuum-tube oscillator shown in Fig. 20. When Q_1 is cut off, the potential on the collector will rise to the full B+ supply potential. R_4 and R_5 form a voltage divider network and the capacitor C_2 charges to a potential equal to the difference between the B+ supply potential and the potential at the junction of R_4 and R_5.

When Q_1 begins conducting it will draw a comparatively high current through R_6. This will place a positive potential on the emitter of Q_2. At the same time, the current flowing through R_2 will develop a voltage drop across it so that C_2 must discharge. C_2 will discharge through R_4, increasing the voltage drop across this resistor, so that the positive potential on the base of Q_2 will go down. As a result, there will be a reverse bias across the emitter-base junction of Q_2 due to the drop in the positive potential on the base of the transistor and the high positive potential on the emitter. With the reverse bias across Q_2, the transistor will be cut off.

When C_2 has discharged, the voltage drop across R_4 will decrease so the voltage at the junction of R_4 and R_5 will increase. The increase in voltage will be sufficient to cause the base of Q_2 to go positive with respect to the emitter. When this happens Q_2 will begin conducting and start drawing current through R_6. This will increase the positive potential on the

emitter of Q_1, causing the forward bias on that transistor to decrease. As soon as this happens, the current flow through the transistor will decrease, the voltage drop across R_2 will decrease, and capacitor C_2 will begin to charge to a higher potential. This will result in an increased current through R_5 which will swing the base of Q_2 still further in a positive direction. This will in turn cause the current to increase in this transistor, thus increasing the voltage drop across R_6 and reducing the current flow through Q_1 still further. This action happens so rapidly that the current flow through the transistor Q_1 will be cut off almost instantly.

When C_2 has charged again to the voltage equal to the voltage at the junction of R_4 and R_5 and the full B-supply voltage, the current through R_5 will drop back to the normal value that would be obtained with this voltage divider connected from B- to B+; this will cause the positive potential on Q_2 to decrease. As soon as it decreases, the forward bias across Q_2 decreases, causing the voltage drop across R_6 to go down. Once this happens, Q_1 starts to conduct again and the cycle then repeats itself.

The parallel-resonant circuit in the collector circuit of Q_1 consists of L_1 and C_3. This circuit performs the same function as the parallel-resonant circuit does in the circuit shown in Fig. 20. It shapes the waveform applied to the base of Q_2 so that the conduction of Q_2 becomes less susceptible to noise pulses that might be fed through Q_1 to Q_2. The resistor R_2 across the resonant circuit is placed across the circuit to load the circuit in order to prevent the parallel-resonant circuit from developing too high a voltage swing.

SYNCHRONIZATION OF SAWTOOTH OSCILLATORS

A horizontal sawtooth oscillator can be set at the line rate frequency and a vertical sawtooth oscillator at the field rate frequency of the television receiver,

but adjusting each oscillator to the correct frequency is not enough to obtain a stationary, locked-in picture. The oscillators must be held rigidly to a specific frequency and must maintain a definite phase relationship with the scanning beam at the camera tube. Consequently, it is necessary to convey sync pulses from the transmitter to the receiver, and to introduce these sync pulses into the deflection system of the receiver. The sync pulses lock in the frequency and phase of the sweep oscillator. The sync pulses do not generate the sawtooth wave or determine the frequency of the sawtooth wave. They serve to hold the oscillator rigidly at the required frequency and phase.

This characteristic is often helpful in determining whether a defect is in the synchronization or in the sawtooth-generating sections of a TV receiver. Generally, when there is a sync defect, it is possible to lock in the picture momentarily by varying the frequency controls. However, with improper sync, the picture remains locked in for just a short time and then drifts out again. Usually, if there is a sawtooth-generation defect, it is not possible to tune the defective oscillator to the correct frequency.

The process of synchronization is discussed in detail in a later lesson. However, a brief introduction to synchronization here will give you a better understanding of the operation of the deflection system in a television receiver. There are two basic methods of establishing rigid control of the frequency and phase of a sawtooth oscillator--by application of the sync pulses to the oscillator and by the establishment of a dc voltage at the sawtooth oscillator that depends on the incoming sync pulses.

When a sync pulse is introduced into the input circuit of a blocking oscillator in order to synchronize it, the hold control is adjusted so that the oscillator will operate at a slightly lower frequency than the desired frequency. The sync pulses will speed the oscillator up slightly so that it will operate in synchronization with the sync pulses. If the oscillator is operating at a slightly higher-than-normal frequency it
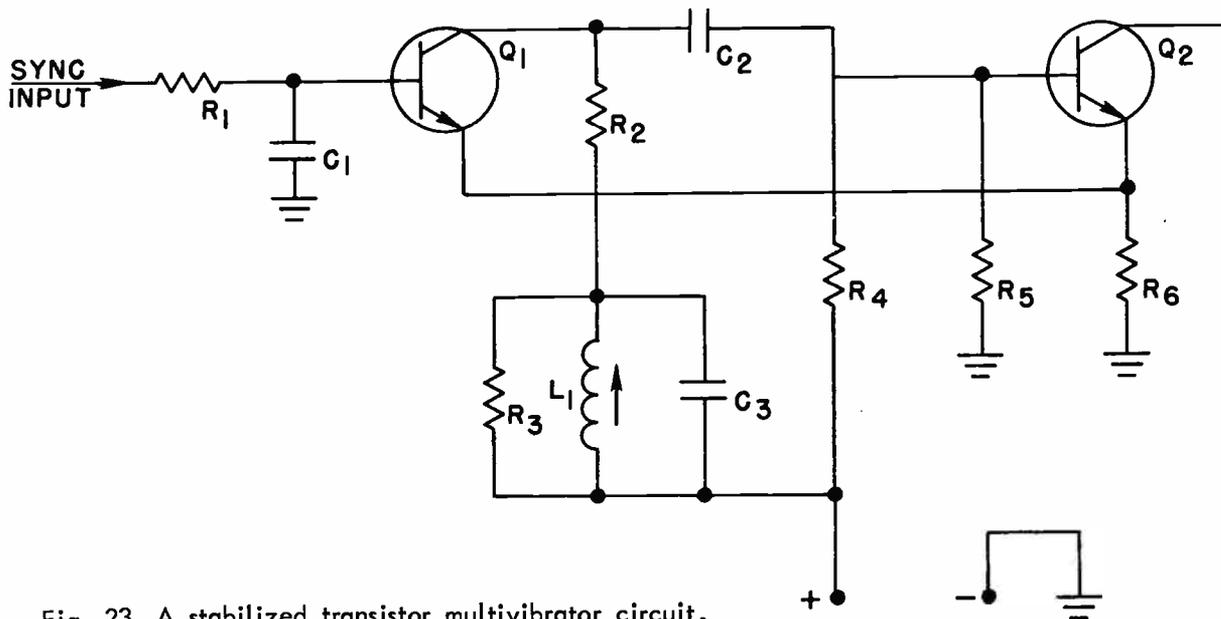
Fig. 23. A stabilized transistor multivibrator circuit.
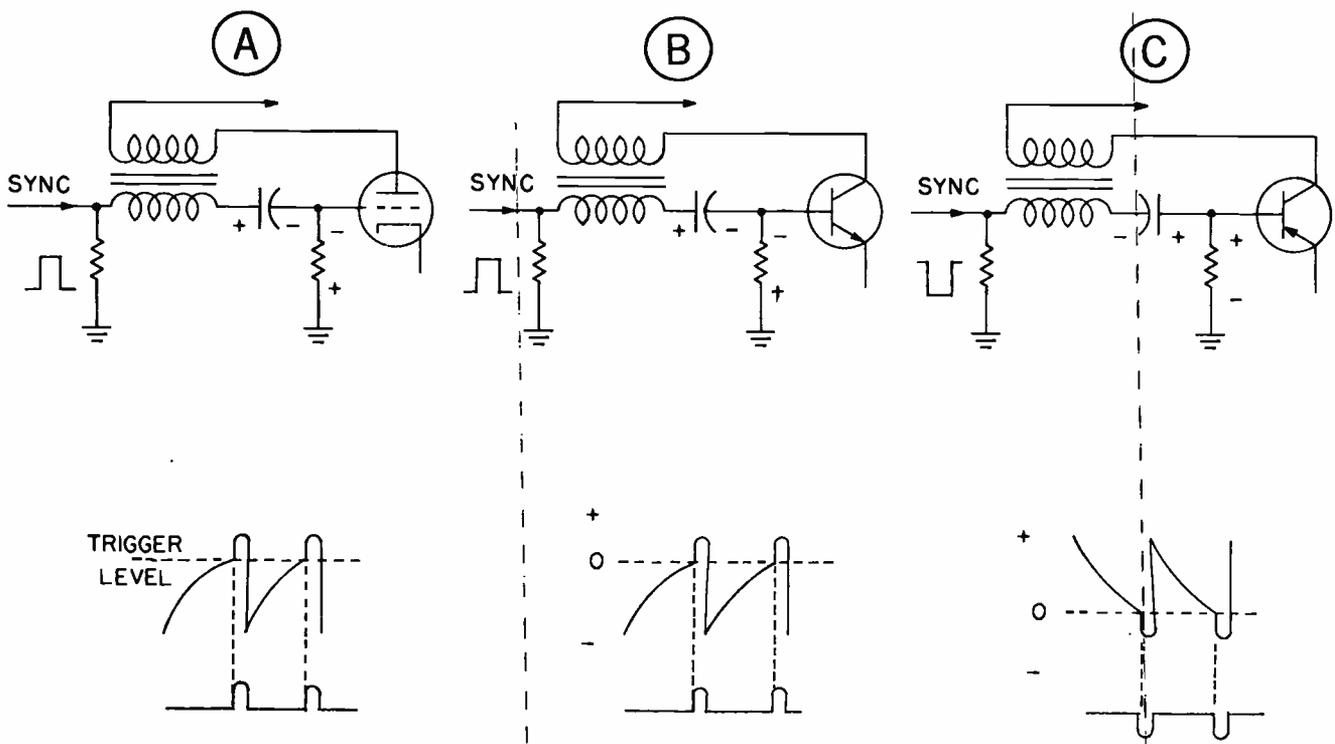
Fig. 24. Synchronization of vertical blocking oscillator.

will not be synchronized by the sync pulses as required.

In Fig. 24 we have shown partial schematics of three blocking oscillator circuits. These circuits are typical of the circuits used as vertical sweep oscillators in modern television receivers. The vertical oscillator is synchronized by the application of a sync pulse of the correct polarity.

In the circuit shown in Fig. 24A we have shown a triode tube used as the blocking oscillator, and beneath the diagrams, the grid circuit waveform and the sync pulses. Notice that the sync pulse is a positive-going pulse and it is fed into the grid circuit through the blocking oscillator transformer and through the grid capacitor. In operation, the grid capacitor will discharge through the grid resistor and hold the tube cut off. The charge on the capacitor should be almost down to the level where the tube will start to conduct when the sync pulse arrives. The sync pulse should arrive just ahead of the normal conduction time. This will drive the grid in a positive direction so that the grid voltage is driven instantly from the cutoff region into the conduction region and plate current begins to flow. Notice that in this case we've referred to this level as the trigger level. This is not zero voltage because the tube starts conducting with some negative voltage on the grid.

The circuit shown in Fig. 24B illustrates a partial schematic of a blocking oscillator using an NPN transistor. Notice that it is essentially the same as the circuit for the vacuum tube. We've left out the pulse-limiting diodes that are frequently found in circuits of this type using transistors; we've left them out deliberately because they do not contribute anything to the synchronization of the oscillator.

In the circuit the capacitor in the base circuit is charged with the polarity shown; in discharging through the base resistor it sets up a voltage drop across it that places a reverse bias across the emitter-base junction so that no current can flow through the transistor. However, as the capacitor discharges, it has reached a low value by the time the sync pulse arrives, so that the sync pulse can drive the base of the transistor positive with respect to the emitter and thus place a forward bias across the emitter-base junction so the transistor will conduct. Again, the hold control is adjusted so that it will take slightly longer than the time between sync pulses for the transistor to start conducting. This places the responsibility for the start of each cycle on the sync pulse. Thus, the frequency and phase of the oscillator are controlled by the arriving sync pulses.

Reversed Polarities.

In the circuit shown in Fig. 24C we have shown a blocking oscillator using a PNP transistor. The operation of this circuit is essentially the same as the circuit using an NPN transistor, except that the polarities are reversed and a negative-going sync pulse is required to trigger the oscillator.

The base capacitor will be charged with the polarity shown and in discharging through the base resistor will develop a bias that puts a reverse bias across the emitter-base junction of the transistor so the transistor cannot conduct. Just before the bias drops to zero and the transistor starts conducting, the negative-going sync pulse arrives and drives the base of the transistor negative with respect to the emitter. Once the base is negative with respect to the emitter, holes can cross the emitter-base junction, flow to the base, and then flow across the base-collector junction to the collector. Thus we have a current flow through the transistor.

Negative-Going Sync Pulse.

Once again, the start of each cycle is controlled by the arrival of the sync pulse (in this case the negative-going sync pulse), so the frequency and phase of the oscillator are controlled by the sync pulses.

In each of the circuits shown in Fig. 24 the RC time constant of the frequency-determining network must be adjusted close to the required value; otherwise, the sync pulse will not trip the oscillator into conduction. In each case, the oscillator must be set up to run slightly too slowly so that the sync pulse will speed up and control its frequency and phase.

The horizontal deflection system is more often synchronized by a dc voltage. This dc voltage is established initially by comparing the frequency of the sync pulses with the frequency of the horizontal deflection waveform. When there is any difference in frequency or phase between the two signals, the dc voltage changes, causing a correction in the frequency or phase of the sawtooth oscillator. The manner in which this dc voltage is produced is described in more detail in your lesson on the sync system.

With this method of synchronization it is not necessary to apply the sync pulses to the sawtooth oscillator directly. Instead, the sync pulses are applied to the comparison circuit that develops the dc voltage. This voltage is then applied to the oscillator, as shown in the circuit in Fig. 25.

In Fig. 25 there is a vacuum-tube blocking oscillator at A, a transistor blocking oscillator using an NPN transistor at B, and a transistor blocking oscillator using a PNP transistor at C. Immediately beneath each of these circuits we have shown how the change in dc voltage from the comparison circuit affects the frequency of the oscillator. The curve drawn in each case in the solid line represents the oscillator operating at the correct frequency. When the oscillator is operating at the correct frequency, the dc control voltage from the comparison circuits will be practically zero. The other two curves show the effect of changing the dc output voltage from the comparison circuit and the direction in which the change occurs in order to change the oscillator frequency.

Looking at the vacuum-tube circuit, we see that the negative charge placed on the grid capacitor C_1 establishes a bias voltage that must be discharged to the conduction level before the blocking tube again conducts. If a dc voltage is introduced in conjunction with the negative capacitor charge, the time required to discharge to the conduction level can be altered. For example, when a positive dc voltage is fed in the control circuit, it subtracts from the voltage across C_1 and the capacitor discharges from a less negative voltage and it reaches the conduction level earlier. Inasmuch as the discharge time has been made shorter with the introduction of the positive voltage, the frequency of the blocking tube rises.

If the applied dc control voltage is negative, it adds to the charge across C_1 and the capacitor discharges from a higher negative voltage. The time of discharge to reach the conduction level is longer; this causes the oscillator to operate at a lower frequency. Thus, small changes in the dc may vary the oscillator fre-
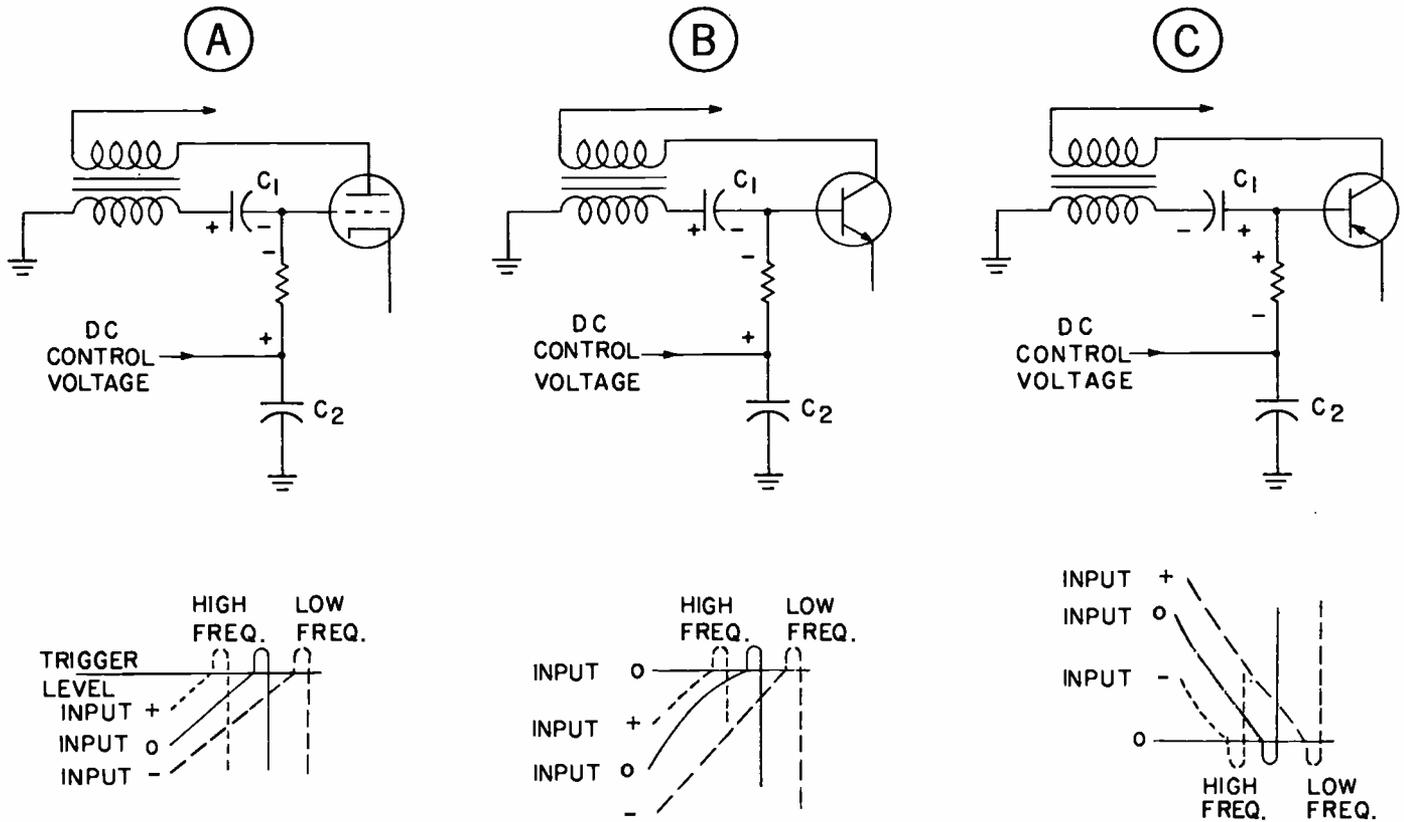
Fig. 25. DC synchronization of blocking oscillators.
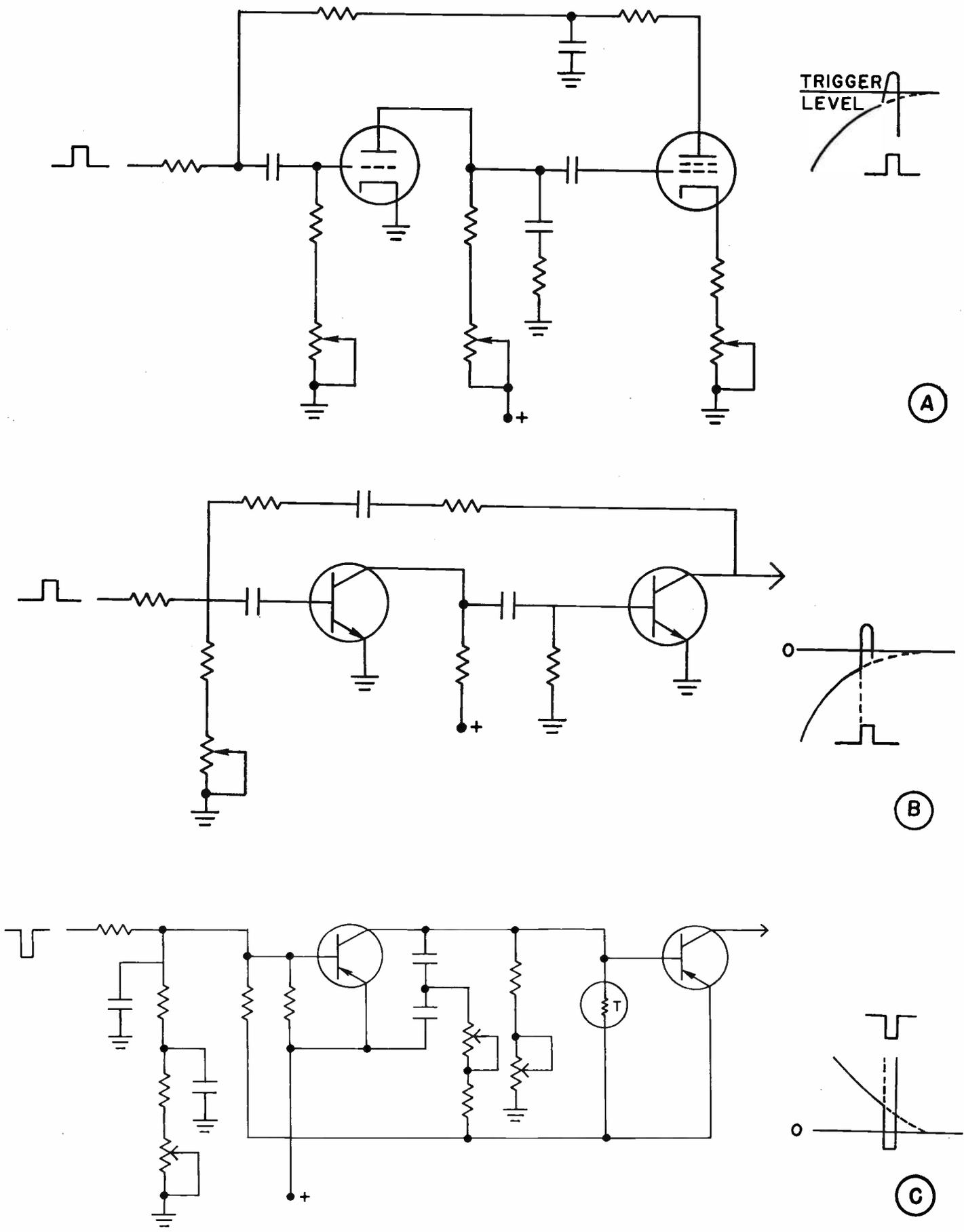
Fig. 26. Synchronization of vertical multivibrator by application of vertical sync pulses.
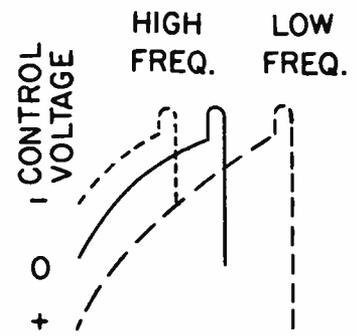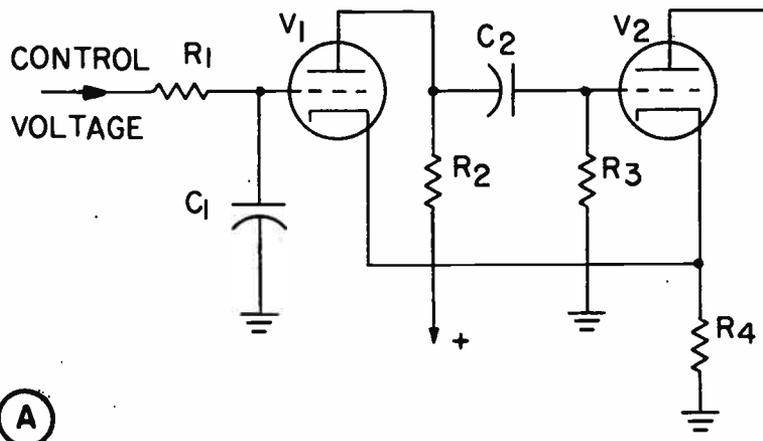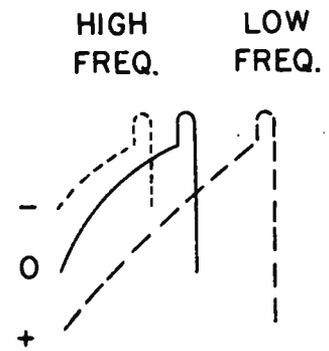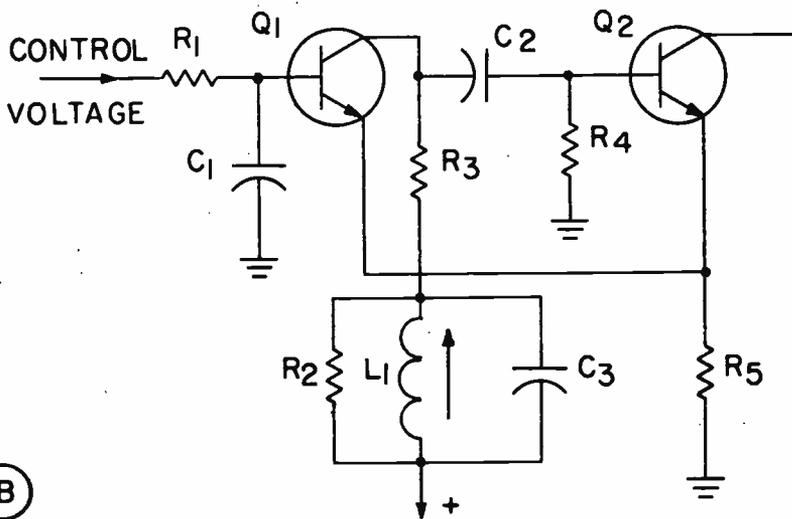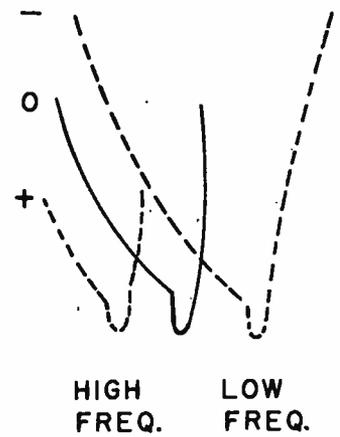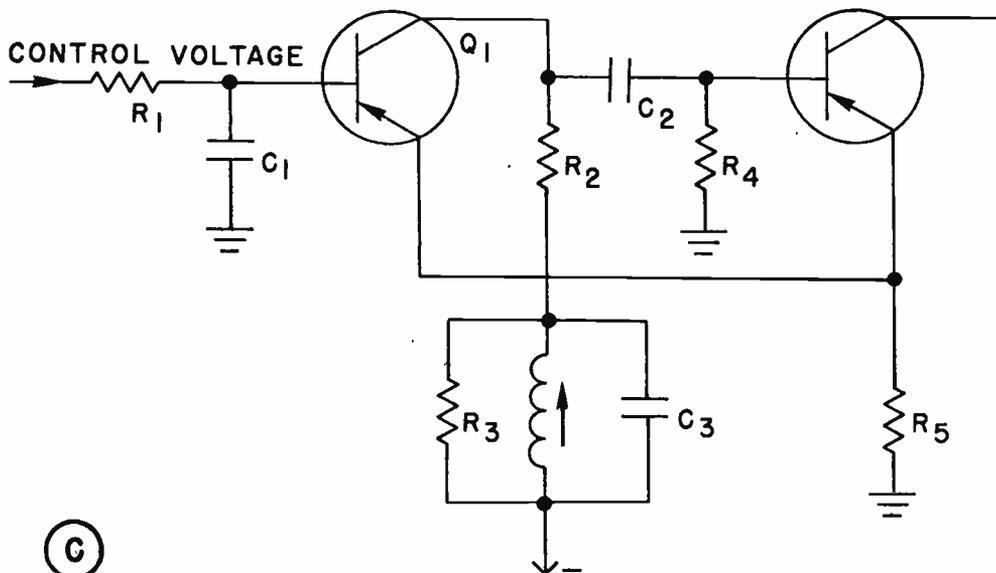
Fig. 27. Synchronization of multivibrator by a dc control voltage.

quency and phase over a limited range to permit them to follow the frequency and phase of the sync pulses.

In the circuit shown in Fig. 25B, where we have an NPN transistor, essentially the same thing occurs as in the tube circuit. A positive voltage from the control circuit will shorten the time required for the capacitor C_1 to discharge and increase the oscillator frequency. The negative voltage, on the other hand, will add to the capacitor voltage and increase the discharge time, thereby lowering the oscillator frequency.

In the PNP oscillator shown in Fig. 25C, the voltage polarities are reversed. A positive voltage will add to the bias on C_1 and increase the time required for the capacitor to discharge, thereby lowering the oscillator frequency. A negative voltage will subtract from the capacitor voltage and shorten the discharge time, thereby increasing oscillator frequency.

The comparison circuit can be arranged to provide either the negative or positive voltage required to increase the oscillator frequency. You will see how this is done when you study the sync circuits.

Just as in the blocking oscillator circuits it is possible to control the frequency of a multivibrator either with a direct application of sync pulses or with the use of a dc control voltage. When a multivibrator is used as the vertical-sweep oscillator synchronization is usually by means of direct application of the sync pulses, as shown in Fig. 26. In the three circuits in Fig. 26 we have shown a vacuum-tube multivibrator, a multivibrator using NPN transistors, and a multivibrator using PNP transistors. In each case, to the right of each circuit we have shown how the arriving sync pulses drive the input stage in the blocking oscillator into conduction and thereby control the multivibrator frequency. As we pointed out previously, the multivibrator is set up to operate at a slightly lower-than-normal frequency so that the arrival of the sync pulse triggers the conduction of the first stage and thereby controls the frequency.

The schematic diagrams in Fig. 27 show how the frequency of a multivibrator is controlled by a dc voltage applied to the input of the first section. The dc voltage acts as a grid bias in the case of the tube circuit shown at A and determines the plate current of V_1. The plate current determines the voltage drop across the plate-load resistor R_2 and hence the voltage to which C_2 must charge. A positive voltage on the grid of V_1 will cause the plate voltage to drop to a lower value; thus, C_2 must discharge to a lower value. This will increase the time required for C_2 to recharge to a value equal to the B supply voltage and will increase the time when current flows through R_3 and biases the grid of V_2 positive. This will permit V_2 to continue to conduct heavily and develop a high bias across R_4 that will keep V_1 cut off. This will increase the time constant of the circuit and reduce the oscillator frequency. When a negative voltage is applied to the grid of V_1, the opposite effect is produced and the oscillator frequency will increase.

In the NPN-transistor circuit shown in Fig. 27B, a positive voltage applied to the base of Q_1 will add to the forward bias across the emitter-base junction and cause a higher collector current to flow. This will cause the collector voltage to drop to a lower value and cause C_2 to discharge to a lower value. This means that C_2 will have to start charging from a lower voltage to charge up to the supply voltage when Q_1 is cut off. Therefore, a high charging current will flow through R_4 longer and keep Q_2 conducting. The voltage developed across R_5 by the high current through Q_2 will keep Q_1 cut off. This will increase the time constant of the circuit and reduce the oscillator frequency. A negative voltage will have the opposite effect and increase the oscillator frequency.

In the circuit using the PNP transistor shown in Fig. 27C, a negative voltage on the grid of Q_1 will increase the forward bias on the emitter-base junction, causing a higher current to flow and hence a greater voltage drop across the collector-load resistor. This will cause C_2 to discharge to a lower level and hence increase the voltage to which it must recharge when Q_1 is cut off. Once again this causes Q_2 to conduct longer, holding Q_1 cut off. This will lower the oscillator frequency. A positive voltage will reduce the forward bias across the emitter-base junction of Q_1 and have the effect of increasing the oscillator frequency.

You'll study synchronizing circuits in detail later; the important thing for you to remember at this point is that there are two methods of synchronizing the sweep oscillators in a TV receiver. The first method is the direct application of the synchronizing pulses to the sweep oscillator, and this system is used in the vertical sweep section of the TV receiver. The second method is by means of a dc voltage developed in a comparison-type circuit which compares the sync pulses at the output from the vertical-deflection system. This method is used to control the frequency of the horizontal oscillator.

SELF-TEST QUESTIONS

(i) What are the two basic sawtooth oscillators?

(j) What components in the blocking oscillator shown in Fig. 13 determine the oscillator frequency?

(k) Why are R_4 and C_3 in Fig. 13 chosen with such long time constants that C_3 accumulates a charge of only approximately 10% of the supply voltage?

(l) If R_4 in Fig. 16 was overheated and its value decreased, what would the effect be on the oscillator frequency?

(m) What two types of vacuum-tube multivibrators are used in TV receivers?

(n) If in Fig. 17 $C_1 = C_2$ and R_1 is three times larger than R_4, which of the waveforms shown in Fig. 18 will the output taken from V_{1B} look like?

(o) What parts determine the oscillator frequency in Fig. 19?

(p) What purpose do C_2 and L_1 serve in Fig. 20?

(q) Through what path does C_2 in Fig. 22 discharge?

(r) What are the two methods of synchronizing the sweep oscillators in a TV receiver?

Magnetic Deflection Amplifiers

The purpose of the deflection amplifiers (horizontal and vertical output stages) is to produce sawtooth current waves in the deflection coils. The deflection coils are attached around the neck of the tube so that their magnetic fields penetrate the glass envelope and deflect the electron beam. The excitation or drive for the deflection output stages is the modified sawtooth voltages generated by the sawtooth oscillators.

The deflection or sweep output stage is similar in some respects to an audio output stage. It consists of a power amplifier and an output transformer system in which the current change in the output stage causes a substantial current change in the deflection coil. The large current change is necessary to create a changing magnetic field of sufficient strength to deflect the scanning beam as it passes along the neck of the picture tube toward the screen. Since the horizontal scanning rate is much higher in frequency than the vertical scanning rate, much more output power is required for horizontal than for vertical deflection. In addition, at the higher-frequency horizontal rate, there are added circuit and transformer losses to be overcome.

To obtain the necessary peak efficiency in the deflection output circuits, a transformer or an autotransformer arrangement, as shown in Fig. 28, is used to reflect the proper load to the output stage from the low-impedance deflection coils.

The technician must realize that the high efficiency and high power required by the output stages make them subject to defects caused by minor disturbances

Fig. 28. Basic deflection amplifiers (A), using an auto-transformer for output; (B), using a transformer for output.

in the operation of the sawtooth generators or in the power supply system of the television receiver. Low excitation or low voltages in the deflection output circuit influence the size and linearity of the picture. A very common defect in older television receivers that use a rectifier tube or a selenium rectifier is a weak rectifier tube or selenium rectifier in the low-voltage power supply. The low-voltage power supply is the first place to look for trouble when the picture does not fill the entire screen. A power supply defect can cause an appreciable change in picture size with just minor fluctuations in line voltage, whereas if the power supply is operating properly, the line voltage changes usually will not cause any noticeable change in the picture. Even in later model sets that use silicon rectifiers, low capacity in the input filter capacity may upset the operation of the power supply substantially and this in turn may reduce the size of the picture.

TRAPEZOIDAL WAVES

Since the deflection field in an electromagnetic system is proportional to the current through the coils, we need a sawtooth current to produce the proper deflecting action. Because a coil resists sudden changes in voltage, such a sawtooth current cannot be produced by applying a sawtooth voltage to the coil. Let's see what shape the applied voltage must have to make the coil current a sawtooth current.

Let's suppose we have a perfect coil (no resistance) as shown in Fig. 29A and want the sawtooth current shown in Fig. 29B to flow through it. If we apply a dc voltage (Fig. 29C) to the coil the current through the coil will build up as shown in Fig. 29D. The rate at which this current rises depends on the inductance, on the voltage, and on how long the voltage is applied. In a perfect coil, this current could reach infinity if the voltage were applied long enough.

If we apply the voltage for just a short period of time and then cut it off for an equal period of time (Fig. 29E), we will get the triangular current flow shown in Fig. 29F. We can change this into a sawtooth current by finding some way of making a right-hand edge of the wave more nearly vertical.

A voltage having the form shown in Fig. 29G will do the trick. The high, short negative pulse will make the coil current drop suddenly, producing the sawtooth current in Fig. 29H.

The voltage shown in Fig. 29G is very similar to the output from a blocking oscillator or multivibrator. Therefore, if the output of one of these devices could cause enough current to flow, and if the coil had negligible resistance, we would get a sawtooth coil current by driving the coil directly by a blocking oscillator or multivibrator.

However, the coils with which we are dealing have appreciable resistance (which, as we shall show later, is needed to damp out oscillations). A practical coil, therefore, is like the combination shown in Fig. 30A.
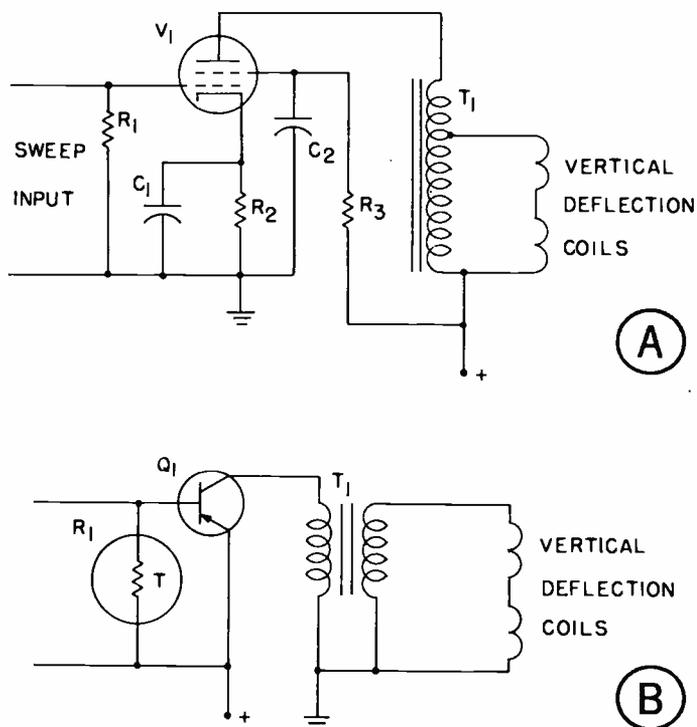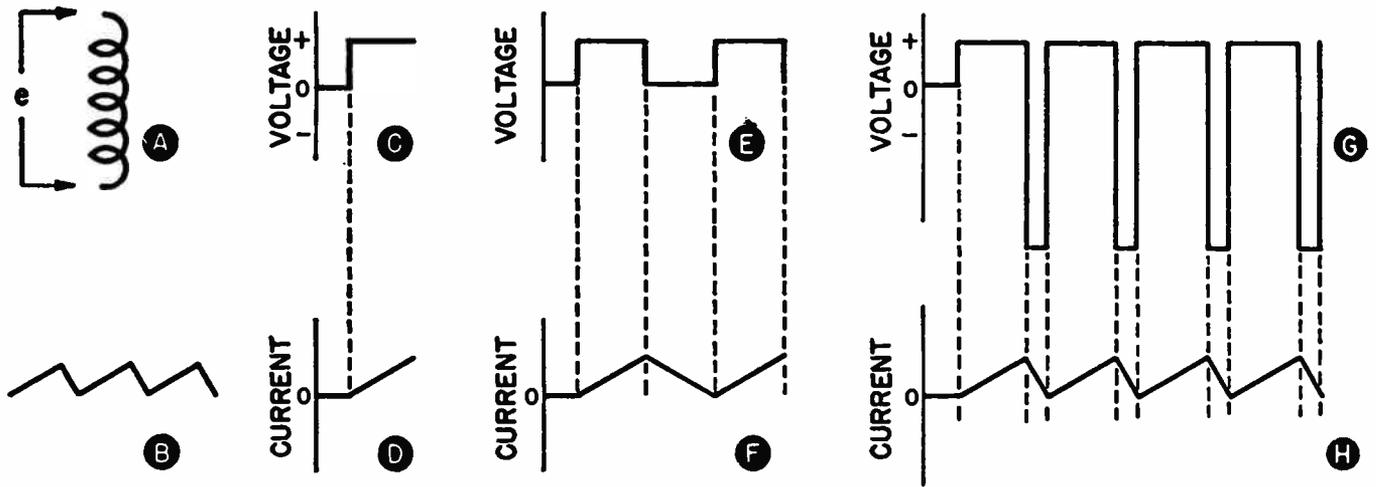
Fig. 29. How a sawtooth current can be made to flow in a perfect coil.

A voltage having a rather unusual waveshape must be applied to get a sawtooth current to flow through this combination. A voltage having the form shown by curve 1 of Fig. 30B must be used to create a sawtooth current in an inductance, and one having a shape shown by curve 2 must be used to create such a current in a resistance; therefore, the two voltages must be combined, producing the "trapezoidal" wave shown in Fig. 30C, to create a sawtooth current through a combination of inductance and resistance.

The proportion of pulse voltage to sawtooth voltage needed in the trapezoidal wave depends on the relative proportions of inductance and resistance in the coil. Therefore, the circuits used to shape this trapezoidal wave must be designed to suit the particular deflection coils to be used with them and may be widely different in parts values in different receivers.

VERTICAL DEFLECTION SYSTEM

Since the vertical deflection coil must produce a linear deflection at a low frequency, the vertical deflection coils will have a higher inductance and higher resistance than the horizontal deflection coils. In the modern receiver, the excitation voltage for the vertical output stage consists of both a pulse and a sawtooth component. A vertical deflection output stage fed by a sawtooth oscillator is shown in Fig. 31. The modified pulse-sawtooth wave is formed across capacitor C_1 and resistor R_{1B}. This combined waveform is coupled through capacitor C_2 to the grid of the vertical output stage. A long time-constant grid circuit is required to prevent misshaping of the low-frequency vertical sawtooth.

The output of the vertical sawtooth amplifier is
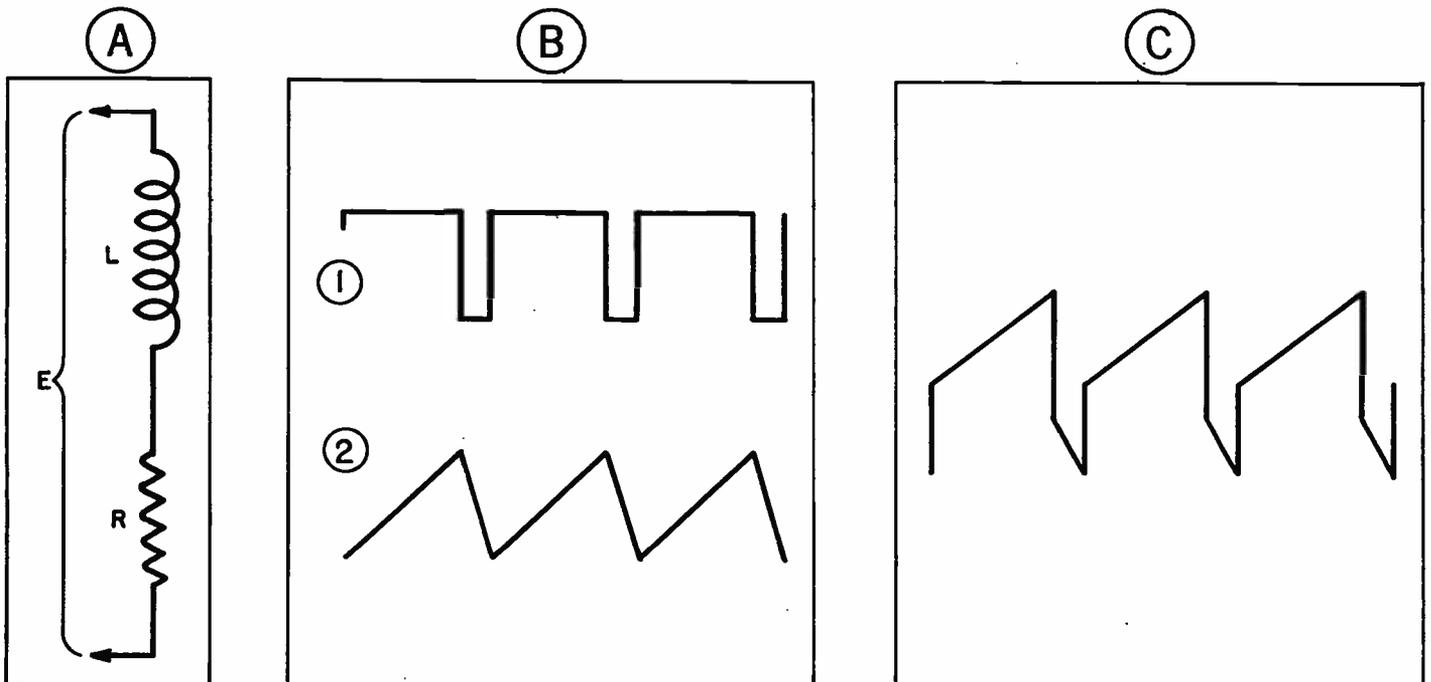
Fig. 30. A trapezoidal voltage wave must be applied to a practical coil to produce a sawtooth current.
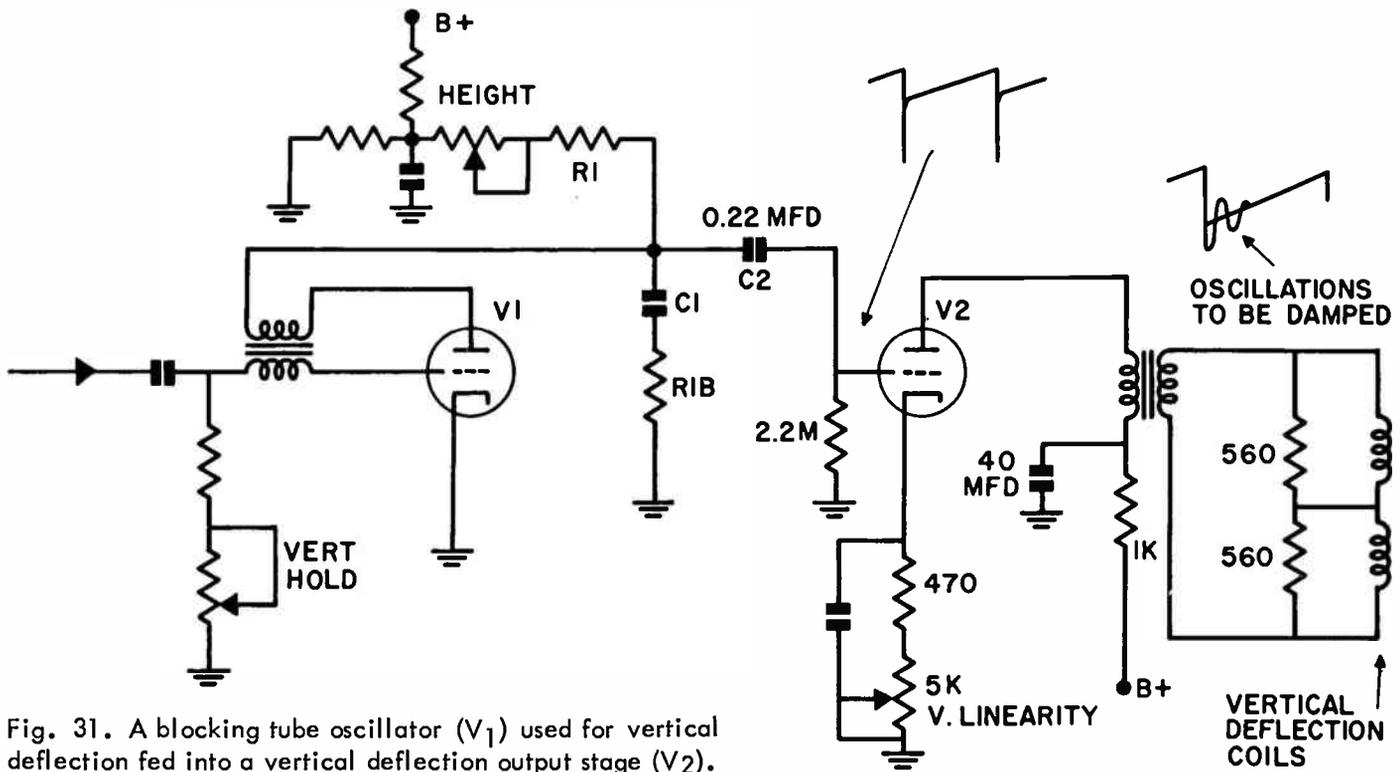
Fig. 31. A blocking tube oscillator (V₁) used for vertical deflection fed into a vertical deflection output stage (V₂).

transformer-coupled to the vertical deflection coils. The transformer ratio is chosen to reflect the proper load to the output tube from the low-impedance deflection coil. During the long trace period of the vertical deflection cycle, it is possible that the sawtooth may curve instead of riding linearly because of the non-linear charge on the sawtooth-forming capacitor, or because of poor low-frequency response in the coupling circuit. To correct for any distortion that might occur in the vertical trace, a vertical linearity control is inserted in the cathode circuit of the vertical output tube.

The vertical linearity control, as shown in Fig. 32, permits the biasing of the vertical output stage on the non-linear part of the characteristic curve. By moving this bias point with the linearity control, it is possible to choose a point of curvature on the curve that will match the rounding of the applied sawtooth wave.

Therefore, a linear sawtooth is developed at the plate of the output tube, with the non-linearity of the tube compensating for the non-linearity in the shape of the grid sawtooth wave.

At times, distortion of the sawtooth occurs in the deflection output system, and the linearity control must adjust the shape of the sawtooth wave before the actual distortion occurs. Although you might think that if the sawtooth applied to the grid of the amplifier is linear no linearity control would be necessary, the linearity system may be necessary to correct for distortion later in the deflection system.

In some vertical output circuits the low side of the peaking resistor is often returned to the cathode of the vertical output amplifier, as shown in the optional connection of Fig. 32. This connection picks up a low amplitude waveform at the cathode circuit, which has an opposite curve to that of the generated sawtooth
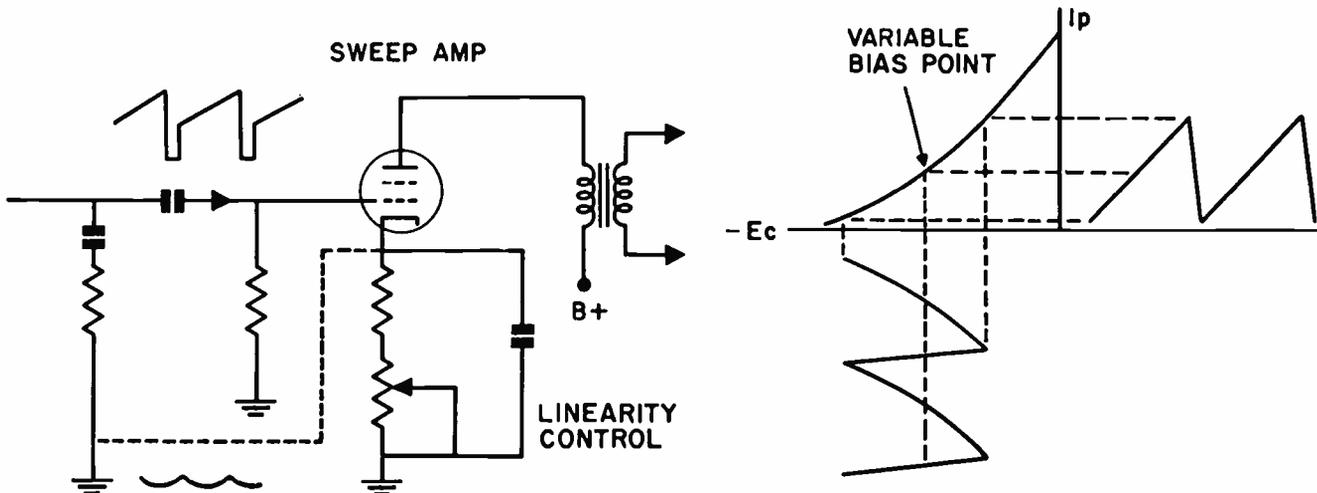
Fig. 32. A curve in the trace portion of the sawtooth current may be eliminated by adjusting the linearity control to select the proper bias point on the sweep amplifier transfer curve.
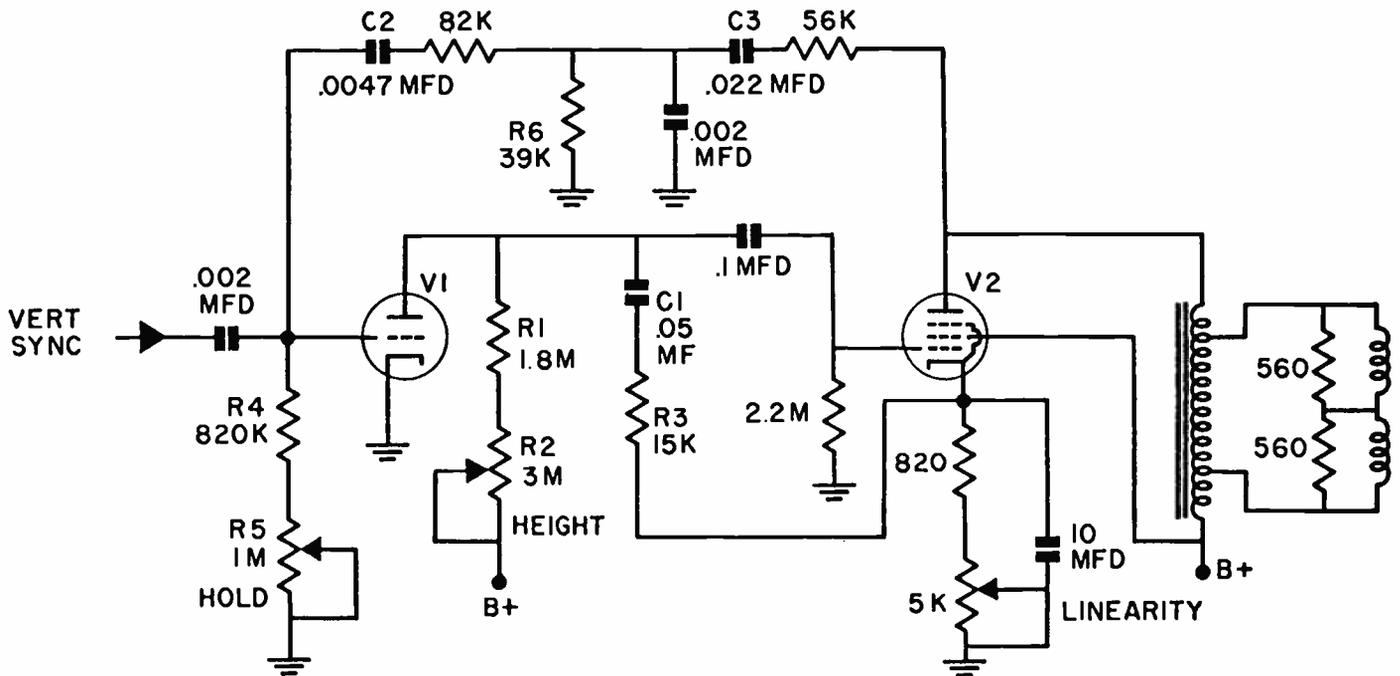
Fig. 33. The pentode section of a multivibrator (V₂) also serves as a vertical output stage.

wave. The addition of the two components through the feedback connection produces further improvement in the sawtooth linearity.

With a linear sawtooth applied to the grid of the vertical output amplifier, the plate current of the tube rises linearly, resulting in the transfer of the combined waveform to the secondary of the output transformer. However, the step-down transformer (the voltage is stepped down but the current is stepped up) can have a ratio of approximately 10-to-1. Therefore, a change in sweep amplifier plate current might result in a change ten times as large in the secondary of the output transformer. Thus, at the time that the applied sawtooth has reached its peak, a very high peak current is flowing in the deflection coil, and a strong magnetic field surrounds the coil. At the peak of the sawtooth wave, the grid excitation is removed suddenly as the tube falls to cutoff. Consequently, there is no energy to support the magnetic field surrounding the deflection coil, and it collapses rapidly. In so doing it starts the vertical retrace, which reshapes the vertical deflection field quickly. However, the rather high resistance and inductance in the deflection coil circuit extend the retrace time so that it continues over an appreciable segment of the vertical blanking period.

The rapid collapse of the magnetic field can cause high amplitude oscillations at the self-resonant frequency of the deflection circuit. To prevent these oscillations from being generated and continuing over into the trace portion of the vertical period, some damping is required; otherwise the oscillations could cause non-linearity in the vertical scanning cycle.

You have learned that the strength and the duration of oscillations depend on the Q of the resonant circuit across which they occur. Also you know that the insertion of resistance in a resonant circuit can lower the Q, and if the Q is made low enough, it can stop

the oscillations abruptly. Serious oscillations in the vertical deflection circuit can be reduced by the insertion of resistance. The vertical deflection coils are shunted by damping resistors connected across the coils and also by the low resistance of the output tube which begins to conduct again soon after the magnetic field collapses. The resistance damping is such that the oscillations are suppressed, but the loading is light enough to permit full vertical retrace to occur during the vertical blanking period.

Multivibrator Output.

In the early TV receivers, a blocking oscillator followed by a separate pentode or triode amplifier was used in the vertical sweep circuit. In modern TV receivers with vacuum tubes, a multivibrator is used that consists of a combination sawtooth generator and deflection output stage. The multivibrator consists generally of a triode first section and a pentode second section, as shown in Fig. 33. The pentode second section serves as one half of the multivibrator and as the vertical deflection output stage.

The triode section serves as the frequency-controlling and sawtooth-forming stage; the pentode, in addition to driving the deflection coil circuit, serves as the feedback tube for the multivibrator section. As you can see from Fig. 33, the circuit is a plate-coupled multivibrator. The sawtooth-forming circuit consists of capacitor C_1, which charges through resistor R_1 and the height control R_2. Resistor R_3 serves as the peaking element to form the modified sawtooth waveform used to excite the grid of the output section. The peaking resistor is returned to the cathode of the output tube to improve linearity. Linearity can be adjusted precisely with the cathode-bias control.

The frequency of the multivibrator is determined mainly by the grid time constant of the triode section, consisting of capacitor C_2, resistor R_4, and the fre-
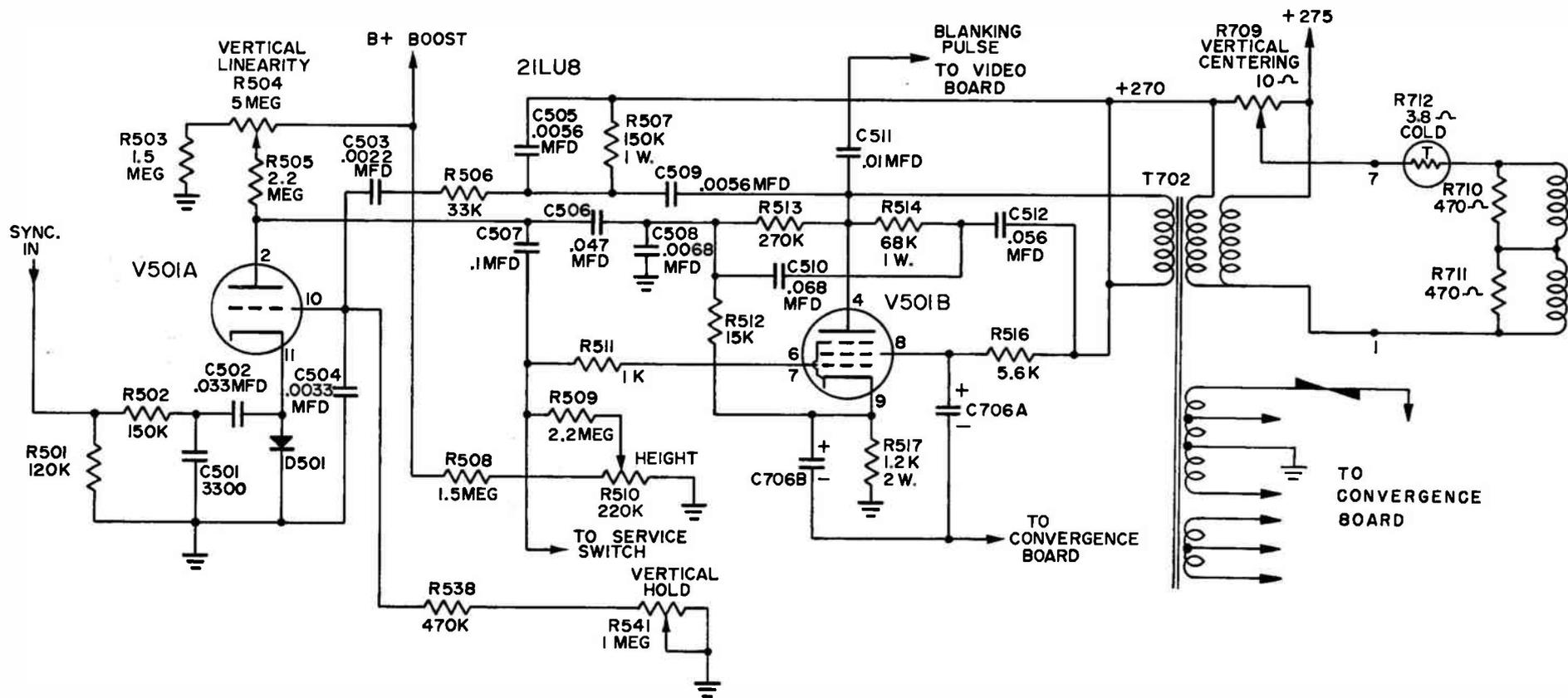
Fig. 34. Multivibrator type sweep from a color TV receiver.

quency control potentiometer R_5. This time constant determines the discharge time of capacitor C_2; and therefore the length of time that the triode is held cut off. During the cut-off period of the triode section, the sawtooth wave is present on the grid of the pentode, and the tube plate current is increasing linearly.

The output of the pentode section is coupled through the vertical output transformer to the vertical deflection coils.

Since the waveform at the plate of the pentode is trapezoidal, it is differentiated by capacitor C_3 and resistor R_6 so that only the pulse portion is fed back to the grid of the first section. This pulse is of proper polarity to support the feedback cycle during the conduction time of the first tube. When the triode section conducts, capacitor C_1 discharges, and the retrace portion of the generated sawtooth wave is formed. In addition to forming the feedback pulse, the network between the plate of V_2 and the grid of V_1 attenuates the pulse section, and shapes it so as to establish the best synchronization with relation to the incoming vertical sync pulses.

During the trace portion of the vertical sweep, in the circuit shown in Fig. 33, V_1 is cut off and V_2 is conducting. To start the trace V_1 must be brought into conduction. With the sync signal fed to the grid of V_1, this will require a positive sync pulse. The output from most sync separators is negative so a sync inverter stage is used between the sync separator and the vertical input to get the correct polarity sync pulse. In some receivers, to avoid the necessity of this additional stage, the sync pulse is fed into the plate circuit of V_1. However, this does not provide as positive a sync as feeding the sync signal into the grid does, and therefore with the multi-function tubes available today it is just as easy to use a tube such as a compactron that contains an extra stage in the same envelope and use this stage to invert the sync signal so it can be fed into the grid circuit.

Color TV Vertical Sweep.

Another multivibrator circuit quite similar to the circuit of Fig. 33 is shown in Fig. 34. This is the vertical-sweep from a color TV receiver. Again, we have a plate-coupled multivibrator; the signal from the plate of the V501A is fed through C507 and R511 to the grid of V501B. The signal from the plate of V501B is fed through C509, R506 and C503 back to the grid of V501A.

Notice that in this circuit the sync signal is fed into the cathode of V501A. The sync signal is a negative-going pulse and it drives the cathode in a negative direction. This has the same effect as driving the grid in a positive direction: it increases the potential between the grid and cathode, making the grid positive with respect to the cathode, so that the stage is brought into conduction. The diode, D501, is placed in the circuit so that the tube current can flow through the diode. It will flow from B- to the cathode of the diode and encounter little or no opposition since this is the direction in which the diode will conduct. However, when the sync pulse is applied to the cathode, it will make the anode of the diode negative so the diode acts as a high impedance and does not short out the sync pulse.

You'll notice that in the deflection-yoke circuit there is provision for vertical centering. Adjusting the vertical centering varies the dc current that will flow through the deflection coil. This varies the fixed field and hence will move the raster in a vertical direction. The 3.8-ohm thermistor R712 is used in the sweep circuit to improve linearity.

Notice that in addition to the winding connected to the vertical-deflection coils we'll also have a number of leads going to the convergence circuit. The purpose of the convergence circuits is to keep the three electron beams landing on the correct cluster of phosphor dots. The electron beam is converged in the center of the picture by means of permanent magnets; we call this static convergence. The dynamic convergence keeps the beams adjusted on the outer edges of the picture. The signals taken from the secondary of T702 are used for this purpose. We'll go into convergence circuits later in this lesson.

The important thing for you to notice when you study Fig. 34 is that it is really quite similar to the circuit shown in Fig. 33. In both cases we have a multivibrator. We have a triode in the first stage and a pentode in the second stage and the pentode serves as the vertical output stage.

Before leaving the circuit shown in Fig. 34 it might be well to point out that a pulse is taken from the plate of V501B and fed through C511 back to the video circuit. The pulse is a high-amplitude positive pulse that is produced at the plate of V501B when the tube is cut off. This of course occurs at the start of the retrace. This high-amplitude pulse is fed to the cathodes of the tricolor tube and the positive pulse cuts off the three guns so that the vertical retrace does not appear on the screen.

A transistorized vertical-sweep circuit is shown in Fig. 35. This circuit uses a blocking oscillator as the vertical oscillator – we have already described the operation of this oscillator in detail. It is the oscillator shown in Fig. 16. If you forget how this oscillator operates you should go back and review the discussion of Fig. 16.

The output from the oscillator is a sawtooth wave which is fed through C_2 to the base of Q_2. Q_2 is called the driver and it is used in an emitter-follower circuit. You will remember that the emitter-follower or common-collector circuit, as it is sometimes called, has a high input impedance and a low output impedance. Therefore, the high input impedance of the driver stage prevents loading of the oscillator, and at the same time the low output impedance provides a good match to drive the vertical-output transistor Q_3.

Notice that a signal is fed from the emitter of the vertical-output transistor through R_{10} and R_9 to the junction of C_3 and C_4. The sawtooth developed by the vertical oscillator will appear across C_3 and C_4. This sawtooth will have somewhat of an exponential waveform, which would result in vertical distortion. A signal is fed from the emitter of Q_3 back to the junction of C_3 and C_4 to correct the waveform and provide the correct waveshape for the driver in order to get the best possible linearity. The resistor R_9 is the vertical-linearity control in the circuit.
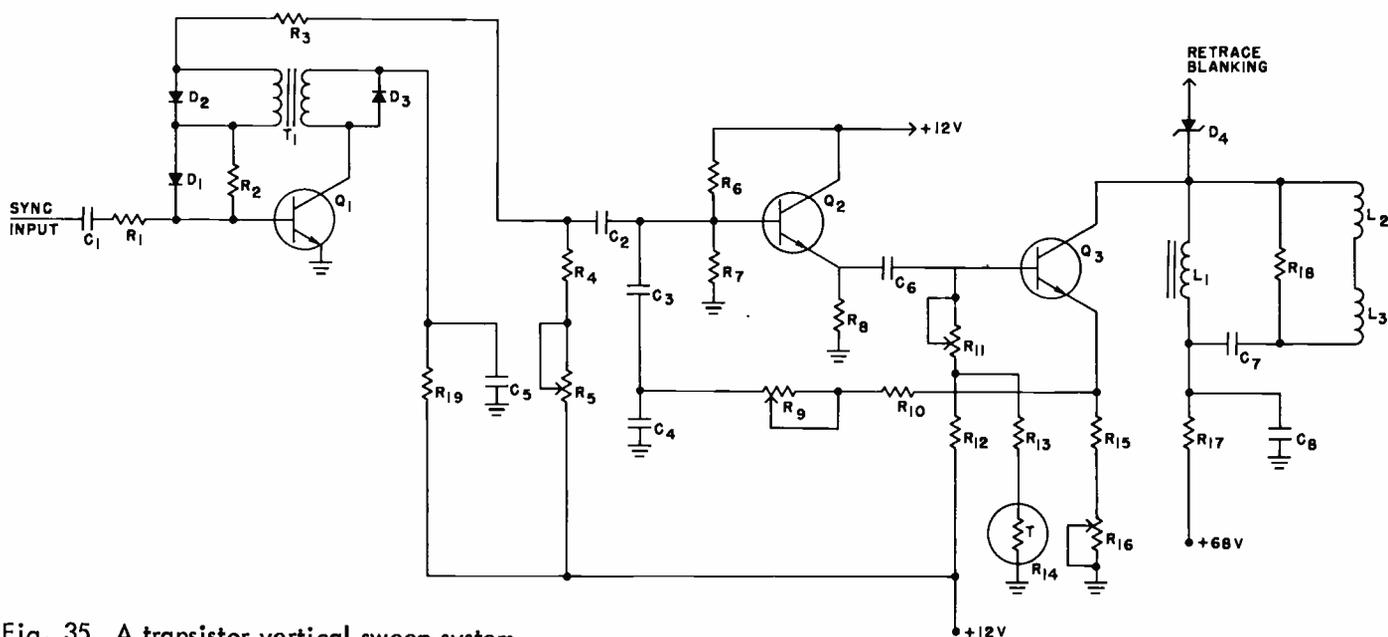
Fig. 35. A transistor vertical sweep system.

The output from Q_2 is fed through C_6 to the base of the output transistor Q_3. Notice that the output transistor gets its forward bias through R_{12} and R_{11}. The setting of R_{11} is quite critical; the output transistor must pass the correct collector current, otherwise the vertical linearity would suffer. R_{11} is provided so that the bias on the transistor can be adjusted to give the correct collector current. Collector current can be measured by placing a milliameter across R_{17}. R_{17} is a 22-ohm resistor; normal collector current is 120 milliamperes. If you connect a milliameter having a range of about 200 milliamperes across R_{17}, it will have such a low resistance that all the current will flow through the milliameter and little or none through R_{17} so you can measure the collector current in this way.

Notice that the resistor R_{11} through which the bias is applied to Q_3 connects to the junction of a network made up of R_{12}, R_{13} and R_{14}. R_{14} is the thermistor. This thermistor is mounted close to Q_3. As the temperature of Q_3 increases, the collector current through the transistor will have a tendency to increase. However, if Q_3 increases in temperature, it will cause the temperature of R_{14} to increase also because it is mounted close to it. This will cause the resistance of R_{14} to go down and as a result the voltage at the junction of R_{12}, R_{11} and R_{13} will go down. This will reduce the forward bias applied to the output transistor, Q_3, and tend to keep the collector current constant.

Collector current can also be varied in Q_3 by the setting of R_{16}. The more resistance there is in this circuit the more degeneration there will be in this circuit and hence the lower the amplitude of the sawtooth current developed in the output. Thus R_{16} is the height control. In the actual receiver R_{15} and R_{16} are all one potentiometer. There is a step in the potentiometer so that there is minimum resistance in the circuit at all times. In the event that you have to service a receiver of this type and find the control open, it might be easier to use separate resistors as replacements, as shown in Fig. 35.

The dc current is kept from flowing through the deflection coils by means of the blocking capacity of C_7. This capacitor provides low impedance to the sawtooth current waveform, but prevents dc from flowing through the coils. The dc will flow through the choke L_1 which has a high inductance so that there will be no ac current flow through it. There is no output transformer required in the stage because the output impedance of Q_3 is comparatively low and the deflection coils L_2 and L_3 provide a reasonable match for the collector circuit of the transistor. The resistor R_{18} is the usual damping resistor across the deflection coils to prevent oscillation.

A blanking pulse is taken from the collector of Q_3 and fed to the video amplifier for vertical retrace blanking. A zener diode, D_4, is used for this purpose. The diode has a breakdown voltage of approximately 100 volts so that until the positive pulse at the output of Q_3 reaches that value there will be no current flow through the diode. Once the pulse reaches this value the diode will break down and the pulse will be fed through it on into the video-amplifier circuit.

Another three-stage transistor vertical sweep using three NPN transistors is shown in Fig. 36. While this circuit is similar to the one shown in Fig. 35, there are enough differences to make it worth studying.

Q_1 is used in a typical blocking-oscillator circuit. When the power is applied, current flows through the transistor Q_1 and through the primary winding of T_1, inducing a voltage in the secondary that will drive the base of Q_1 in a positive direction. This causes the collector current to build up to a high value. At the same time base current flows, charging the capacitor C_1 with the polarity shown. When the collector current reaches saturation there will be no further change in current through the primary of T_1. When this happens, the voltage across the secondary will drop to zero and the negative voltage on C_1 will bias the transistor so that it is cut off. The transistor will be cut-
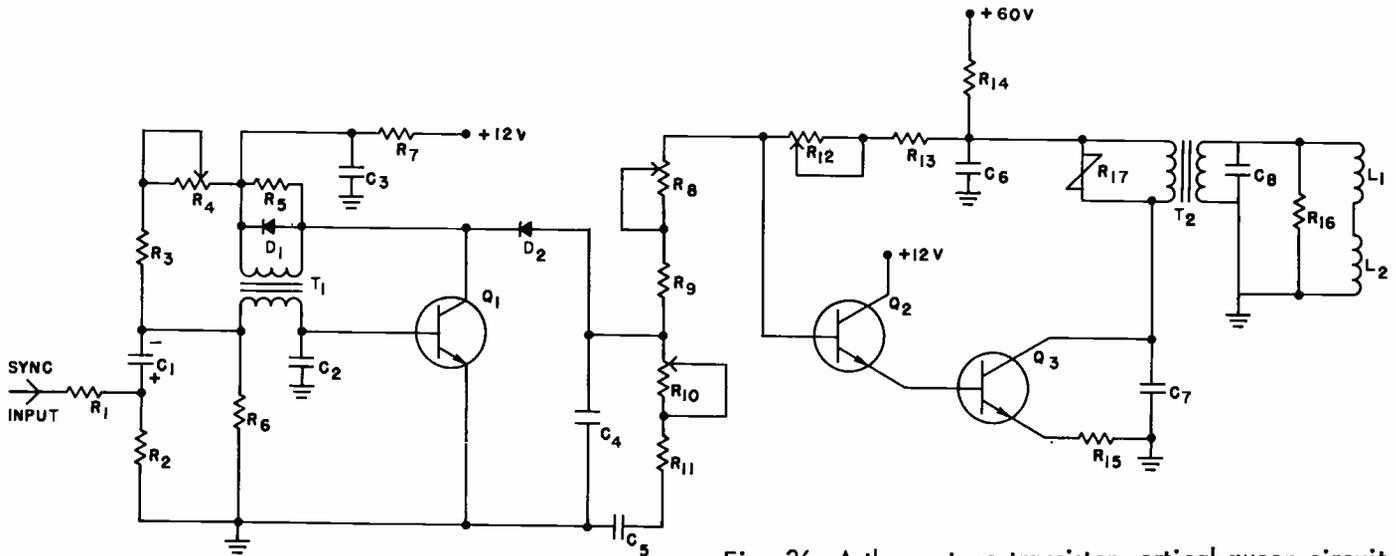
Fig. 36. A three-stage transistor vertical sweep circuit.

off while C_1 discharges through R_6 and R_2. The transistor will be just about ready to conduct when the next positive sync pulse is fed through R_1 and C_1 and the secondary of T_1 to the base of the transistor.

The diode D_1 is placed across the primary of T_1 because when the transistor is cut-off there will be a voltage induced across the primary which will swing the collector voltage highly positive. This might cause the transistor to continue to conduct, but the diode D_1 conducts and discharges the current produced by the field.

The diode D_2 is used to isolate the oscillator from the driver stage Q_2. However, when collector current flows, the collector voltage will swing in a negative direction and when this happens the reverse bias across D_2 will disappear and current can flow through the diode. The negative pulse is shaped by the network in the input circuit of Q_2 to provide the required linearity and is then fed to the base of the transistor. Q_2 is connected in the emitter-follower circuit so the output pulse is a negative pulse. The collector current from the output transistor Q_3 is fed to the primary of T_2 and the primary induces a current in the secondary which flows through the deflection coils L_1 and L_2. Resistor R_{16} across the coils provides loading to prevent oscillation.

In the primary circuit of the transformer you will notice that a resistor, R_{17}, is connected across the primary winding. This is a special type of resistor called a voltage-dependent resistor. As the voltage across the resistor rises the resistance of the resistor decreases. The purpose of this resistor is to load the primary when the transistor Q_3 is cut off at the end of the vertical sweep. When the transistor is cut-off almost instantly a high voltage will be induced in the primary winding of the transformer and this voltage might cause the transistor to break down. The resistor effectively loads the transformer primary to prevent the voltage from building to too high a value.

The vertical sweep circuit from a transistorized color TV receiver is shown in Fig. 37. The sweep is a free-running multivibrator. Q_1 is one transistor in the multivibrator and Q_5 is the other. The transistors

Q_2 and Q_3 are connected between Q_1 and Q_5 but they are used to shape the pulse driving Q_5. The actual feedback between the two stages is between Q_1 and Q_5.

During the trace time Q_1 is cut off and Q_5 will conduct. The trace time is governed by the charging time of the series connected capacitors C_6 and C_7. These are electrolytic capacitors and they must charge through R_9 and R_{10}. When Q_5 is conducting, Q_1 is cut off, and the electron beam has reached the bottom of the picture tube, the positive-going sync pulse arrives at the base of Q_1. This drives the base positive and causes Q_1 to go into conduction. When Q_1 begins conducting the collector voltage will drop and thus a negative pulse will be fed through C_4 and R_6 to Q_2. Q_2 is a PNP transistor and therefore the negative pulse applied to the base drives the transistor into conduction and current flows through the transistor.

Collector Voltage Drops.

At the same time, when Q_1 starts conducting, the collector voltage drops and C_6 and C_7 discharge. The output signal from Q_1 is also fed to the base of Q_3 so the base voltage drops. This causes the emitter voltage to swing in a negative direction and the base of Q_5 swings in a negative direction, cutting off this transistor. When Q_5 is cut off, a high positive pulse is developed in the collector circuit and this is coupled back through C_3 and R_4, R_3 and C_1 to the base of Q_1. All this action happens essentially at the same time so that at the arrival of the positive vertical sync pulse at the base of Q_1 we get almost instantaneously a positive pulse from the collector of Q_5, so that Q_1 is driven to a high level of conduction in a very short time.

When Q_1 is conducting, current will flow from the emitter to the base and will charge C_1 with the polarity shown. This potential on C_1 will cut off Q_1 after the vertical sync pulse and the pulse from Q_5 have disappeared. Meanwhile, the fact that Q_2 is conducting will alter the start of the charge on C_6 and C_7 so that these capacitors do not start to charge until the beginning of the next trace. As the capacitors begin to charge, the positive voltage is fed to the base of Q_3. This causes the emitter of Q_3, which is connected di-
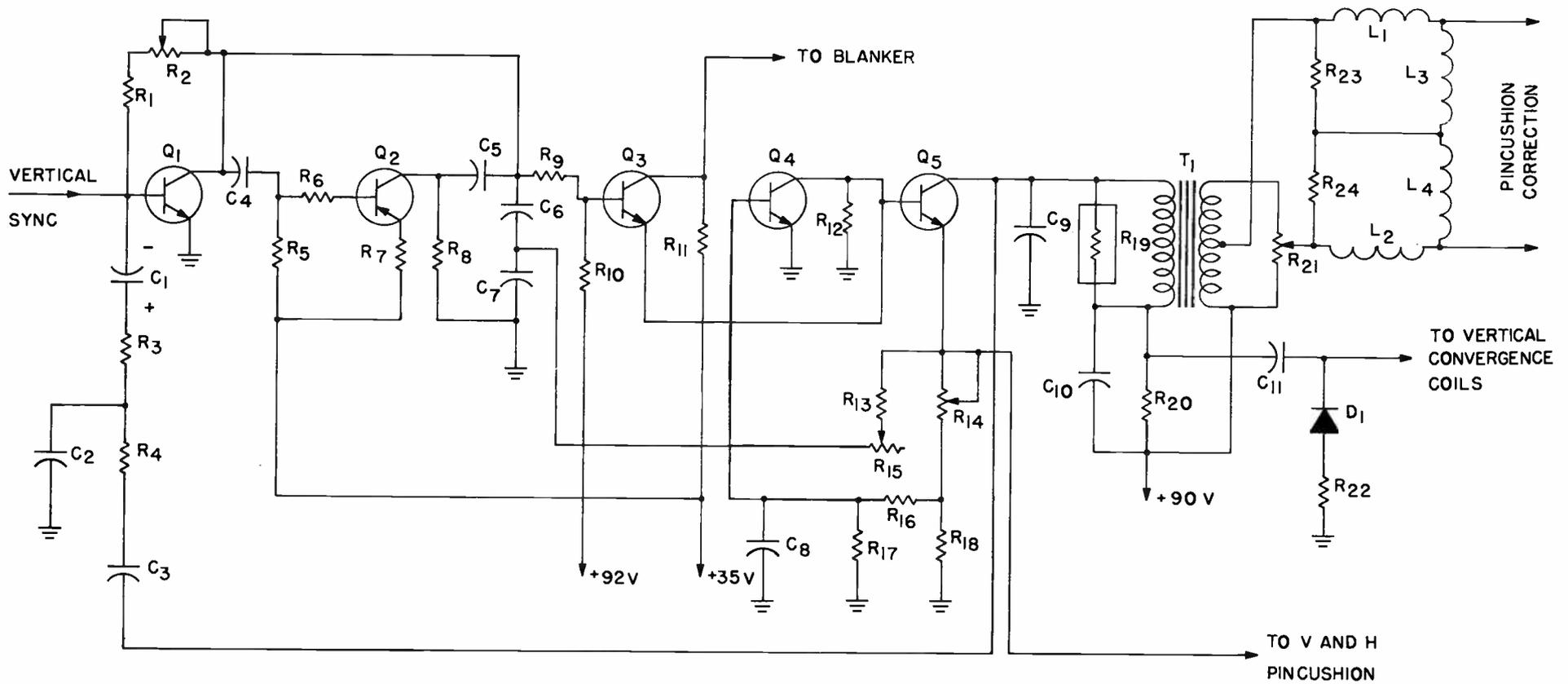
Fig. 37. A transistor vertical sweep for a color receiver.
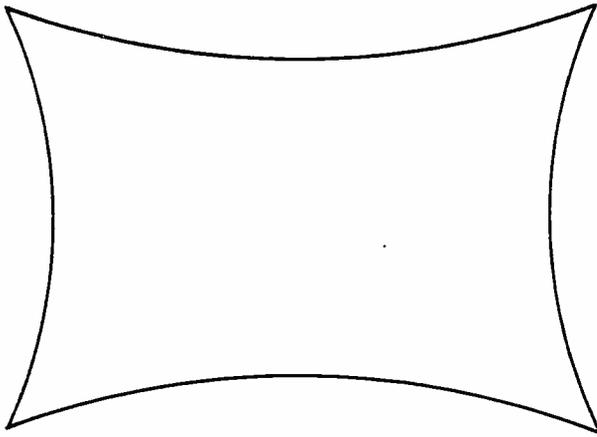
Fig. 38. Curvature on top, bottom, and sides of raster due to pincushion distortion.

rectly to the base of Q_5, to swing in a positive direction. Therefore, the base of Q_5 begins to swing in a positive direction and the sawtooth curve begins to build up through this transistor.

The coils L_1 and L_2 are the deflection coils. Notice they are connected across the secondary of T_1. One end of the two coils connects to the tap on the secondary and the other end connects to R_{21}. R_{21} is the vertical centering control and it varies the dc current through the deflection coils and hence the vertical centering of the raster.

L_3 and L_4 are pincushion-correcting coils. They are driven by a pincushion-correcting circuit. You'll notice that a signal is taken off from the emitter of Q_5 to provide a pincushion-correcting signal. This is fed through an amplifier stage which along with the signal from the horizontal sweep provides the necessary pincushion-correcting signal. The pincushion effect results in a curving of the raster along the outer edges. For example, consider how a raster would look if you took a square raster and then pulled it over a pincushion. The top of the raster would have a parabolically-shaped top which would curve somewhat towards the bottom and the bottom would curve towards the top. Similarly, there would be some curvature on the two sides as shown in Fig. 38. The pincushion-correction circuit is designed to correct this effect which results because of the curvature at the face of the tube.

Also notice that there is a signal taken off from the primary circuit of T_1 and fed to the vertical convergence coil. We'll go into these convergence circuits of color TV receivers later.

R_{19} is a voltage-dependent resistor. When the collector current on Q_5 is cut off almost instantly by the arrival of the vertical sync pulse and the subsequent signal fed to the base of the transistor, a high transient voltage will be developed across T_1. Since this is a positive-type pulse it will tend to keep Q_5 conducting. R_{19} is a resistor whose resistance decreases as the voltage increases. Therefore, when this high pulse is developed the resistance of R_{19} goes down and loads the primary of Q_1, limiting the amplitude of the pulse.

The transistor Q_4 is designed as a current-limiter-stage. Notice that the base of this transistor is connected back to the emitter of Q_5. Any increase in current through Q_5 results in an increase in the voltage applied to the base of Q_4. This will reduce the forward bias on Q_5 and tend to correct for the increase in current through the output transistor.

Separate Multivibrator.

Notice that a signal is taken from the collector of Q_3 and fed to the blanker. In this receiver the blanker is a separate multivibrator which generates a blanking pulse to blank out the three electron beams in the tricolor tube during the retrace period. You will remember that blanking can be accomplished either by feeding a positive-going signal to the cathodes of the tube during retrace time or by feeding a negative-going signal to the grids of the tube.

The vertical-sweep circuit shown in Fig. 37 is actually not a great deal more complex than the circuit that we have described previously. It is simply made up of a number of simple circuits, and if you take these circuits one at a time you can work out the details of the various circuits.

Before leaving this circuit it might be well to mention that the frequency of the vertical discharge or vertical-oscillator stage Q_1 is controlled by the vertical-hold control R_2. The overall size of the raster is controlled by R_{14}, which is called the vertical-size control, and the linearity of the raster by R_{15}. This regulates the size of the pulse fed back to the junction of C_6 and C_7 for linearity correction.

Since this circuit is an important circuit, it would be worthwhile to go over it several times and make sure you understand the various sequences of events that occur in it. If you understand a circuit of this type, you will probably be able to figure out any other transistorized vertical-sweep circuit that you are likely to encounter.

HORIZONTAL DEFLECTION SYSTEM

The horizontal output stage has some basic characteristics that are similar to those of the vertical output stage. However, there are a number of added features associated with the horizontal sweep amplifier. The horizontal output stage is part of the complete horizontal deflection system. This system usually consists of a beam power tube or a power transistor, a horizontal deflection output transformer or direct-drive auto transformer, a damper system, and a high-voltage power supply. In color TV receivers we also have a focus power supply which is usually associated with the complete horizontal deflection system, a high-voltage regulator circuit and convergence circuit.

The horizontal deflection coils present an inductive load to the output stage. The load is not pure inductance -- there is some resistance in the circuit and we must use a modified sawtooth voltage as excitation for the output stage. The impedance of the horizontal deflection coils is comparatively low. Therefore, when the output stage is a vacuum tube, a transformer is used to match the high output impedance of the tube to the low impedance of the deflection coils. When the output
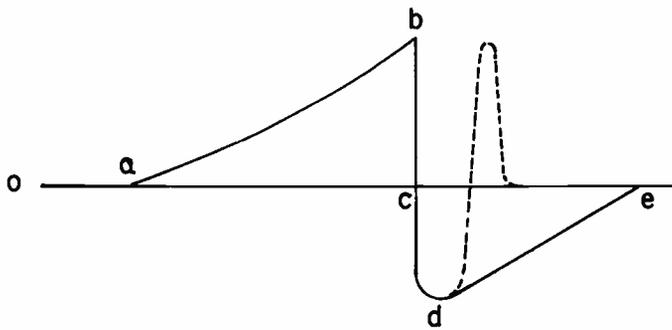
Fig. 39. Damper stage action.

stage is a transistor, often the deflection coils are driven directly by the output transistor. However, an output transformer is still used in transistor receivers, but here instead of using the transformer to match the deflection coils to the output transistor, the transformer is used to develop the high voltage required by the picture tube and other control signals.

The rise of current in the output stage during the sawtooth trace develops a linearly rising current through the deflection coils. At the conclusion of the trace, the horizontal output stage is suddenly cut off and the field built up about the deflection coil collapses. Because this is a strong magnetic field, and the deflection coils along with their distributive capacity are resonant to a high frequency (approximately 75 to 100 kilocycles), the abrupt collapse of the field causes the circuit made up of the deflection coils and its associated components to go into oscillation.

If allowed to run freely until overcome by the circuit resistance, these oscillations will cause distortion in the beginning of the next trace. Therefore, some method of damping this oscillation is essential.

However, the effects of this oscillation are not all bad. At the end of each horizontal line, when the electron beam has deflected over to the extreme right side of the picture tube, we need some method of moving

the electron beam rapidly from the right side of the picture tube back to the left side to start the next line. To accomplish this we permit the oscillation to occur for one half-cycle.

The waveform shown in Fig. 39 is an example of what happens. The curve from a to b represents the current build up in the deflection coils that move the electron beam from the center of the tube to the right edge. When the electron beam reaches the right edge the current will be at point b on the curve. At this instant the current at the output stage is cut off, and the deflection circuit begins to oscillate and goes through one half cycle from b to d. If allowed to continue to oscillate the current would go through the waveform represented by the dashed line. However, at point d we damp out the oscillation and allow the current to slowly decay from point d to point e. This moves the electron beam at a linear rate from the left side of the screen to the center of the picture tube. With this brief explanation of what we mean by damping, let us look at the horizontal output stage shown in Fig. 40.

Provide Linear Sweep.

In the schematic diagram in Fig. 40, we have shown the horizontal output tube V_1, the damper stage V_2, and the high-voltage rectifier V_3. These three stages function together to provide a linear sweep to move the electron beam linearly from the left side to the right side of the picture tube and also to provide the high voltage required to drive the picture tube.

In Fig. 40, the input signal from the oscillator causes the current to V_1 to increase. The increase in current causes the electron beam to move from the center of the tube to the right edge. This is represented by the curve shown from a to b in Fig. 41.

At the instant the current waveform reaches b, the output tube V_1 is suddenly cut off by a negative pulse from the horizontal oscillator. The rapid collapse of current from the output stage causes the deflection coils to oscillate, and the current goes through one half-cycle from point b to point c and moves the elec-
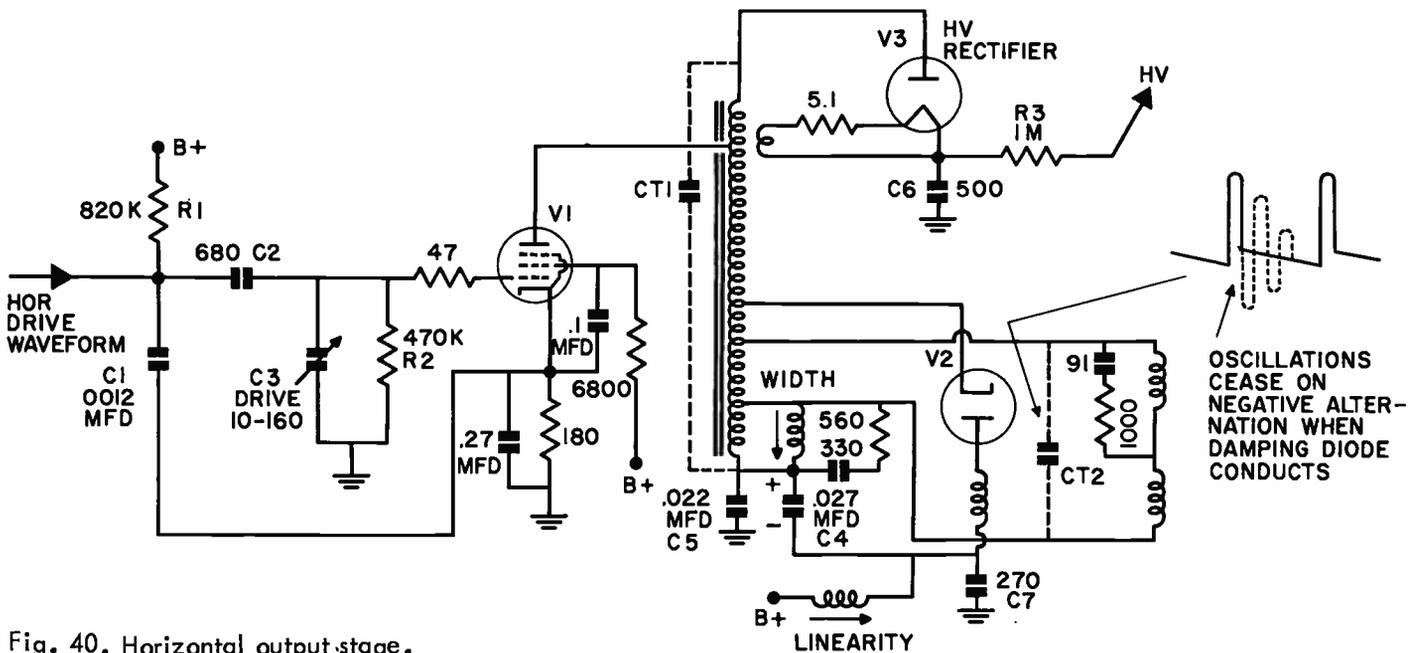
Fig. 40. Horizontal output stage.
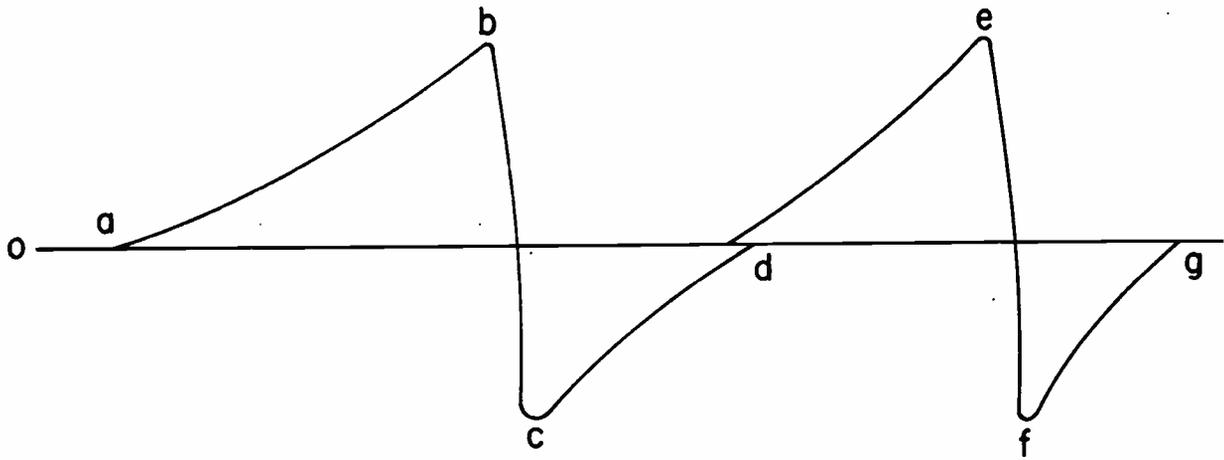
Fig. 41. Current waveform in the deflection circuit.

tron beam from the right side of the picture tube to the left side.

Inductive Coils.

The waveform shown in Fig. 41 is a current waveform. The deflection coils are primarily inductive and therefore the voltage across the two coils will lead the current by 90°. Thus, when the current reaches point c, which is its maximum negative value, the polarity of the voltage across the deflection coils will be such that the plate of the damper tube starts to go positive with respect to the cathode. In other words, the voltage waveform will be 90° ahead of the current waveform and even though the current is at its maximum negative value, the voltage will be at zero and starting to go positive. As a result, the damper begins to conduct, loading the circuit and producing a current change through the deflection coils shown from c to d in Fig. 41. By the time the current reaches point d, which is zero current, the output stage begins to conduct again, and once again the current builds from d to e.

The trace from c to d is slightly concave in one direction and the trace from d to e is concave in the other direction. The net effect is that the two tend to cancel so we get essentially a linear current change from point c to point e. Therefore, the electron beam is moved at a linear rate from the left side of the picture tube (which represents the current at point c) to the center of the tube (which is represented by the current at point d) on over to the right edge of the picture tube (which is represented by the current at point e).

The rapid collapse in current in the deflection coils and in the horizontal output transformer induces a very high voltage in the transformer. This transient or high induced voltage causes the plate of V3 to become highly positive. Therefore, V3 conducts and charges the capacitor C6 to a high value. The voltage across C6 is used as the high voltage to operate the picture tube. The actual voltage that will be developed will depend upon the number of turns on the horizontal output transformer. If the high voltage winding on the transformer has a sufficient number of turns, voltages of 25,000 volts or more can easily be produced.

Another horizontal output, damper and high-voltage

rectifier circuit is shown in Fig. 42. This is the horizontal output stage for a color TV receiver. Notice that at first glance, from the schematic diagram, it is not too different from the circuit shown in Fig. 40.

The horizontal oscillator input signal is fed through C525 to the grid of the horizontal output tube V701. A variable bias voltage which controls the current through the horizontal output tube and hence the amplitude of the high voltage developed is fed through R531 and R530 to R701 and to the grid V701. You will study the operation of high voltage regulator circuits later when you study power supplies in detail.

The output from the horizontal output tube is fed to the horizontal output transformer. The transformer steps down the high impedance from the output tube to match the low impedance of the deflection coils marked L701D and L701C on the diagram. The capacitors across the deflection coils are used to tune the coils to resonance so that they will oscillate at about 75 kc. This will provide the rapid retrace required to get the electron beams from the right side of the picture tube back to the left side. The horizontal centering control provides a method of varying the dc flowing through the horizontal deflection coils, and this in turn will enable you to move the raster in a horizontal direction.

The damper, V703, damps the oscillation of the deflection coils after one half-cycle of oscillation. The coils L702 and L703 in the damper circuit are used to prevent any oscillation in the damper itself.

Notice that there is a high-voltage winding on the horizontal output transformer T701; this winding is connected to V702, which is the high-voltage rectifier tube. A voltage of approximately 22,000 volts is developed at the output of this rectifier and fed to the picture tube. Notice that there is no capacitor connected between the cathode of the high-voltage rectifier and ground. The aquadag coating on the picture tube forms this capacity.

There is an aquadag coating on the glass on the inside of the picture tube and another aquadag coating on the glass on the outside. The coating on the inside of the picture tube connects to the high-voltage output from the rectifier tube and the coating on the outside is grounded. Thus the picture tube itself forms a ca-
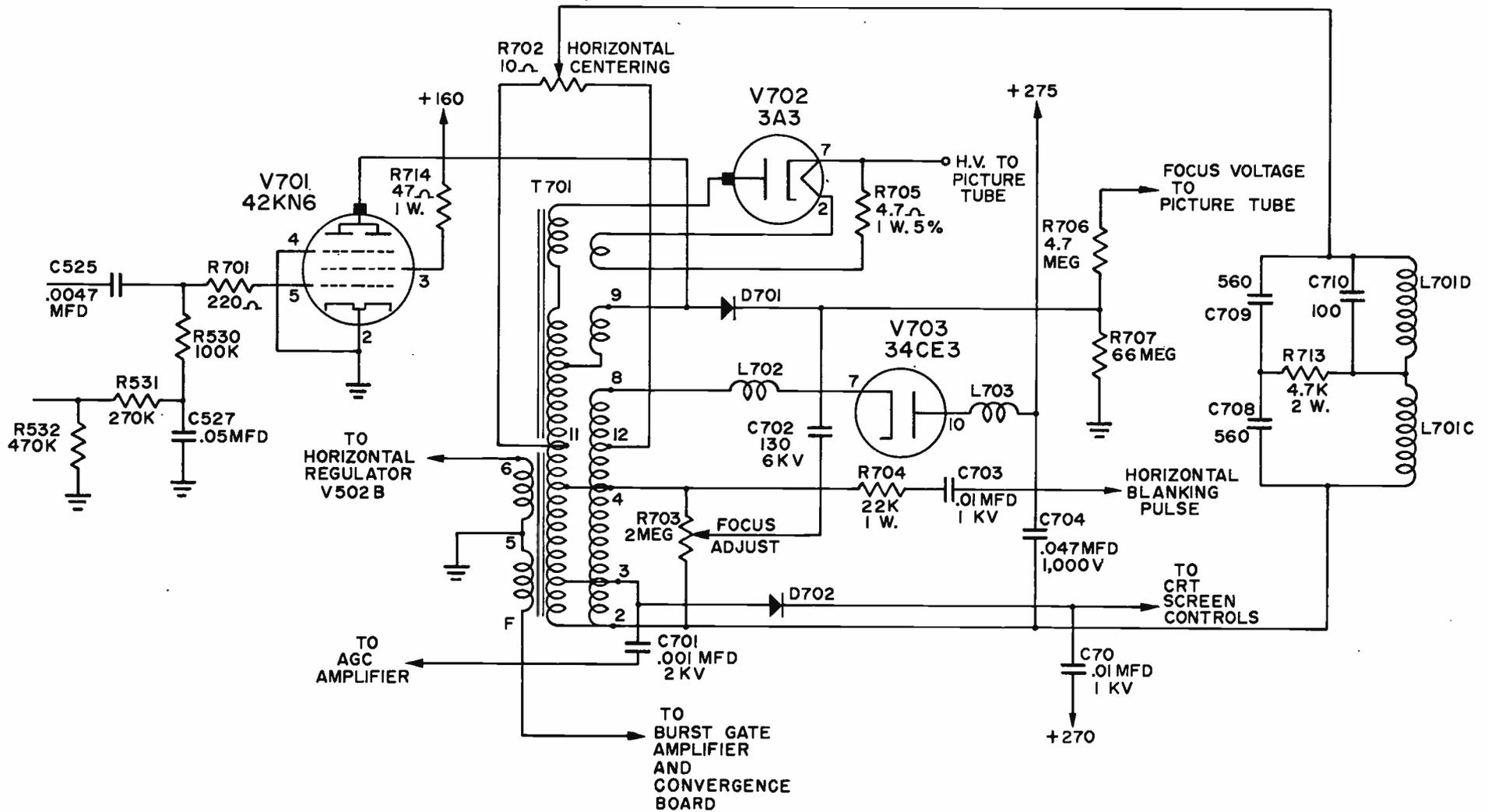
Fig. 42. The horizontal output, damper, and high-voltage rectifier stages.

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pacitor, the two coatings acting as the plates of the capacitor and the glass as the insulation.

Notice that the filament voltage to operate the rectifier tube is obtained from the winding on the horizontal output transformer. This is common practice. Usually, this winding consists of a one or two-turn winding around the transformer core. The 4.7-ohm resistor, R705, in the heater circuit is placed there to limit the current through the tube heater to prevent its burning out.

In addition to the high voltage for the second anodes of the picture tube, we also develop a voltage of several thousand volts for the focus electrode. This voltage is developed by the focus rectifier D701. During the retrace interval when there is a high positive pulse induced at terminal 9 of the horizontal output transformer, the diode conducts and develops a voltage of several thousand volts across C702 and the 66 megohm resistor R707. This voltage is fed through R706 to the focus electrode. The amount of voltage developed across C702 can be varied by varying R703. C702 is connected to the center terminal of the focus voltage adjustment control R703. By moving the position of the center terminal the voltage applied to the rectifier circuit can be varied and hence the focus voltage developed can also be varied.

The other circuits taken off the horizontal output circuit all perform a definite function. We'll take these functions up later and then you'll see why these extra windings are placed on the transformer and why these extra leads are taken off. The main part of the circuit that we want you to see and understand at this time is the horizontal output stage and the action of the damper circuit.

Autotransformer Type.

The horizontal output system of another color TV receiver is shown in Fig. 43. In this circuit V_1 is the horizontal output stage and connects to the tap marked 1 on the transformer. The lower end (the tap marked 6) represents signal ground potential so that the current supplied by the tube flows from terminal 1 down to terminal 6. The transformer is an autotransformer type and the deflection coils are connected between terminals 4 and 6. The center tap of the deflection coil is connected to tap 5. Thus the low-impedance deflection coils are connected between terminals 4 and 6 and the high-impedance output of the tube between terminals 1 and 6.

The damper stage operates essentially as the damper described previously: when the plate of the tube goes positive, the tube will conduct and the oscillation of the deflection coils damp out. The coil marked L_{14} is called the horizontal efficiency coil. By properly adjusting this coil, the current through the horizontal output tube can be kept at the correct value to obtain best efficiency in the horizontal output stage.

In this receiver a vacuum tube is used as the focus voltage rectifier, V_3 in this case. The voltage developed between terminals 2 and 6 during the flyback interval is fed to the plate of V_3. The tube will conduct and the voltage taken off at the adjustable tap on potentiometer R_9 is supplied to the focus electrode on the picture tube. The filament voltage required by the

focus rectifier is developed by the winding L_9 on the horizontal output transformer.

The high voltage is developed by the high-voltage rectifier V_4. Notice the additional turns on the transformer to obtain the high positive voltage needed during retrace to develop the approximately 25,000 volts required to operate the picture tube in this receiver. The high voltage is taken from the filament of the rectifier tube and fed through R_{19} to the picture tube.

V_5 is the high-voltage regulator tube. This tube keeps the high voltage at a constant value. The setting of R_{16} will control the amplitude of the high voltage and changes will be kept constant by V_5. We'll go into the operation of this circuit later when you study high-voltage power supplies.

Various pulses are taken off the winding L_7. These pulses and their uses will be discussed later.

Before leaving this circuit, notice the similarities and differences between the circuits shown in Fig. 42 and 43. They both accomplish the same thing. Insofar as the output stage, deflection coils and high-voltage rectifier circuits are concerned they are essentially the same. However, in one set we have a solid focus rectifier and in the other we have a vacuum-tube rectifier. In one circuit we regulate the high voltage at the output of the high-voltage power supply and in the other we regulate the high voltage by regulating the current through the horizontal output tube.

Transistor Circuits.

In Fig. 44 we have shown the horizontal sweep system from a transistor receiver. The horizontal oscillator consisting of Q_1 and Q_2 is a multivibrator circuit; you studied this type of circuit previously. The frequency of this circuit is controlled by a dc voltage from the sync circuit.

The output from Q_2 is fed through the transformer T_1 to a horizontal driver stage. The sole purpose of transistor Q_3 is to develop a high driving current to drive the horizontal output transistor Q_4. The transformer T_1 steps up the current so a high emitter-base current flows. Notice that the transistor is a PNP transistor. Holes will flow from the emitter, across the emitter-base junction, across the base, across the base-collector junction when the base is negative with respect to the emitter. Thus when the transformer provides this polarity voltage, there will be a high electron current flow from ground to the collector to fill the holes arriving at the collector.

At the same time there will be a large number of electrons leaving the emitter and flowing through the primary winding of T_2 to the 34-volt tap on the power supply to R_{10}. This high current flowing through the primary of T_2 will drive the base of Q_4 negative with respect to the emitter. This will cause a high current flow through the transistor. When the large number of holes begin flowing through the transistor there will be a high current flow from ground to the collector and then from the emitter over to C_8. Electrons will flow into one plate of C_8 and out of the other, causing the current to flow through the horizontal deflection coils that will move the electron beam over to the right side of the picture tube.

When the voltage polarity across the secondary of
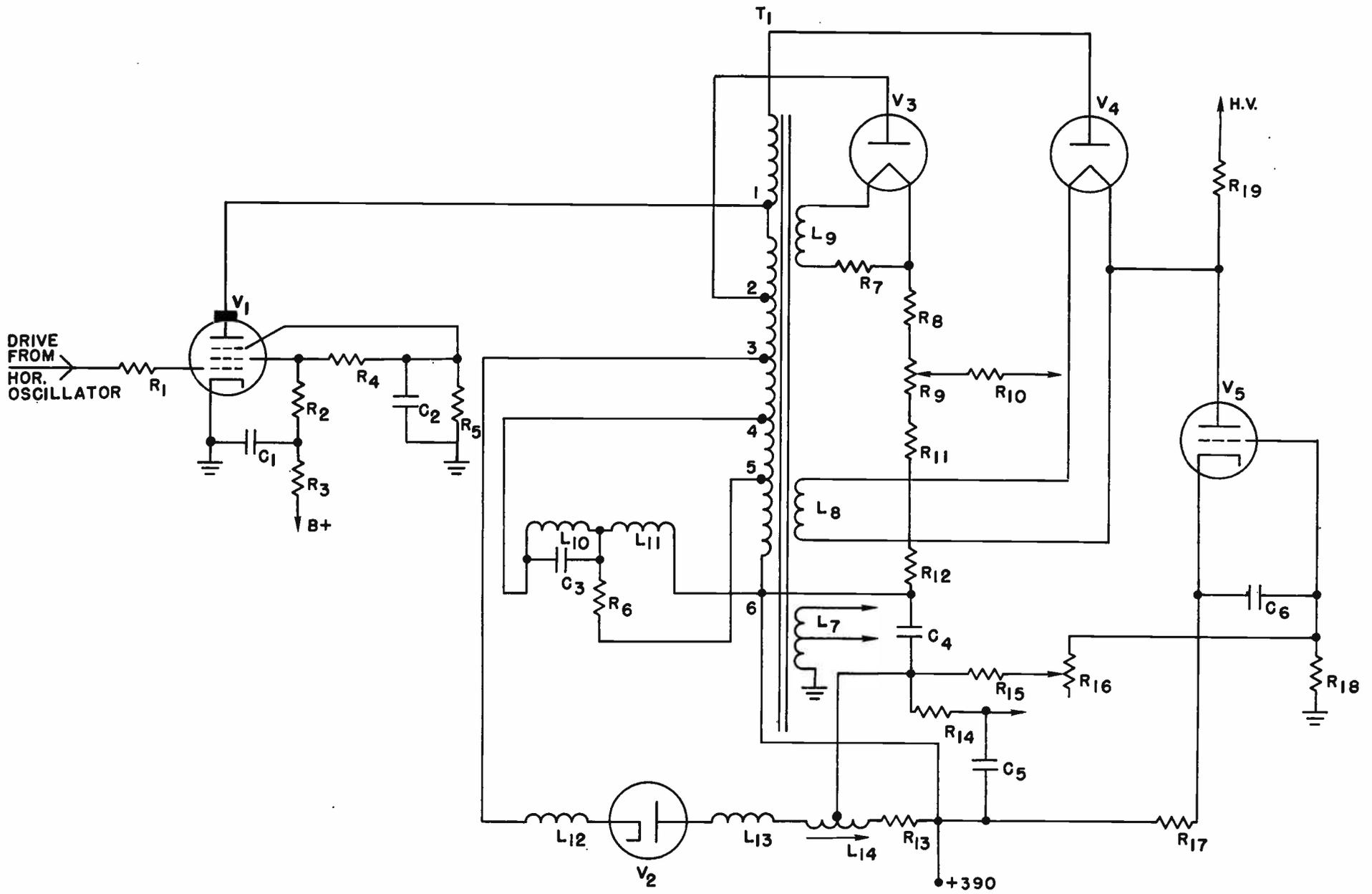
Fig. 43. Horizontal output circuit in a color TV receiver.

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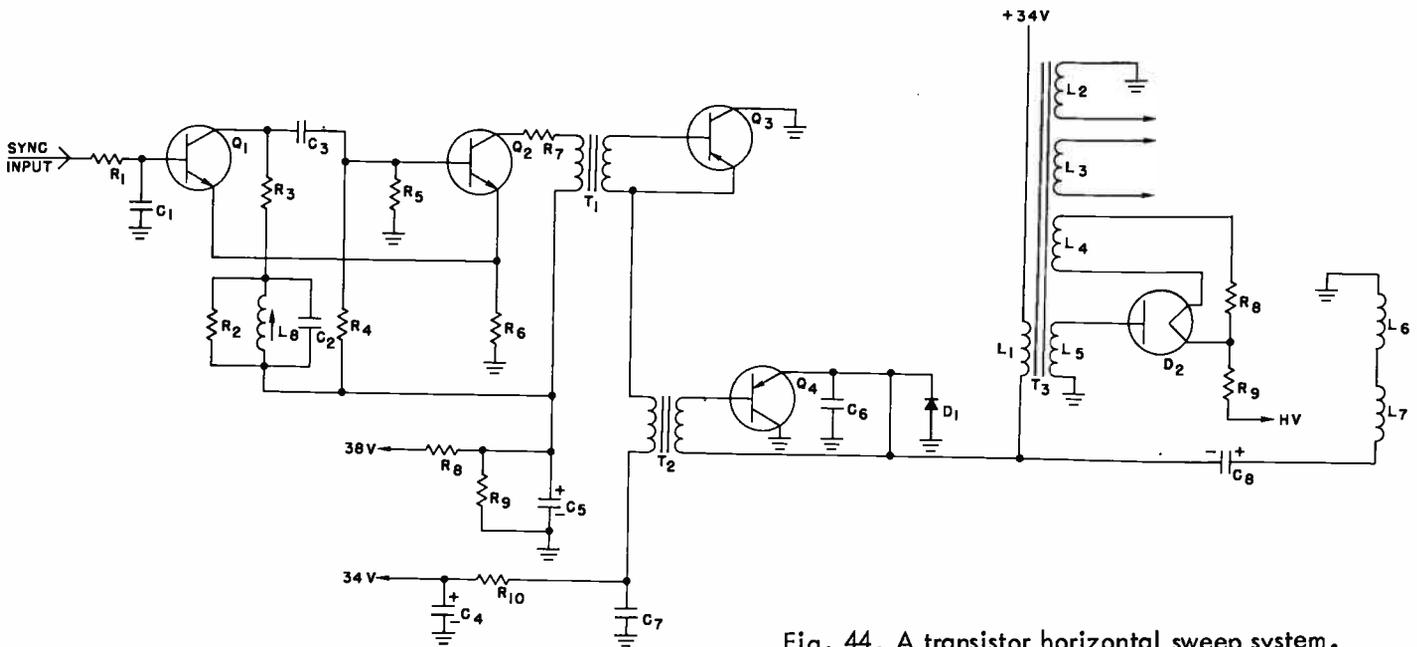
Fig. 44. A transistor horizontal sweep system.

T_2 reverses, as it will at the end of the horizontal scan, the hole flow through the output transistor Q_4 will drop instantly to zero. This means that the current being supplied to the deflection coils L_6 and L_7 will be suddenly cut off. The coils will then go into oscillation, just as in the preceding horizontal sweep circuits, and the current field built up will begin to collapse rapidly, finally reverse polarity, and begin flowing in the opposite direction.

When the current flow through the coils reaches its maximum value flowing in the opposite direction and then begins to collapse, the voltage across L_6 and L_7 will be leading the current by 90° (as in the circuit discussed previously); this will cause the anode of D_1 to become positive with respect to the cathode. Thus the damper diode D_1 begins conducting and the oscillation in the deflection coil is damped out and allowed to drop to zero in a linear fashion. Once again we make use of this half-cycle oscillation in the deflection coils to move the electron beam rapidly back from the right side of the picture tube at the end of the line to the left side to start the next horizontal scan.

As far as the deflection coils and the output transistor are concerned, there is no need to match the impedance of one to the other by means of a horizontal output transformer. The deflection coils have a comparatively low output impedance and they can be used in the emitter circuit of Q_4 without benefit of a transformer.

However, the output transformer T_3 is used to develop the high voltage required by the picture tube. During the retrace interval a comparatively high current will flow through the primary of L_1. This current will be changing very rapidly and it will induce a high voltage in the secondary winding of L_5 having a polarity such that the anode of the rectifier tube D_2 will be positive with respect to the filament. When this happens there will be a current flow through the tube and a high voltage developed to power the second anode of the picture tube. This voltage is applied to the pic-

ture tube through R_9. Once again, the picture tube itself acts as a filter capacitor across the high voltage supply.

Notice that the winding L_4 is used to supply the filament power required by the high-voltage rectifier tube. Current through the filament is limited by R_8. The winding marked L_2 is used to provide horizontal blanking. The signal from this winding is fed to the picture tube in order to blank the electron beam during the retrace interval when the beam is being moved from the right side of the picture tube back to the left side of the picture tube. The winding marked L_3 is used in conjunction with the automatic gain control circuit in the receiver. We mention this at this time, because you will study automatic gain control circuits in your next lesson and you'll see why this winding on the transformer is required.

Although the circuitry in Fig. 44 differs considerably from the vacuum-tube circuits, notice that, in general, we have the same stages performing the same functions. We have the horizontal output stage, which is used to supply the current to the deflection coils. We have a damper stage, which damps out the oscillation developed in the horizontal coils after a one-half cycle oscillation. We have the high-voltage rectifier stage, which is used to develop the high voltage required to operate the picture tube.

HORIZONTAL SWEEP SYSTEM

A simplified diagram of the horizontal sweep system in a color TV receiver is shown in Fig. 45. We say that the diagram is simplified because some of the important circuits have been left out. For the present we are concerned primarily with the horizontal sweep system used to drive the deflection coils.

The horizontal oscillator is a multivibrator-type circuit. The positive pulses required to drive the multivibrator into conduction are fed from the output transistor back through C_3 to the base of Q_1. The negative

pulses developed at the output of the oscillator Q_1 are fed to the base of the PNP transistor Q_2, which causes this transistor to conduct and amplify and invert these pulses.

The positive-going pulses produced at the output of the PNP transistor Q_2 are fed through R_9 to the base of Q_3, which is the horizontal driver. The positive pulse is fed to this transistor, causing it to conduct, and current flows through the primary winding of the driver transformer T_1. The driver transformer is arranged so that there is no phase inversion of the driving signal. When the driver conducts, the output pair, Q_5 and Q_6, do not conduct. When the driver stops conducting, the output voltage at the collector rises very rapidly. This causes a high positive signal in the secondary of T_1 which is fed through R_{16} and C_9 to the base of Q_5 and through R_{17} and C_{10} to the base of Q_6. Q_5 and Q_6, the output transistors, are essentially in parallel.

When the output transistors conduct, the electron beams in the tricolor tube are deflected from the center of the screen to the right side. When the beams reach the right side, the output transistors stop conducting and the deflection coils L_6 and L_7 go into oscillation, permitting the beam to swing rapidly from the right side of the tube to the left side. When the current has built up to its maximum value in the opposite direction through L_6 and L_7, the beam will be deflected all the way back to the left side of the picture tube.

Anode Swings Positive.

Once again, at this instant as the current begins to level out and start to decrease, the anode of D_1, the damper, will swing positive and this will damp out the oscillation and permit the current to discharge through the damper. This discharge will be a linear

rate providing deflection from the left side of the screen to the center. When the beam reaches the center of the screen the output transistors will be turned on again and current will build up through them in a linear fashion and continue the motion of the electron beams through the center of the screen on over to the right side.

Switching Transistors.

The output transistors might be considered as switching transistors. The switching on and off of these transistors cause certain transients to be produced. The diode D_2 prevents the collectors of Q_5 and Q_6 from rising to a very high positive potential when the current through these transistors is suddenly shut off. The transistor collectors could rise to such a high potential that the transistors might continue to conduct or they could be destroyed.

The transistor Q_4 is referred to as an arc gate. The circuit is used to protect the output transistors in the event of a high-voltage arc. If there is a high-voltage arc, the stage Q_4 conducts. This causes Q_3 to conduct; you will remember our stating earlier that Q_5 and Q_6 cut off when the driver Q_3 is conducting. Therefore, it there is an arc, Q_5 and Q_6 will be cut off and protected.

Notice that a blanking pulse is taken from the collector circuit of Q_5 and Q_6. This pulse is used to control a blanking circuit and thus to cut off the picture tube when the electron beams are being moved from the right side of the picture tube to the left side during retrace. Notice that the pulse is also fed to the color gate. The color gate is a stage which permits the color burst to pass through it. Since the color burst is transmitted on the back porch of the horizontal sync pulse, the color burst is transmitted during the
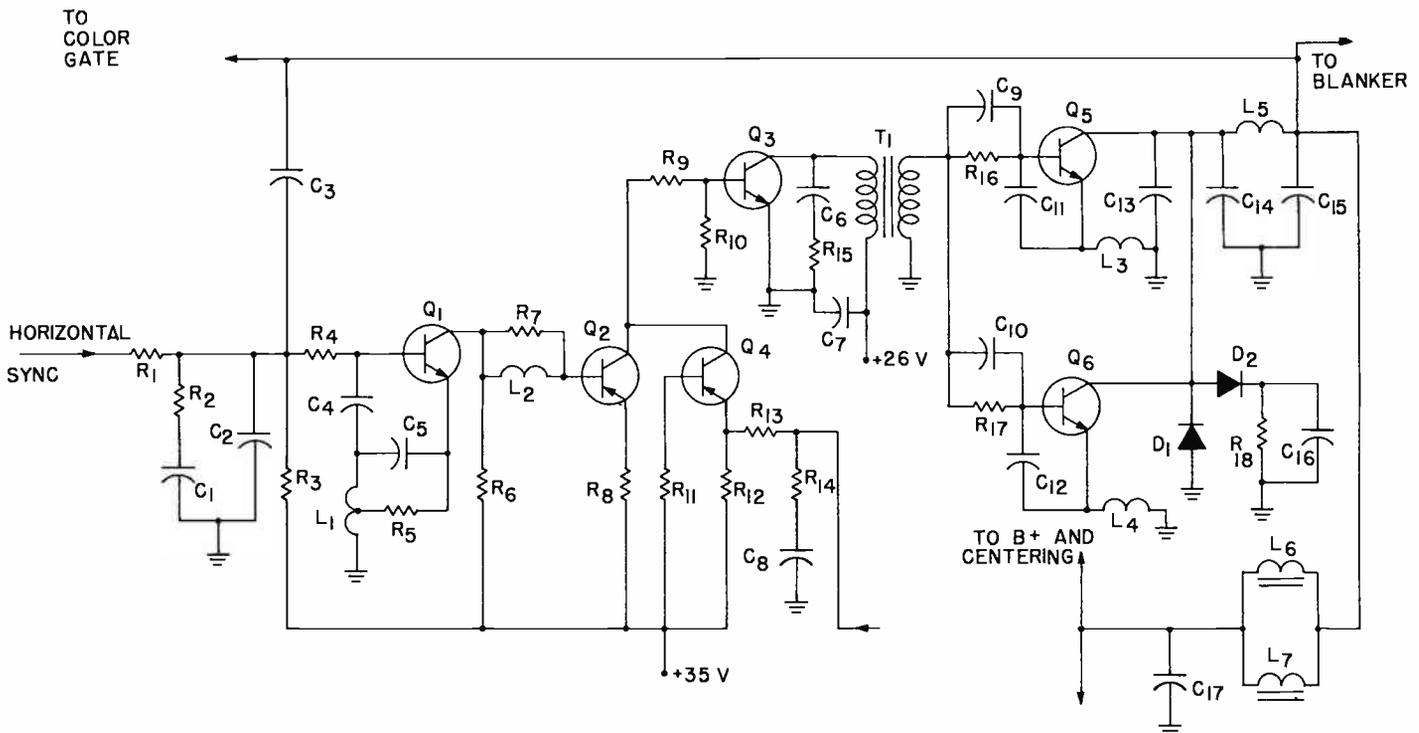
Fig. 45. Horizontal sweep system in a color TV receiver.

retrace interval. The color burst to the gate opens the gate and allows the stage to conduct so that the color burst can be fed through to the phase comparator which will control the phase and frequency of the color oscillator.

AGC pulses are also taken off from a flyback transformer as are signals to control convergence. We've left the horizontal output transformer out of the circuit, because it does not serve any purpose insofar as the deflection is concerned. You'll notice that the deflection coils L_6 and L_7 are directly in the collector circuit as Q_5 and Q_6. This is one thing that you can do in transistor circuits because of the low impedance output of the transistors which could not be done in vacuum-tube circuits, because of the high output impedance of the tubes. Later when you study high-voltage power supplies and when you study convergence circuits you'll study the remainder of the circuits used in this receiver.

SELF-TEST QUESTIONS

(s) How is oscillation in the vertical deflection coils prevented?

(t) Is a sawtooth voltage used to drive the vertical deflection coils?

(u) How does the vertical hold control in the circuit shown in Fig. 34 actually control the oscillator frequency?

(v) Why is there no vertical output transformer used in the vertical sweep circuit shown in Fig. 35?

(w) What purpose does C_7 serve in the sweep circuit shown in Fig. 35?

(x) What purpose does D_1 in Fig. 36 serve?

(y) Why is D_2 in Fig. 36 used?

(z) What purpose does Q_4 in the circuit shown in Fig. 37 serve?

(aa) How is the electron beam moved rapidly from the right side of the picture tube back to the left side during the horizontal retrace?

(ab) Does the output stage provide the current required to sweep the electron beam from the left side of the tube to the center of the tube?

(ac) In the color horizontal output circuit shown in Fig. 42, how many electron beams are swept by the deflection coils?

(ad) What purpose does V_3 serve in the circuit shown in Fig. 43?

(ae) How is the filament voltage required for V_3 and V_4 obtained in the circuit shown in Fig. 43?

(af) What purpose does D_1 serve in Fig. 44?

(ag) What purpose does T_3 serve in Fig. 44?

Convergence Circuits

Convergence circuits are used to make the three electron beams in the tricolor tube fall essentially on the same spot at the same time. You know that on the face of the tricolor tube phosphor dots are arranged in clusters of three. They are arranged in triangles with a blue phosphor dot on the bottom and red and green phosphor dots on the top. The red phosphor dot is on the left looking at the tube from the back and the green phosphor dot is on the right. If we refer to this group of dots as a single point, and they are so close together that they are almost a point, we want the three beams to coincide at the face of the tube so they strike the three phosphors in this particular cluster.

Fig. 46. (A) The three electron guns positioned in a tricolor tube; (B) and (C), two forms of misconvergence.
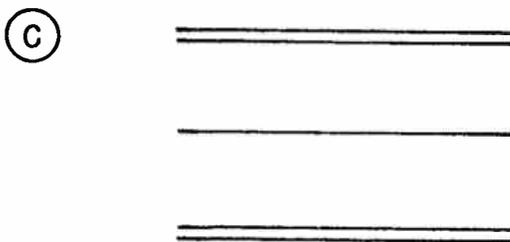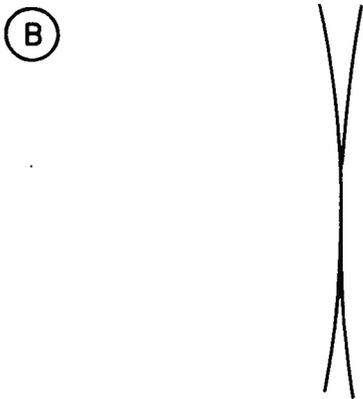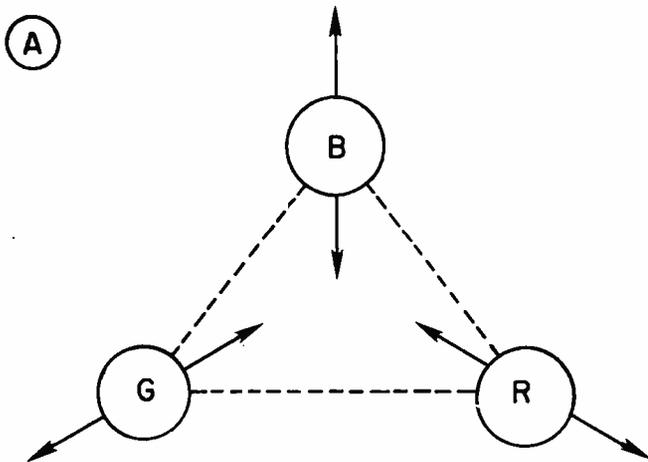
For example, the beam from the blue gun must go through the hole in the shadow mask and strike the blue phosphor dot. The beam from the green gun must go through the hole in the shadow mask and strike the green phosphor dot that belongs in that particular group. Similarly, the beam from the red gun must go through the hole in the shadow mask and strike the red phosphor dot in that particular triangle.

In the tricolor tube the three electron guns are positioned as shown in Fig. 46A. This is the view looking at the back of the receiver. Notice that the blue gun is on the top, the green gun on the lower left and the red gun on the lower right. If we simply applied the high voltage to the picture tube and let the three beams go down and strike the face of the tube they would go down the neck of the gun in essentially a parallel path. They would strike the face of the picture tube some distance apart; the distance apart would be approximately equal to the distance that the guns are placed apart. However, this is not what we want.

We want the three beams to converge at a single point, go through the hole in the shadow mask and then strike the three phosphor dots on the face of the tube that are in the center of the tube. In order to accomplish this we must provide some external magnetic field to bend the beams together so they will converge and go through the same hole in the shadow mask. Convergence in the center of the tube is accomplished by means of permanent magnets.

Blue Convergence Magnet.

The blue convergence magnet is placed above the blue gun and by moving it you can move the blue beam up and down and so arrange it to go through the correct hole in the shadow mask and strike the blue phosphor dot. Similarly, the green convergence magnet will move the green beam in the direction shown in Fig. 46A; by adjusting it you can get the green beam to go through the same hole in the shadow mask as the blue beam has gone through and to strike the green phosphor dot. The red convergence magnet will move the red beam in the direction shown and it also can be made to go through the same hole in the shadow mask and strike the red phosphor dot.

Notice that the magnet above the blue gun will provide only vertical movement of this beam. Sometimes horizontal movement is also required and this is accomplished by another magnet called the blue lateral magnet. This blue lateral magnet also has some effect on the red and green beams, moving them primarily in a horizontal direction.

The permanent magnets used to converge the electron beam in the center of the tube are called the static convergence adjustments. If we begin to sweep the three electron beams over the face of the tube, these static convergence adjustments will keep the beam converged over an area in the center of the picture tube. However, as we reach the outer edges of the picture tube we begin to run into problems.
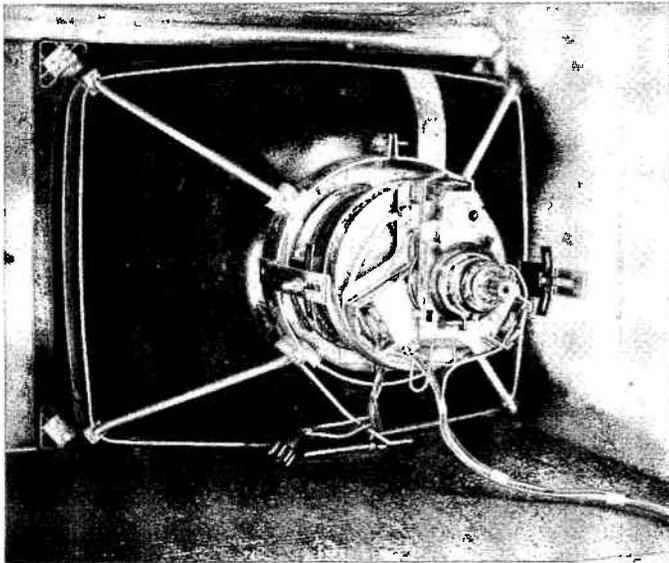
Fig. 47. A typical convergence yoke.

Consider first the red and green beams. After adjusting the convergence magnets to make them converge at the center of the picture tube, if the beams are swept up and down we may find that instead of getting a single yellow line (which we will get when the two are converged) the beams split apart and we can see the separate red and green lines at the top and bottom of the screen, as shown in Fig. 46B.

The reason for this is that if we adjust the magnets to make the beams converge in the center of the picture tube and then deflect the beam up to the top of the screen the electron beams are traveling further. Therefore, the amount of bending that caused them to come together at the center of the screen will be the same at the top of the screen because the permanent magnets are causing this bending. However, since the distance to the top of the screen is further than the distance to the center of the screen, we have bent the beams too much, so instead of falling together they actually crisscross and form the separation shown at the top and bottom as in Fig. 46B.

Another problem that may be encountered is shown in Fig. 46C. As we sweep the beam across the face of the tube we might find that we get reasonably good convergence in the center of the screen and the red and green beams converge and give us a yellow line. However, at the top of the screen and at the bottom the two may separate and give us separate red and green lines.

Obviously, the static adjustments provided by the magnets are not sufficient to keep the beams converged over the entire face of the tube. An additional type of convergence, called dynamic convergence, is required to keep the beams together.

In converging a TV receiver, the first step is to adjust the static convergence adjustments (the permanent magnets, in other words) to get the best possible convergence in the center area of the screen. To converge the beams on the outer edges of the screen, the dynamic convergence must then be adjusted.

There are two types of dynamic convergence: vertical and horizontal. Convergence is accomplished by means of convergence coils positioned in essentially the same position as the convergence magnets. There are two coils for each gun: one associated with the vertical convergence circuit and the other with the horizontal convergence circuit. The two operate essentially independently -- there is some interaction, but it is not too severe in most cases.

Fig. 47 is a photo of the convergence yoke assembly. The blue magnet and coils are on top, the green magnet and coils on the lower left and the red magnet and coils on the lower right. Now let us go ahead and look at some of the dynamic convergence circuits.

VERTICAL CONVERGENCE

When you studied vertical sweep circuits in the circuit shown in Fig. 34 earlier in the lesson, there were a number of leads shown that went to the convergence board. We did not show the convergence circuit because at the time we were concentrating on the vertical sweep circuit. The vertical convergence circuit is shown in Fig. 48. This circuit looks quite formidable at first glance, but it can be redrawn in the form of a bridge as shown in Fig. 49.

The part numbers given in Fig. 48 and Fig. 49 are for the same parts so you can compare these two circuits. Notice that the winding L_1 on the transformer has a fourth connection that feeds to a voltage dependent resistor, R_{10}. We have omitted this in Fig. 49 to simplify the drawing. Actually this simply feeds the signal to R_3 to help get the correct waveform from the cathode of the vertical output tube.

To see how the circuit works, let's first assume that R_6 and R_7 are adjusted to the mid-position. When this happens we will have a situation where the slider connection on R_7 is at the same potential as the junction of the red and green coils; thus there will be no current flow through this circuit.

Also, if we adjust R_8 in the center position then the winding L_1 will not supply any current to the coils because when the slider on R_8 is in the center position it is essentially at ground potential.

For the present we will ignore the blue coil and the currents sent through it by R_4 and R_9.

With the various controls set in the mid-position R_3 will tap part of the sawtooth voltage from the cathode circuit of the vertical output tube and feed it through R_5 and D_1 to the green and red coils. Because of the inductance of the coils, the current flow through the circuit will be essentially a parabolic type of waveform. This is the type waveform needed to converge the beams.

In the convergence procedure, the first step is to turn off the blue gun and concentrate on converging the green and red beams. By using a crosshatch generator a pattern of horizontal and vertical lines can be displayed on the face of the tube. We start the green and red beam convergence by adjusting R_3; this controls the amplitude of the circuit through the green and red vertical convergence coils. R_3 is adjusted to converge the vertical lines in the center of the screen as shown
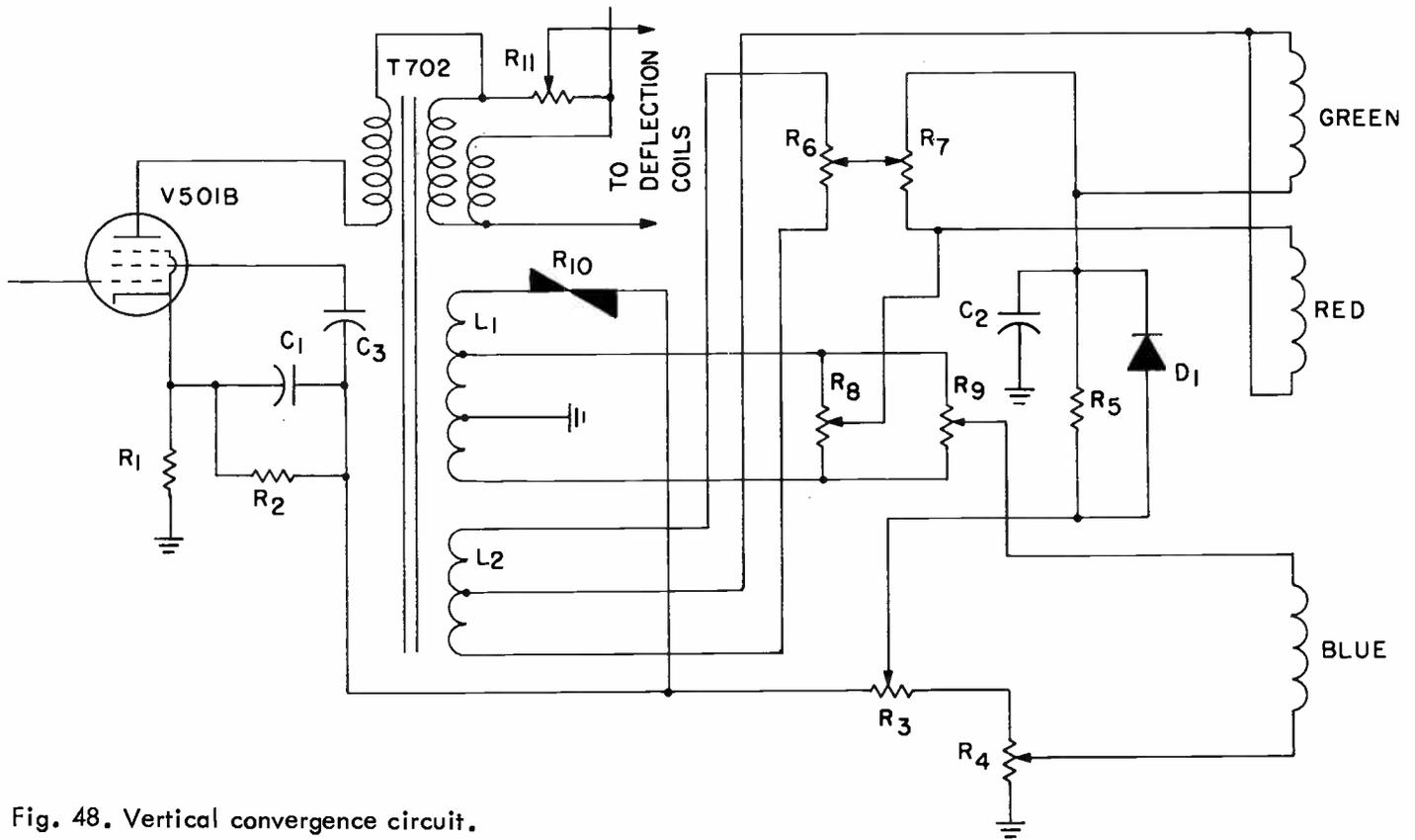
Fig. 48. Vertical convergence circuit.

in Fig. 46B. Some manufacturers tell you to adjust R_3 to bring the lines together at the top; others tell you to bring them together at the bottom. Actually, adjusting R_3 will have an effect on both the top and the bottom, but you should follow the manufacturer's instructions and watch primarily either the top or the bottom as instructed.

After you have adjusted R_3, the next step is to adjust R_8. This provides a sawtooth-type voltage from the winding L_1 on the vertical output transformer. This control is also adjusted to correct the top and bottom displacement of the vertical lines in the center of the screen. You adjust R_3 for best convergence at

the top and you adjust R_8 for best convergence at the bottom. The two controls interact so that it is usually necessary to go back and forth several times until you get the red and green beams converged in a vertical line or several vertical lines in the center of the screen.

Sometimes these controls are referred to by different names. R_3 is sometimes called red/green amplitude and R_8 red/green tilt. R_8 gets the name "tilt" from the fact that the sawtooth, when added to the parabola, tilts the parabolic wave. R_3 gets the name "amplitude" from the fact that it controls the amplitude of this current applied to the convergence coils.
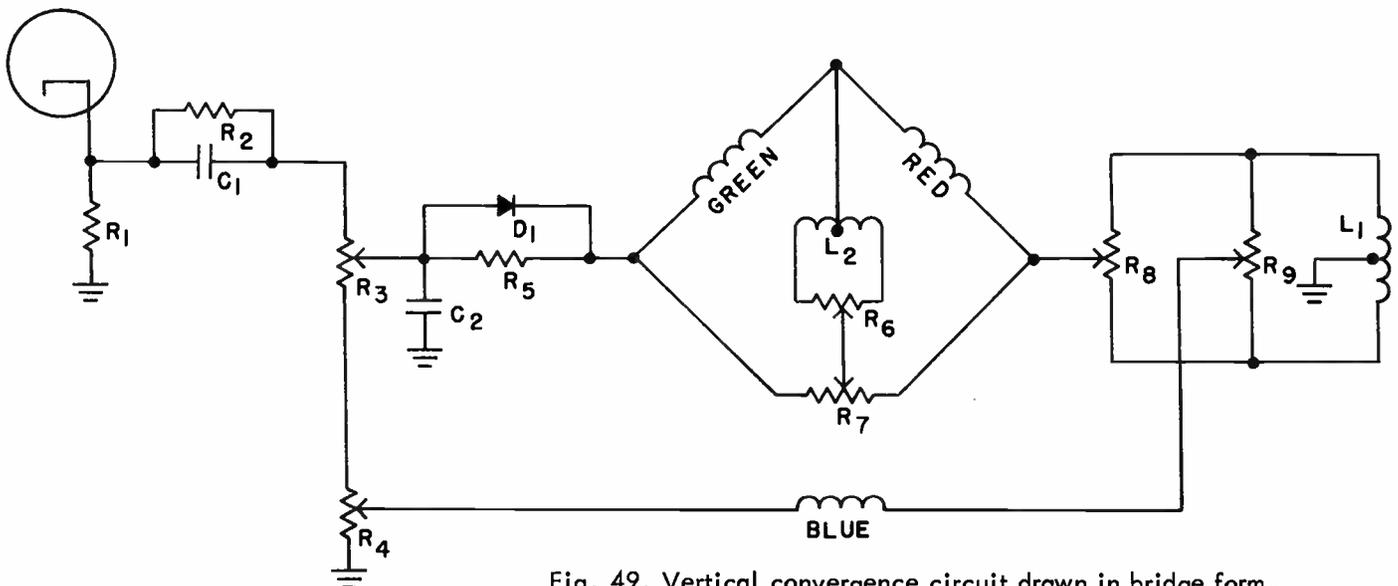
Fig. 49. Vertical convergence circuit drawn in bridge form.
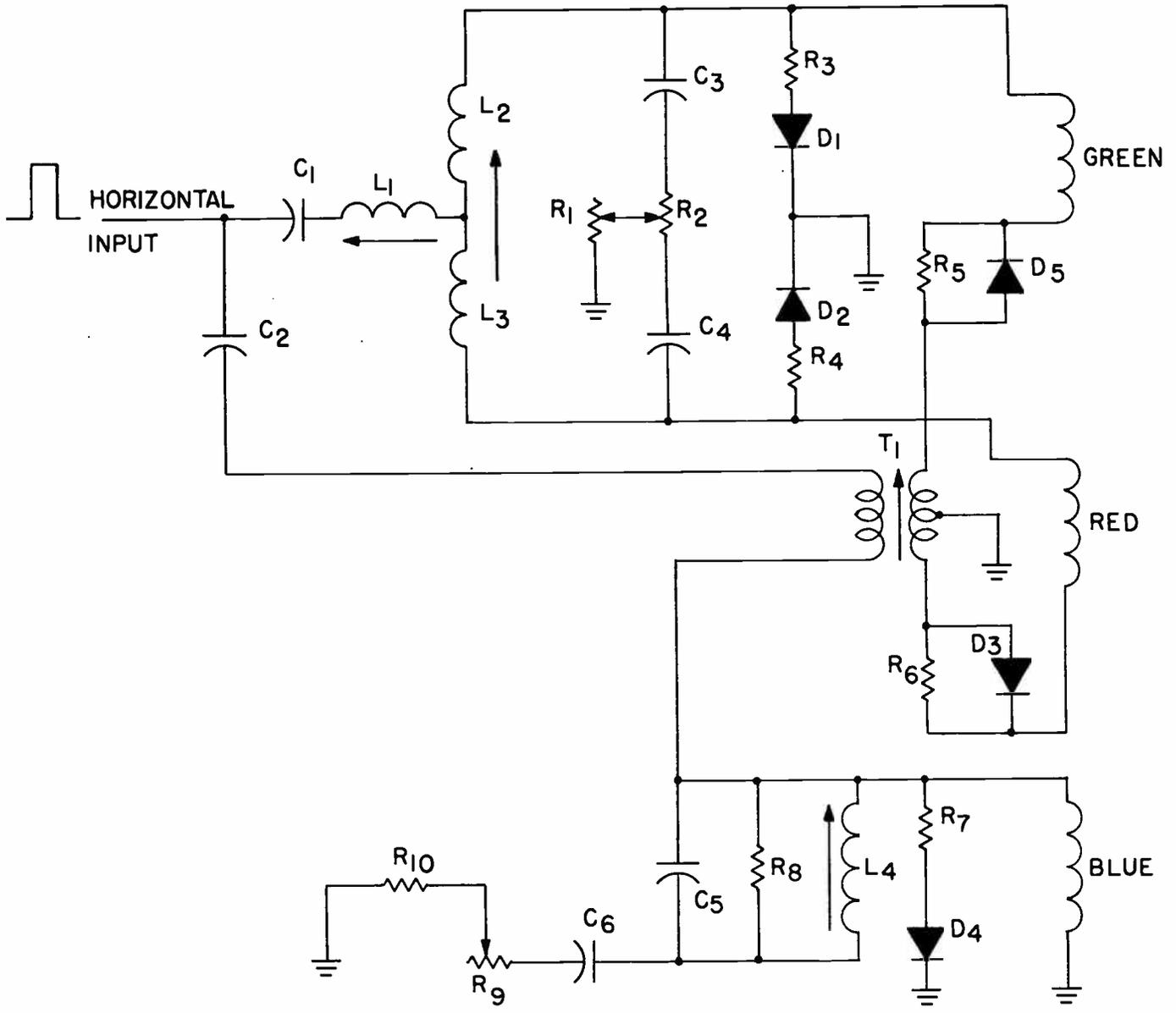
Fig. 50.The horizontal convergence circuits in a color TV receiver.

Other manufacturers just refer to the controls by the adjustment they produce. R_3 is sometimes the vertical red/green top and R_8 the vertical red/green bottom to indicate that they are used to converge a vertical line in the center of the screen, one being used primarily for the top adjustment and the other for the bottom.

The next step in the vertical convergence procedure is to correct the situation shown in Fig. 46C. Again, some manufacturers tell you to correct the top of the picture first and others the bottom. You should follow the procedure the manufacturer recommends.

In the circuits shown in Fig. 48 and Fig. 49, R_6 is used to correct the displacement of the two horizontal lines at the top of the picture and R_7 the displacement at the bottom. The procedure is to adjust R_6 first; this changes the current from L_2 and feeds part of it through the red and green coils. Next, changing the setting of R_7 affects the amount of signal from L_2 plus the amount from the cathode of the rectifier and L_1

that goes through the red and green coils. This will primarily affect the adjustment of the two horizontal lines on the bottom of the screen.

Sometimes the adjustment R_7 is called the red/green differential amplitude and R_6 is called the red/green differential tilt. Again, the differential amplitude control is concerned primarily with the parabolic waveform through the coils; the tilt control is concerned with the sawtooth added to "tilt" the parabolic waveform. R_6 is also referred to as R/G top horizontal, R_7 as R/G bottom horizontal.

After you have adjusted R_6 and R_7 you might notice some displacement of the vertical lines in the center top and bottom of the screen; if this is the case, you should go back and readjust R_3 and R_8 slightly and then, if necessary, go back and readjust R_6 and R_7. You should go over these four adjustments several times until you have the best possible convergence of the vertical red and green lines in the center of the screen and the best possible convergence of the hori-

zontal red and green lines at the top and bottom of the screen.

The blue vertical convergence adjustments are usually performed after the red and green horizontal convergence adjustments are performed. Therefore, we'll go ahead and look at the horizontal circuit and adjustments and then finish up describing the convergence procedure with the blue convergence adjustments.

HORIZONTAL CONVERGENCE

The horizontal sweep output circuit shown in Fig. 42 is used in conjunction with the convergence circuit shown in Fig. 50. A separate winding on the horizontal output transformer provides a series of pulses to the burst-gate amplifier and to the convergence board. We'll concern ourselves with red and green convergence first, and then with blue convergence later.

In the red-green convergence circuit the pulse from the horizontal sweep is fed through C_1 to L_1. L_1 is primarily an amplitude control; it controls the amount of current that will flow through the red and green convergence coils. Remember that these convergence coils are separate coils. They are not the same ones used in the vertical convergence circuit, but they are wound on the same form and around the same pole piece.

The coils L_2 and L_3 actually form a single coil and the adjustment of the coils determines how much of the total current flows through the green convergence winding and how much flows through the red convergence winding. Notice that the two convergence coils connect to T_1 and to ground.

The circuit consisting of R_3, R_4 and the diodes D_1 and D_2 take a certain current from the current produced by the horizontal pulse applied. Similar circuits consisting of C_3 and C_4, R_2 and R_1 allow a certain current to flow. The net result of the removal of these two currents from the total current flowing is that the current waveshape through the red and green convergence coils will be a parabola. The shape of the parabolic waveform can be altered by adjusting R_2 and R_1; the total amplitude of the current flowing and the amplitude of the individual current through each convergence coil can be altered by adjusting L_1 and L_2.

When making the horizontal convergence adjustments, once again you should get the manufacturer's service information and follow his instructions in the order given. However, the general procedure is to first adjust L_1, which is often referred to as the R/G amplitude. This adjusts the amplitude of the total current. L_1 is adjusted to converge red and green vertical lines on the right side of the picture, as shown at A of Fig. 51. After you have adjusted L_1, the next step is to adjust R_1 to converge the red and green vertical lines on the left side of the picture, as shown in Fig. 51B. This adjustment is often referred to as the R/G tilt. Sometimes L_1 is also referred to as the R/G amplitude R, and R_1 as the R/G tilt L; the R and L indicate right and left.

After you have completed these two adjustments, the next adjustment to make is the adjustment in the coil L_2 - L_3. This is referred to as the R/G differential amplitude. This controls the division of the parabolic current between the green and red convergence coils. L_1 affects the total amplitude of the current and the adjustment of L_2 and L_3 determines how this total current divides and flows through the individual coils. The coil is adjusted to converge horizontal red and green lines on the left side of the screen, as shown in Fig. 51C. The final red/green adjustment is R_2, which is referred to as the R/G differential tilt. This control is adjusted to converge the red and green horizontal lines on the right side of the screen, as shown in Fig. 51D. Once again, L_1 and the L_2 - L_3 adjustment primarily control the amplitude of the parabolic
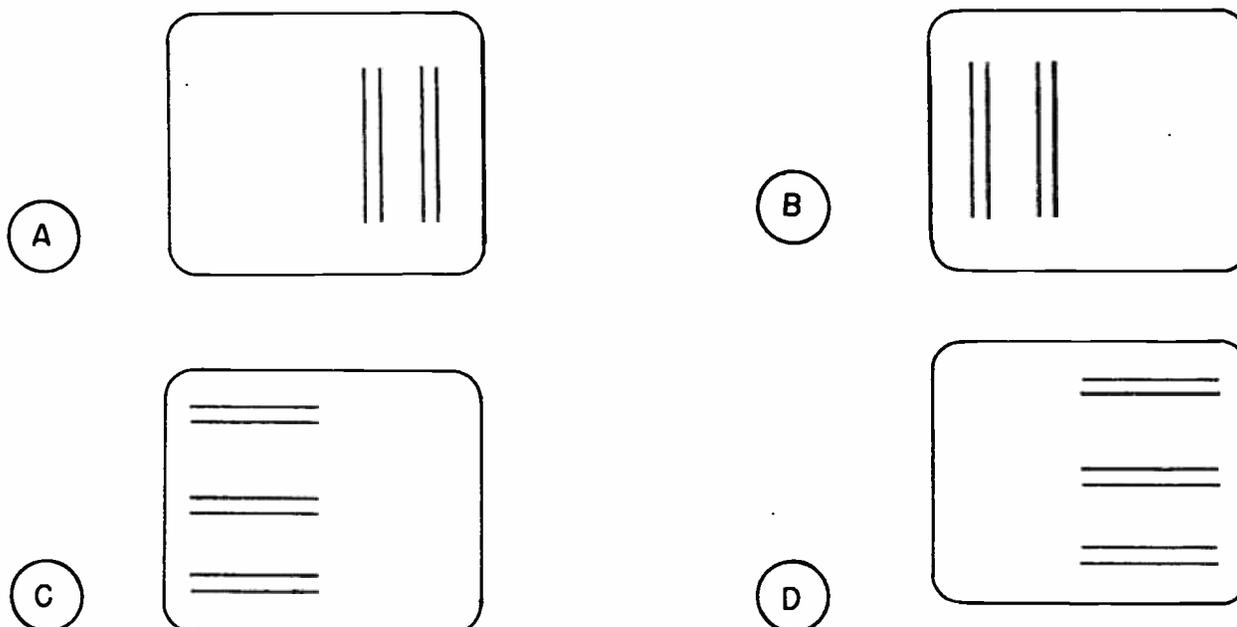
Fig. 51. Horizontal red-green convergence adjustments.
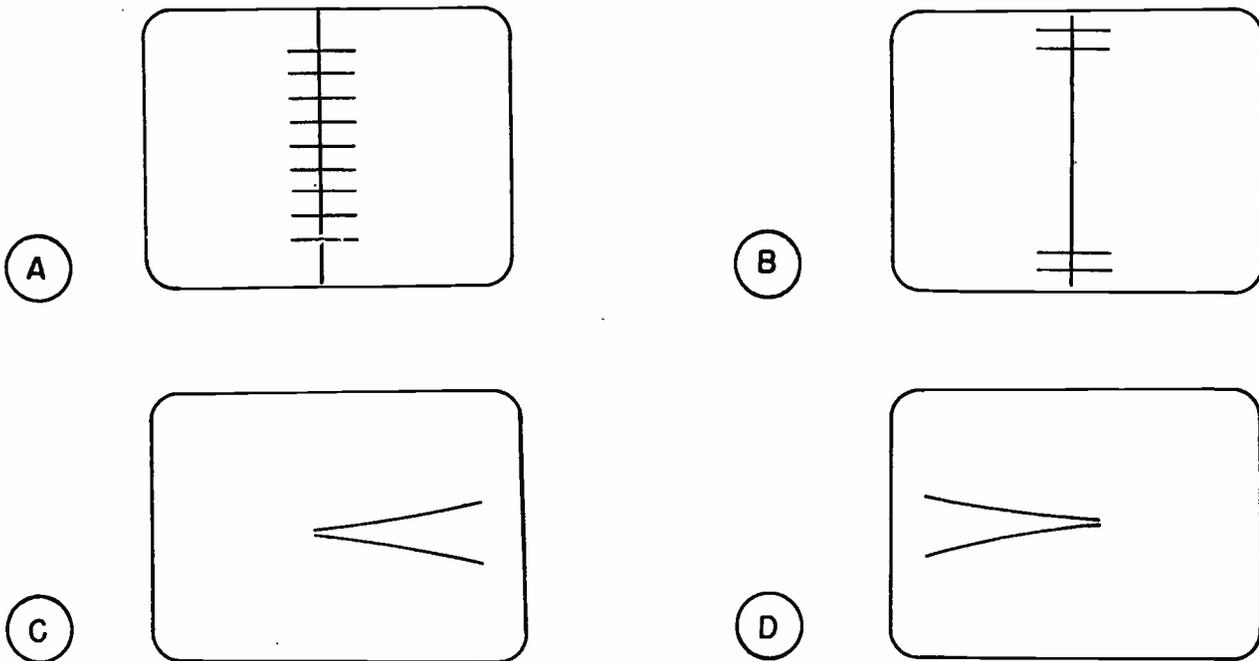
Fig. 52. Blue convergence adjustments.

waveforms; R_1 and R_2 control the current taken from the circuit to tilt the parabolic waveforms and are referred to as tilt controls.

After going through these four adjustments it is usually worthwhile to go back and go through them again because there is some interaction between the controls. Also, you should check the vertical convergence adjustments because they may have been affected by the horizontal adjustments. If necessary, go back and repeat the four vertical convergence adjustments for the red and green guns and then the four horizontal convergence adjustments for best convergence.

BLUE GUN CONVERGENCE

The first step in making the blue convergence adjustments is to go back and make the blue vertical convergence adjustment. The blue gun should be turned on so you can converge the blue lines with the yellow lines produced by the converged red and green guns.

R_4 in Fig. 49 is the blue vertical amplitude adjustment and R_9 is the blue vertical tilt adjustment. R_4 is adjusted to give you equal displacement of the blue lines in the center of the screen, as shown in Fig. 52A. The tilt adjustment, R_9, is made to give you equal displacement of the blue lines at the top and bottom of the screen, as shown in Fig. 52B. There is some interaction between the controls so after you have adjusted both, go back and adjust R_4 again and then readjust R_9.

The blue horizontal convergence adjustments consist of a blue horizontal amplitude and a blue horizontal tilt. T_1 in Fig. 50 controls the blue amplitude; it is adjusted to give you convergence of the blue horizontal line in the center of the screen from the center to the right side, as shown in Fig. 52C. After you have completed this adjustment, adjust the blue horizontal tilt,

R_9, to give you horizontal convergence of the blue line in the center of the screen from the center to the left side of the screen, as shown in Fig. 52D. After you have completed the adjustment of R_9 you should go back and readjust T_1 and then touch up R_9 again.

The coil L_4 is called the blue horizontal center phase adjustment. This coil normally is a factory adjustment and should not be reset in the convergence procedure. However, if it is necessary to replace the coil then you'll have to readjust it. Again, whenever you have a situation like this you should follow the manufacturer's service information exactly.

To adjust this coil you should connect the oscilloscope across it. The peak amplitude of the signal across the coil should be about 45 volts and there should be a notch in the waveshape as shown in Fig. 53. It is important that this adjustment be made as carefully as possible in order to get the correct convergence and also to prevent overloading of parts on the convergence board.

CONVERGENCE OF IN-LINE GUN TUBES

The majority of the color tubes manufactured have the three color guns arranged in a triangular con-
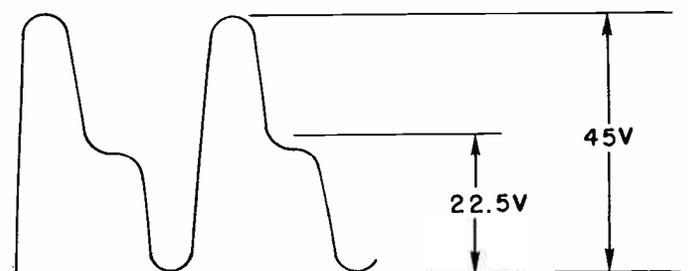
Fig. 53. Waveform across L_4, the horizontal blue center phase adjustment.
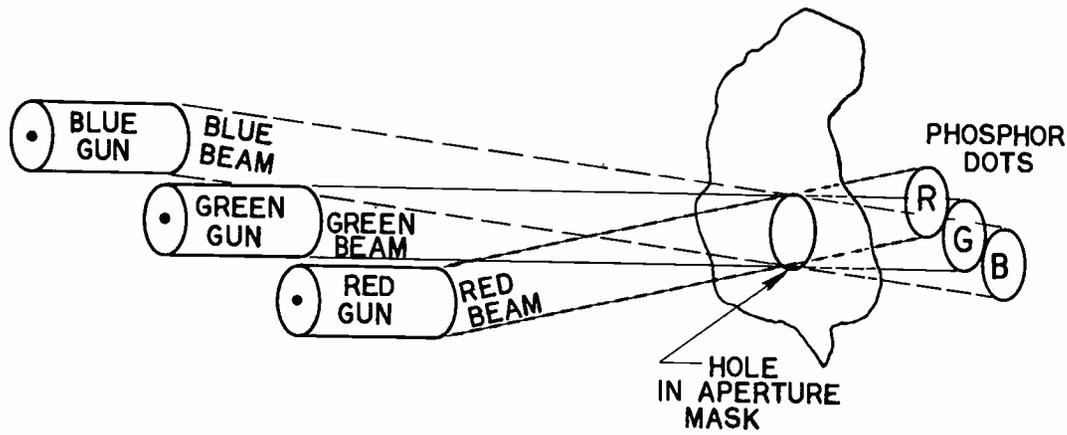
Fig. 54. The three beams converge at the aperture mask, passing through a single hole to excite their corresponding phosphor dots.

figuration. However, some tubes have the guns placed in a horizontal line as shown in Fig. 54. In this type of tube, looking at the tube from the rear, the blue gun is on the left, the green gun is in the center and the red gun on the right. The phosphor dots are arranged in the opposite order looking at the tube from the rear: the red dot is on the left, the green dot in the center and the blue dot on the right, so that the electron beams go through the hole in the mask and the blue and red gun beams crisscross to strike the ap-

propriate color phosphor dot. The green beam, meanwhile, goes straight down the tube and strikes the green dot that is in between the other two.

Convergence of the three beams in this type of tube is considerably simpler than convergence of the triangular-arranged gun tubes. As a matter of fact, there are no variable controls associated electrically with the convergence circuits. Convergence is accomplished primarily by means of magnets (which give you static convergence adjustments) and then by moving
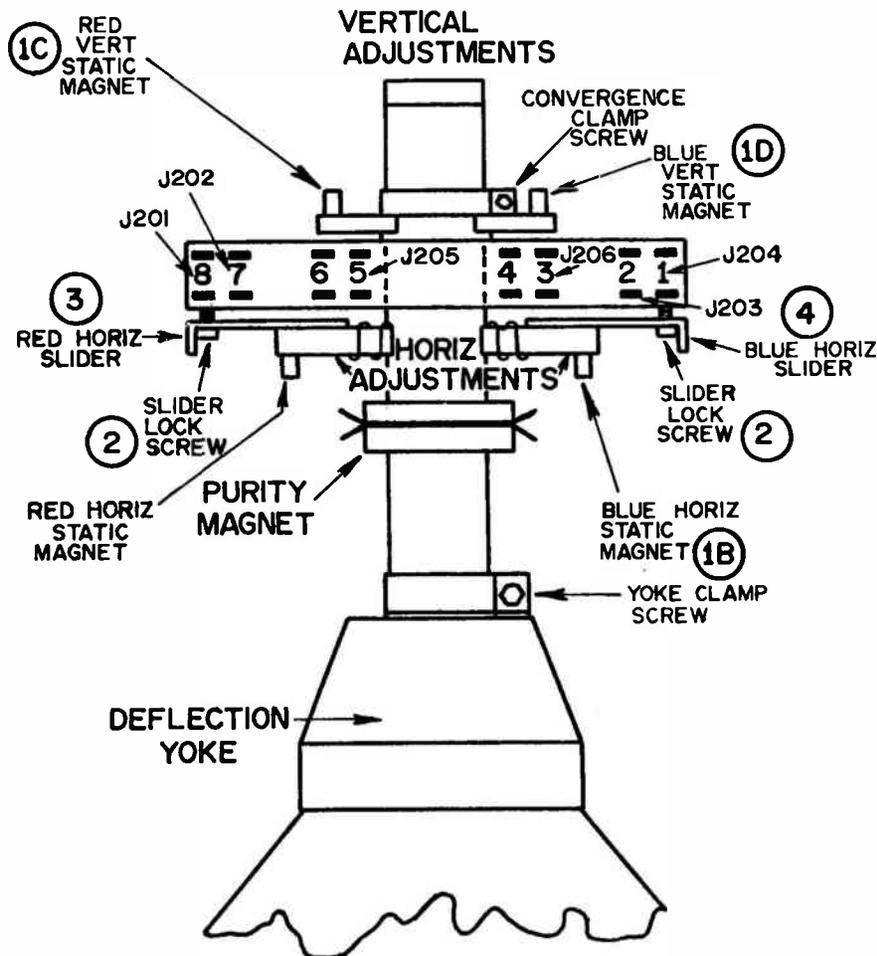
Fig. 55. Location of the convergence system components on the neck of the picture tube.

B510 - 47
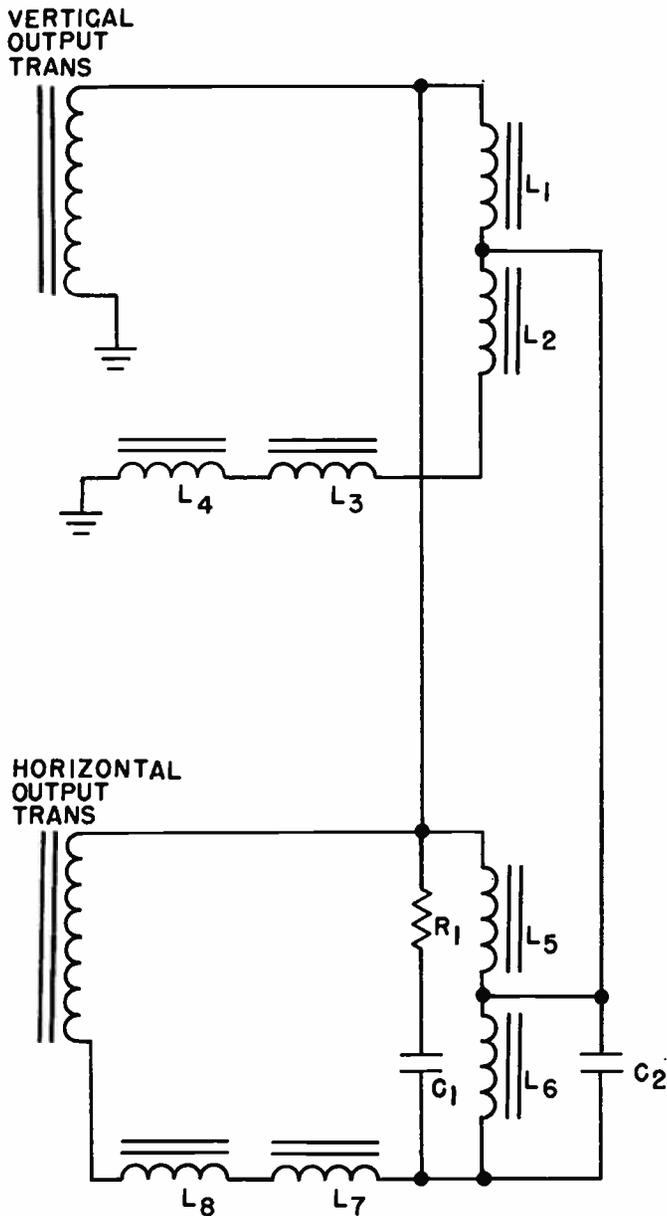
Fig. 56. Vertical and horizontal convergence circuits.

the position of the convergence coils in order to accomplish dynamic convergence.

The position of the various convergence adjustments on the neck of the tube is as shown in Fig. 55. The vertical static adjustments are located towards the rear of the neck of the tube and the horizontal static adjustments towards the bell of the tube. As in the case of the triangular gun tube, you make the static adjustment first for best convergence of the beams in the center area of the tube. The three electron guns in the tube are shielded magnetically in such a way that there is not too much interaction between the various convergence adjustments.

The electrical circuit of the dynamic convergence is shown in Fig. 56. Notice, as we pointed out, that there are no adjustments. L_3 and L_4 are the vertical dynamic convergence coils and L_7 and L_8 are the horizontal dynamic convergence coils. These coils are connected to the board as shown in Fig. 55 by means

of slip-on connections so that, if necessary, the leads to any one of the coils can be removed and reversed to provide better convergence.

CONVERGENCE ADJUSTMENT EFFECTS

Fig. 57 shows the effect of the various convergence adjustments. Notice the shielding shown; as we mentioned previously, this keeps interaction at a minimum. The horizontal convergence can be controlled by means of the slider adjustment that moves the horizontal coils and magnets in and out. As shown in Fig. 55, the red horizontal slider is on the left side and the blue horizontal slider adjustment on the right.

The convergence procedure in this receiver is to first converge the red gun on the green gun in the center of the screen. You can do this with a cross-hatch pattern with the blue gun turned off. The green gun is going to be used as the standard because it is placed in the center -- the red lines will be converged on the green in the center of the screen. Next, turn off the red gun and then converge the blue lines on the green lines in the center of the screen. This is all there is to the center convergence; once this is accomplished then you have the horizontal slider adjustments which can be used to move the vertical lines on the right and left side of the screen. With the blue gun turned off check the relationship between the red and green lines at both sides of the raster. By moving the red horizontal slider you can converge the red and green vertical lines; then turn the red gun off and move the blue horizontal slider to converge the blue vertical lines on the green vertical lines.

We have not given all the details on the convergence procedure (this is given in the manufacturers' service information), but the main thing that we want to emphasize here is that the convergence procedure is much simpler than in the tubes for the triangular-gun arrangement, because there are not very many adjustments to be concerned with.
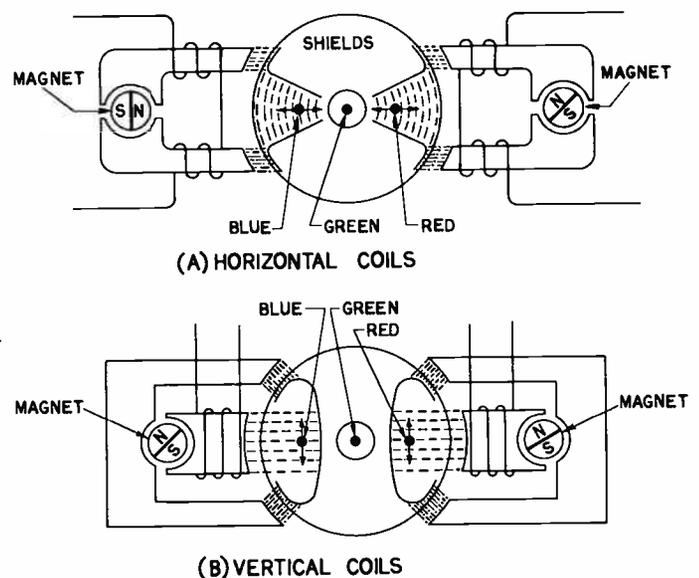
Fig. 57. Convergence system for in-line gun picture tube, showing horizontal system (A) and vertical system (B).
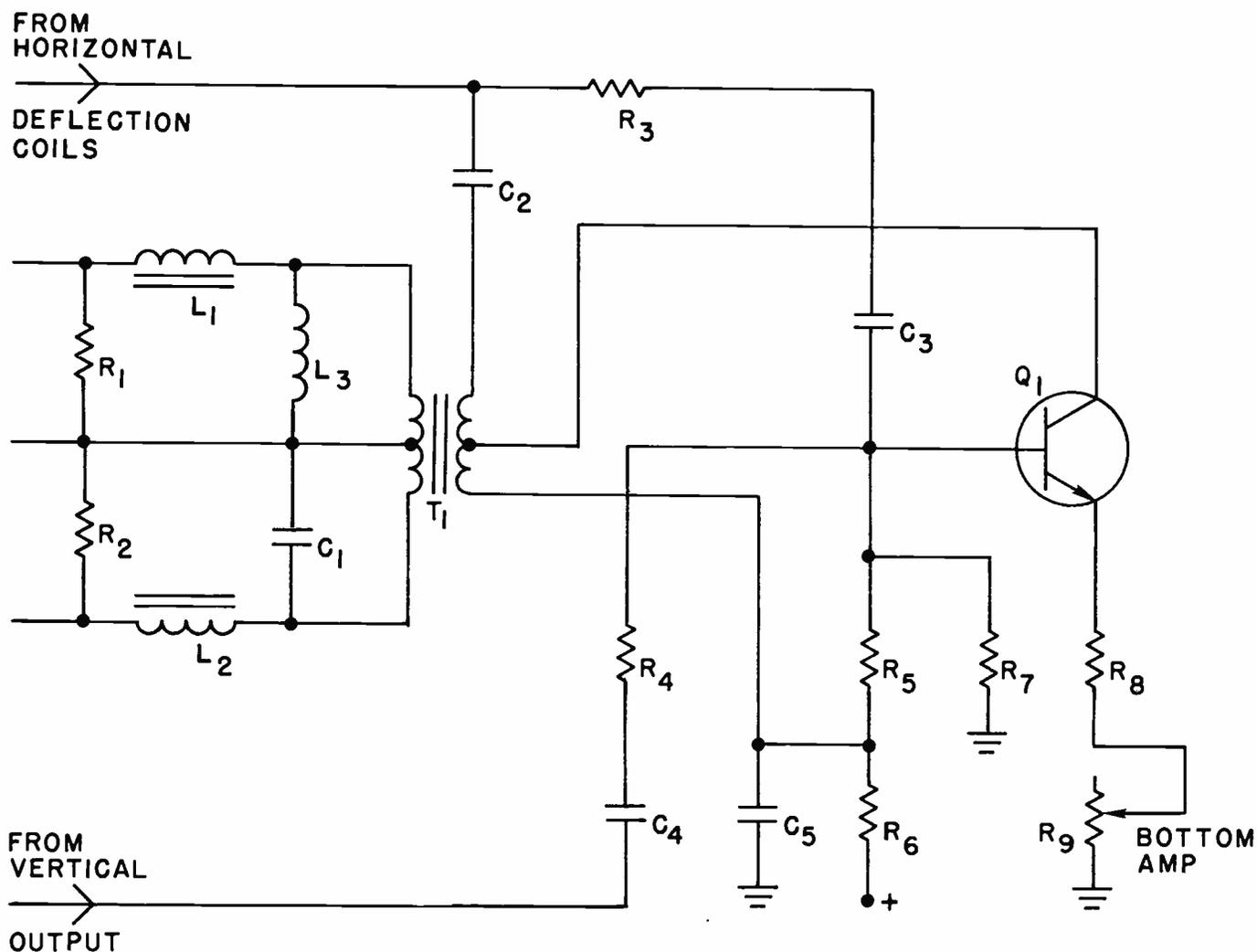
Fig. 58. Dynamic pincushion correction circuit.

PINCUSHION CORRECTION

In monochrome TV receivers using a large-size picture tube, the pincushion effect shown in Fig. 38 is usually corrected by means of permanent magnets placed on the two sides and top and bottom of the deflection yoke. These magnets add to the field produced by the deflection coils so that the pincushion effect can be corrected at the top and bottom and at the two sides so that eventually the square raster is produced on the face of the picture tube.

In color TV receivers special pincushion circuits are sometimes used to correct for this problem. An example of one used in a transistor color TV receiver is shown in Fig. 58. Both horizontal and vertical pincushion correction are provided.

Horizontal correction (that is, the correcting of the sides of the raster that are concaved in particularly towards the center of the picture) is accomplished by means of modulating the B+ fed to the horizontal sweep circuit with a parabolic voltage at the vertical rate.

The parabolic voltage applied to the base of the transistor in the circuit shown in Fig. 58 results in an increased current flow through the transistor, particularly midway between the top and bottom of the picture. This results in an amplified voltage appearing in the output which is fed through C_2 back to the horizontal deflection coils and to the horizontal output stage. The increase in voltage applied to the horizontal output transistors results in an increase in the amplitude of the horizontal sweep. This tends to overcome the bowing or concave effect produced in the center area of the picture and yields straight vertical sides in the raster.

Horizontal Parabolic Signals.

The horizontal parabolic signals are delivered through R_3 and C_3 to the base of the transistor. These signals increase the amplitude of the deflection current through the deflecting coils at a horizontal rate at the top and the bottom of the picture. Thus the bowing at the top and bottom is corrected line by line at a horizontal rate when the signal is fed from the horizontal deflection circuit. The increased deflection currents through the vertical deflection coils L_1 and L_2 increase the amount of deflection at the top and bottom of the picture so that the raster is squared off at top and bottom. The control R_9 provides adjustment at the bottom of the raster for the straightest possible horizontal line.

In color TV receivers, it is important that adjustments such as pincushion correction adjustments be performed before the convergence adjustments. If these adjustments are not performed first, it is quite possible that after the set has been converged and

you try to correct the pincushion problem you will upset the convergence of the receiver.

SELF-TEST QUESTIONS

(ah) What areas of the picture tube do the static convergence adjustments primarily affect?

(ai) What part of the picture tube face does the dynamic convergence affect?

(aj) What does R_3 in Fig. 48 control?

(ak) What purpose does R_8 in Fig. 48 serve?

(al) In the circuit shown in Fig. 50 what effect does adjusting L_1 have on the current flowing through the green and red convergence coils?

(am) What effect does adjusting the slug in the coil L_2 - L_3 in the circuit shown in Fig. 50 have?

(an) Are convergence adjustments more difficult in color picture tubes with a triangular gun configuration or in color tubes having a horizontal gun configuration?

(ao) What is the method most frequently used for pincushion correction?

Answers to Self-Test Questions

(a) A raster.

(b) Three.

(c) Convergence circuits.

(d) Clockwise.

(e) Vertically.

(f) A sawtooth current.

(g) 262-1/2 lines.

(h) Yes. The sweep circuits of a TV receiver are free-running and therefore will produce a raster even when no TV signal is received. When a signal is received, however, the sweep oscillators should lock in with the sync pulses received.

(i) The blocking oscillator and the multivibrator.

(j) C_1, R_1, and R_2.

(k) In order to obtain a linear sawtooth. C_3 will charge at an exponential rate and if too much of the charging curve is used as part of the sawtooth, the one edge of the sawtooth will be curved.

(l) The oscillator frequency will increase.

(m) Plate-coupled and cathode-coupled.

(n) The waveform shown in Fig. 18C.

(o) C_2, R_2.

(p) C_3 and L_1 improve the stability of the multivibrator and make it less susceptible to instability due to noise interference.

(q) R_2, R_3, R_4, the power supply, R_6 in parallel with R_7 and R_5.

(r) (1) Direct application of the sync pulses to the oscillator; (2) by establishing a dc voltage at the oscillator that depends on the incoming sync pulses.

(s) By loading the deflection coils by connecting resistors across them.

(t) No. A sawtooth current is required in the vertical deflection coils. Since the coils represent a fairly high inductive load, a sawtooth current cannot be obtained by applying a sawtooth voltage waveform.

(u) The vertical hold control, in conjunction with the 470K-ohm resistor R538, determines how long it takes the .0033 mfd capacitor C504 to discharge. The hold control is set so that the capacitor has discharged to a point where the

tube is almost ready to start conducting when the vertical sync pulse arrives. Then the vertical sync pulse can drive the tube into conduction and control the oscillator frequency.

(v) A vertical output transformer is not needed because the output transistor Q_3 has a comparatively low output impedance. The deflection coils L_2 and L_3 provide an adequate load when connected directly into the emitter circuit.

(w) C_7 keeps the dc current from flowing through the deflection coils L_2 and L_3. If dc current flows through these coils it will affect the vertical positioning of the raster and may make it impossible to center the raster vertically.

(x) It provides a low impedance path for the field built up in the emitter winding of T_1. This field will cause a high current to flow when the transistor is cut off. The high current could induce a voltage which could cause the transistor to continue to conduct, but the diodes load the winding so that the energy is quickly dissipated.

(y) It is used to isolate the oscillator circuit from the driver circuit and thus provide better oscillator stability.

(z) Q_4 is used to prevent Q_5, the output transistor, from overloading. If the current through Q_5 begins to increase, the voltage across R_{18} will increase. This will cause the current flowing through Q_4 and through R_{12} to increase. An increase in voltage across R_{12} will increase the negative bias applied to the base of Q_5 and hence reduce the current flow through it.

(aa) The beam is moved rapidly from the right side of the tube back to the left side of the tube during the retrace interval by letting the deflection coils oscillate for one half-cycle.

(ab) No. The current required to move the beam from the left side of the tube to the right side of the tube is provided by the deflection coils themselves. The high field built up in the coils at the end of the one half-cycle oscillation is slowly released through the damper tube so that the current through the coils decreases at a sawtooth rate to move the beam in a linear fashion from

the left side of the picture tube to the center of the screen.

(ac) Three. The deflection coils around the neck of the tube must deflect the electron beams from the three guns of the color tube.

(ad) V_3 is the focus rectifier. It develops a high voltage that is supplied to the focus electrode in the tricolor tube.

(ae) Filament voltage for V_3 and V_4 is obtained by means of filament windings on the horizontal output transformer. These windings usually consist of one or two turns of wire around the core of the transformer.

(af) D_1 is the damper. It stops the oscillation of the horizontal deflection coil after one half-cycle.

(ag) T_3 provides a method of applying the operating potential to the output transistor Q_4. It also develops the high voltage required to operate the picture tube and by means of the windings L_2 and L_3 develops pulses for horizontal blanking and agc. It has nothing whatsoever to do with matching the deflection coils to the output transistor. The deflection coils, because of their low impedance and the low impedance of the output transistor, are connected directly across the output of the transistor through the blocking capacitor C_8.

(ah) The area in the center of the picture tube face.

(ai) The dynamic convergence adjustments primarily affect the outer edges of the picture tube.

(aj) R_3 primarily controls the amplitude of the parabolic current flowing through the green and red convergence coils.

(ak) R_8 controls the amplitude of the sawtooth current flowing in the green and red convergence coils. This sawtooth current tilts the parabolic convergence current flowing through these coils.

(al) The adjustment of L_1 controls the amplitude of the parabolic current flowing through the red and green horizontal convergence coils.

(am) Adjusting the slug in the coils L_2-L_3 controls the division of the parabolic current. By adjusting the slug you can increase the parabolic current flowing in the green coil and decrease the parabolic current flowing in the red coil and vice versa.

(an) Convergence adjustments are more difficult and complex in color tubes having a triangular gun configuration.

(ao) Pincushion correction is most frequently accomplished by permanent magnets attached to the deflection yoke.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. Name the two types of oscillators used as sweep oscillators in TV receivers.

2. In what direction through the neck of the tube does the magnetic field flow that causes the electron beam to move vertically?

3. If the blocking oscillator circuit shown in Fig. 16 refuses to operate at the correct frequency what parts should you check?

4. What purpose does the resonant circuit consisting of L_1 and C_2 in the multivibrator circuit shown in Fig. 20 serve?

5. What must be the polarity of the synchronizing pulse that is fed to the base of a vertical blocking oscillator using a PNP transistor?

6. When an NPN transistor is used in a blocking oscillator circuit, what will the effect be of injecting a negative dc control voltage into the base of the circuit?

7. How is oscillation in the vertical deflection coils of a TV receiver prevented?

8. What purpose does L_1 in Fig. 35 serve?

9. What type of oscillator is used in the color TV horizontal sweep system shown in Fig. 45?

10. What is the effect of the current flowing in the convergence coils when adjusting R_4 in Fig. 48?

TV SYNC AND AGC CIRCUITS

●

STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

☐ **1. Introduction. . . . . Pages 1—10**
        What synchronization is, why it is necessary, and how the sync pulses are obtained
        and separated from the rest of the signal.

☐ **2. Automatic Gain Control . . . . Pages 10—16**
        All modern TV receivers use some form of agc. You study simple agc and keyed
        agc.

☐ **3. Noise Rejection in Sync and AGC Circuits . . . . Pages 17—21**
        Two basic methods of noise rejection that are used and circuits in which they
        are used.

☐ **4. Separating Horizontal and Vertical Sync Pulses . . . . . . Pages 22—25**
        The process of segregation--separating the horizontal sync information from the
        vertical sync information.

☐ **5. Synchronization of Sweep Generators . . . . Pages 26—36**
        You study the horizontal and vertical sync systems.

☐ **6. Answer Lesson Questions.**

☐ **7. Start Studying the Next Lesson.**

TV SYNC AND AGC CIRCUITS
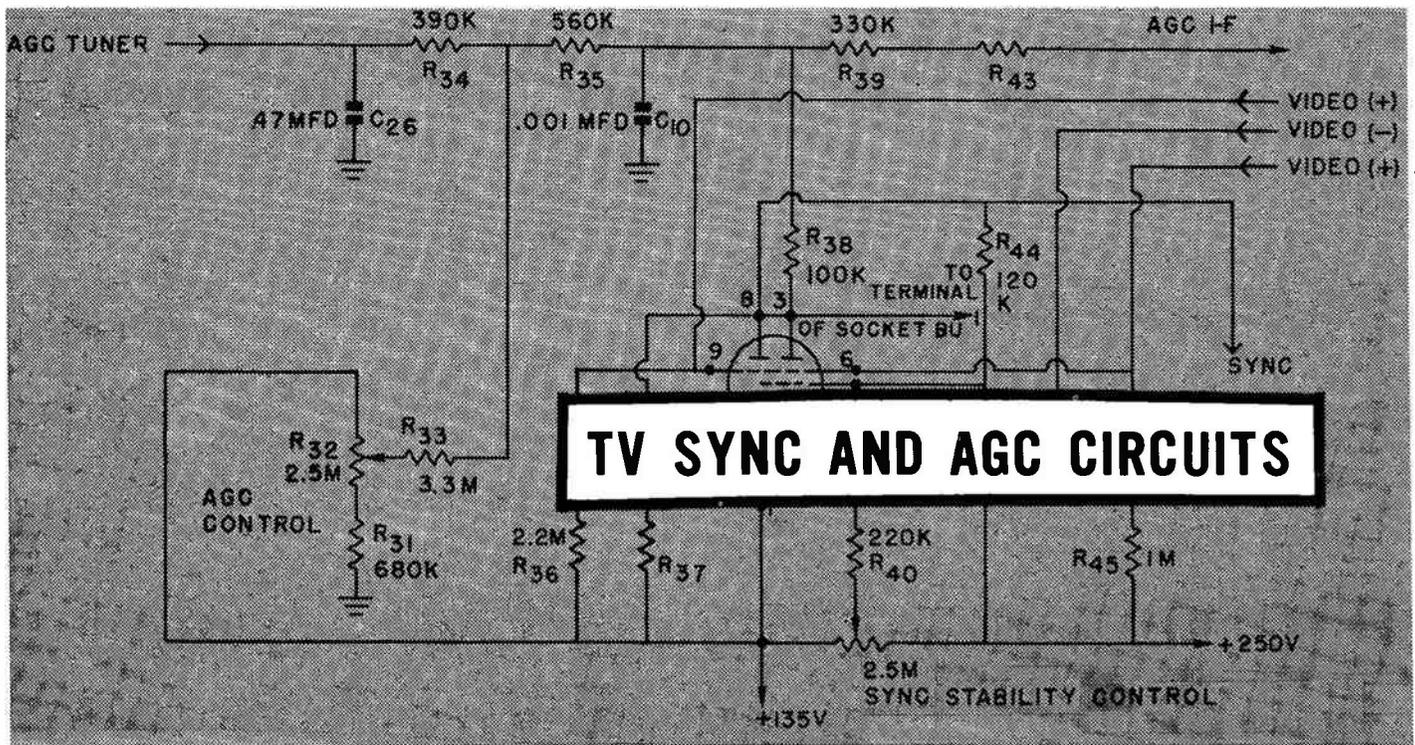
In this lesson you are going to study two important sections of a TV receiver: the sync section and the automatic gain control (agc). You will study the sync circuits first and agc later.

Television pictures are reproduced on the picture tube screen in a definite, orderly manner--element by element and line by line. To reproduce the original scene faithfully, the scanning beam, which paints the picture on the picture tube screen, must follow exactly the path taken by the scanning beam of the camera tube at the station. The camera tube scanning beam releases the picture information in an orderly sequence. The scanning beam at the receiver that is reproducing the picture must be synchronized with the scanning beam at the camera tube. The synchronizing or timing information is sent in the form of pulses, which are called the horizontal and vertical synchronizing pulses. These pulses are used to control the receiver circuits that generate the sweeps, which move the electron beam over the face of the picture tube.

In previous lessons you have followed the television signal from the antenna to the grid of the picture tube. You learned that the signal applied to the grid or the cathode of the picture tube contains brightness, color and blanking information, and modulates, but does not move, the electron beam. The movement of the electron beam is controlled by the energy developed in the form of sawtooth currents in the horizontal and vertical deflection coils. This motion must be synchronized by the sync pulses from the station. Consequently, the television signal present in the video amplifier is also applied to the sync amplifier-separator circuit. The synchronizing circuits must extract the sync pulses from the composite video signal, and prepare them properly for synchronizing and controlling the sweep generating circuits of the receiver.

A number of operations must be performed to sepa-

rate and shape the pulses for control of the sweep generators. A block diagram of this section of a TV set is shown in Fig. 1. First, the composite video signal must be fed from some takeoff point to the sync separator. In most receivers, the sync takeoff point will be located in the video amplifier. If it is located in the video amplifier, it must be arranged so that the sync removal does not disturb the operation and frequency response of the video amplifier. If the sync takeoff point is located in some circuit other than the video amplifier, similar precautions must be taken not to upset the signal at the takeoff point.

Next, the sync is separated completely from the video and blanking signal. In succeeding amplifier and clipper stages, the sync pulses are leveled (the base line and sync tip levels are made flat and free of video information) and made as free of noise impulses as possible. Leveling or clipping at the top and bottom gives the same amount of stable synchronization regardless of the strength of the received signal.
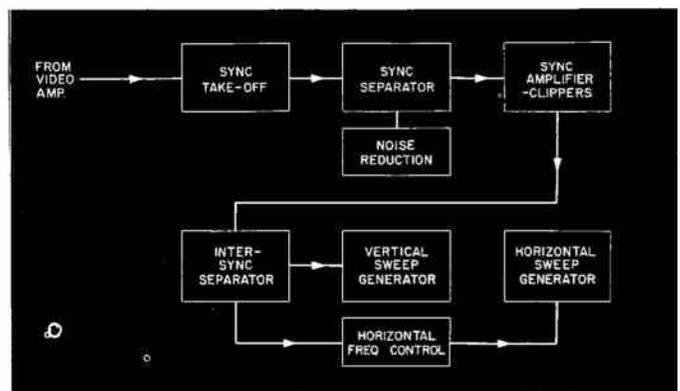
Fig. 1. Functional block diagram of synchronizing circuits.

Fig. 2. Sync circuit defects. A shows loss of horizontal and vertical sync; B, loss of vertical sync; C, loss of horizontal sync.

The next step in the preparation of the sync pulses is to segregate the horizontal components from the vertical components. This must be done so that the vertical sync pulses will go to the vertical sweep generator, and the horizontal sync pulses to the horizontal sweep generator. Clean segregation prevents interaction between horizontal and vertical components, and minimizes the influence of noise impulses on both synchronizing circuits. Sometimes there are additional sync amplifiers after the sync segregating circuits, before the individual sync pulses are applied to the sweep oscillators.

The final step in the synchronizing process is to use the pulses to control the sweep generators. As you have already learned, the sweep generators are free-running; they generate the sawtooth currents that deflect the electron beam, whether sync pulses are present or not. Thus, the scanning raster is always present, but only with the arrival of the sync pulses does the raster lock in so the scanning beam moves in exact synchronism with the scanning beam at the camera. It is important to realize that the sync pulses themselves do not cause the scanning beam to move, but only control the frequency and timing of the waveforms that do move the scanning beam.

The expert technician does not consider the operation of circuits and the servicing of circuits separately. It is his understanding of circuits that permits him to identify and repair defects rapidly. He must therefore train his thoughts to associate the operation of a circuit with the effects of trouble within that circuit and the influence such defects have on overall operation of the receiver. For example, at this very point and with only a limited knowledge of the sync circuits, your fundamental understanding of the reasons for having the sync circuits would permit you to isolate trouble to the sync circuit. If there is a failure in the sync circuit, the horizontal and vertical sawtooth generating circuits will run free, wandering in frequency and phase with respect to the incoming video information, as shown in Fig. 2A. A failure in the sync circuit does not in any way affect the video and blanking

information applied to the grid circuit of the picture tube. Therefore, the scanning beam will still be modulated by the video information and will cause brightness variations on the picture tube screen.

If the sync circuit defect affects just one of the sync signals, the disturbance on the screen will guide you to it. For example, if the defect is in the vertical synchronization, the picture will roll, as shown in Fig. 2B. Although it will be possible to adjust the vertical hold control to lock in the picture vertically, the picture will soon drop out of vertical synchronization, but it will remain synchronized horizontally. If the defect is in the horizontal synchronizing section only, the picture will remain locked in vertically, but will tear out horizontally as in Fig. 2C.

In addition to synchronizing the horizontal and vertical sweep oscillators in the receiver to the sweep oscillator in the camera, in a color receiver we have an additional sync problem; we must synchronize the 3.58-mc oscillator in the TV receiver with the 3.58-mc color subcarrier generator in the transmitter. We will deal with the problem of color synchronization in a later lesson.

SYNC CIRCUIT WAVEFORMS

To gain more complete understanding of the general operation of the sync circuits, let us study the typical waveforms shown in Fig. 3. First the sync information along with an appreciable level of blanking and video information is removed at a convenient point in the video amplifier and applied to the sync circuit. This composite signal fed to the sync separator is shown in Fig. 3A. Next, the composite signal is applied to the sync separator, which almost completely removes all signal information below the blanking level so that only the sync pulses remain, as in Fig. 3B.

In the composite signal, the amplitude of the synchronizing information is greater than that of the video and blanking information. For example, in Fig. 3E, if

the amplitude of the combined horizontal sync and blanking signal is 20 volts at the input to the sync separator, the sync information itself, which is just the upper 25% of the total signal, is only a 5-volt peak component. In the process of sync separation, the rest of the signal (video and blanking) is dropped, leaving only the sync pulses at the output of the separator.

Succeeding amplifier stages remove any extraneous signal and properly flatten both the tips of the pulses and the base line to a prescribed voltage level, which is reasonably constant for a wide variation in applied signal strength.

Now the combined sync information (horizontal and vertical sync pulses) is applied to a sync segregator or inter-sync separator that separates the horizontal from the vertical sync information. One section selects the horizontal pulses from the combined information and, at the same time, blocks out the vertical pulses as shown in Fig. 3C. A second section accepts the vertical pulses and rejects the horizontal, producing the vertical sync pulse shown in Fig. 3D. Finally, the horizontal and vertical information is properly shaped and used to control the frequency and phase of the sweep oscillators.

The location of defects in the sync circuit is a task that can be performed well by an oscilloscope. The disappearance, reduction in amplitude, or change in shape of various waveforms can be observed at key points. When using an oscilloscope in the sync circuits

you should remember, however, that the sync information itself is of very low amplitude and can often be obscured by the higher voltage deflection waveforms that are also present in the latter sections of the synchronizing system. Thus, in signal tracing through the latter sections of the sync system, it is preferable to turn off or remove the sweep generating tubes or transistors. For example, it is not possible to check for the presence of the vertical sync pulse at the grid of the vertical blocking oscillator tube or the base of the vertical blocking oscillator transistor when they are operating, because the waveform produced by the blocking oscillator is much higher in amplitude than the vertical sync pulse.

SYNC TAKEOFF

Let us now consider the individual functions of the various sections of the sync circuits in detail, starting with the removal of the synchronizing information at the sync takeoff point.

The composite video signal containing picture information as well as the horizontal and vertical blanking pedestals and sync pulses is shown in Fig. 3A. The synchronizing pulses ride on top of the blanking pedestals. There is one set of pulses for horizontal or line synchronization, and a second set for vertical or field synchronization. A portion of this composite video signal must be supplied to the sync circuits from the takeoff point without any deterioration of the video information which must be fed to the picture tube.

ACTION OF SEPARATOR
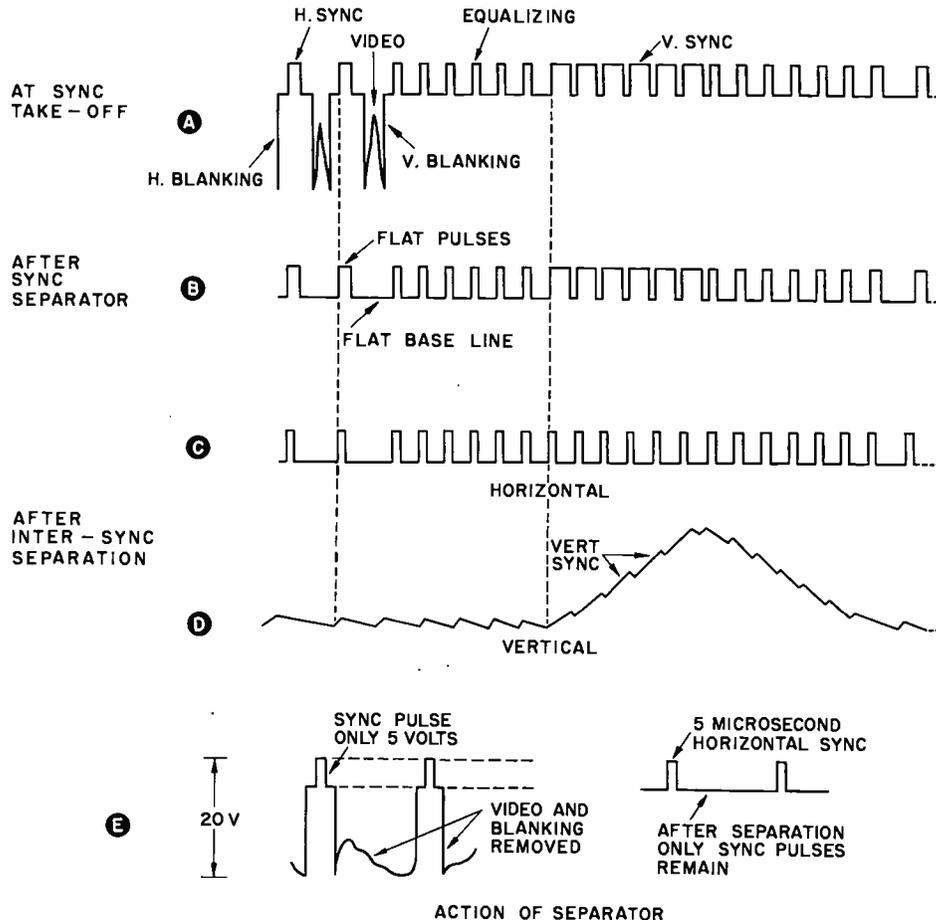
Fig. 3. Sync circuit activities as shown by waveforms.
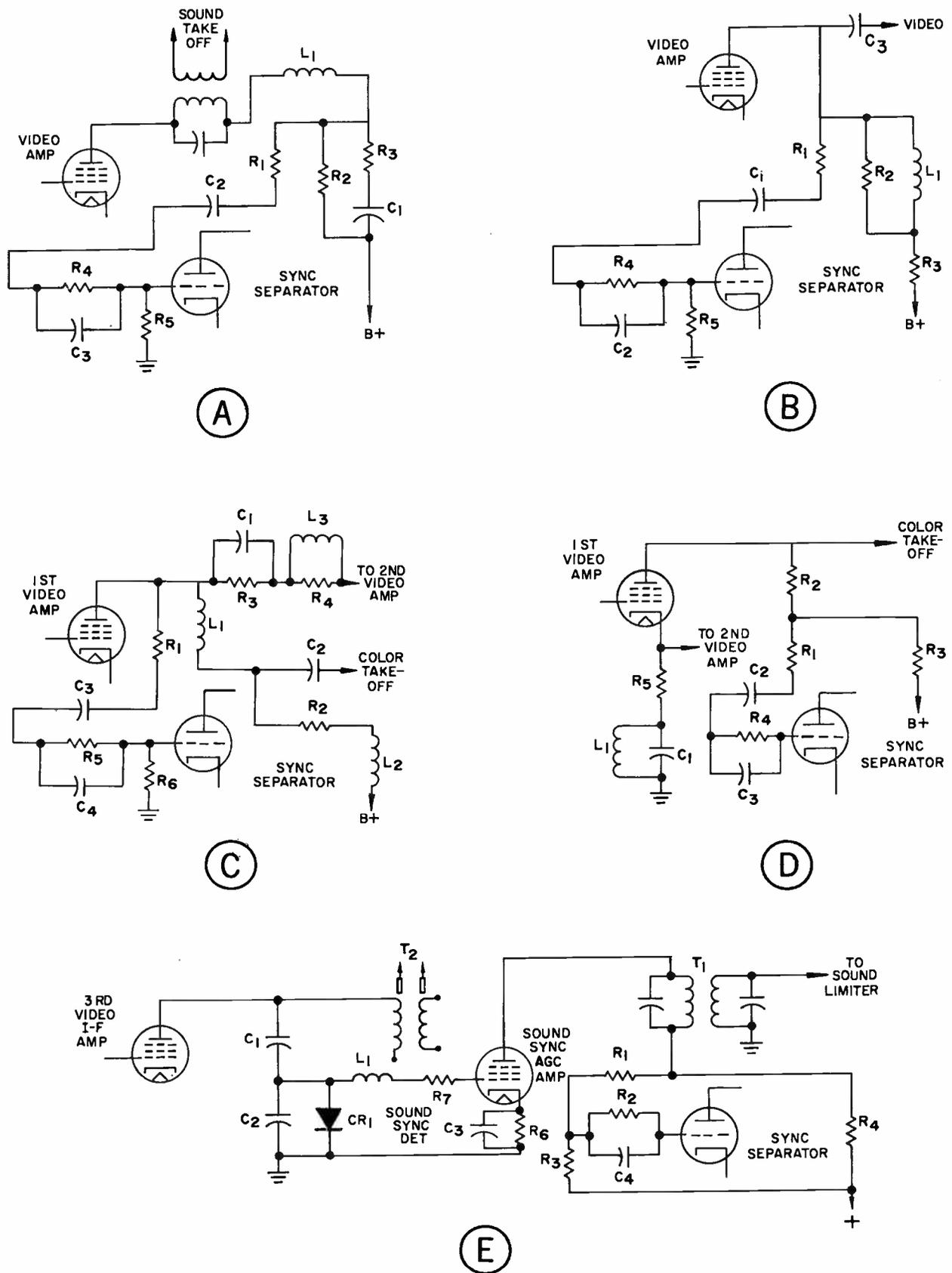
Fig. 4. Sync take-off methods.

There must be no loss of the high-frequency components of the video information (which determine the picture detail) nor can there be any loss of the 3.58-mc color signal in color receivers. Some typical sync takeoff methods are shown in Fig. 4. In the first four circuits shown, Fig. 4A through Fig. 4D, the sync signal is taken off in the video amplifier. This is the arrangement most frequently used. In each case iso-

lating resistors are used to prevent deterioration of the high-frequency response of the video amplifier and loss of color signal in color receivers. Resistor R_1, in each example shown, prevents the input capacity of the sync separator circuits from causing high-frequency loss at the sync takeoff point.

Of course, the presence of the series resistor in the sync circuit input causes attenuation of the video signal. However, this is not important, because the video signal at the point of takeoff is higher in amplitude than required by the input circuit of the sync stages.

In the circuit shown in Fig. 4A the sync information is removed at the junction of the shunt peaking coil and the plate load resistor. It is applied to the grid of the sync separator through an isolating resistor and a noise-filter network. In the takeoff system shown in Fig. 4B, the sync information is taken directly from the plate of the video amplifier. The sync takeoff in Fig. 4B has more tendency to affect the high-frequency response of the video amplifier than the circuit in Fig. 4A.

The takeoff circuits in Fig. 4A and 4B are taken from monochrome TV receivers. The circuits shown in Fig. 4C, 4D and 4E are taken from color TV receivers. In the circuit shown in Fig. 4C, the sync is taken from the plate of the first video amplifier. The video signal is fed through C_1-R_3 and L_3-R_4 to the grid of the second video amplifier. The 3.58-mc color signal is taken off at the junction to the shunt peaking coil L_1 and the plate load resistor R_2. Insofar as the sync takeoff is concerned, the circuit is essentially the same as the one shown in Fig. 4B.

The circuit shown in Fig. 4D is somewhat different. Here the sync takeoff is located at the junction of the plate load resistors R_2 and R_3 in the plate circuit of the first video amplifier. R_1 isolates the sync input from the plate circuit of the tube. C_2 is simply a blocking capacitor and C_3 and R_4 form a noise filter. Notice that in this circuit the sync takeoff cannot interfere with the video response because the video signal is taken off at the cathode of the first video amplifier. Insofar as the video signal is concerned, the stage operates as a cathode follower. The stage provides gain for the sync signal and inverts it. It also amplifies the 3.58-mc color signal which is taken off from the plate circuit. Here the isolating resistor prevents the sync input from loading the color circuit and from reducing the amplitude of the 3.58-mc signal.

The sync takeoff shown in Fig. 4E is the most unusual of all. You'll remember that in a color receiver, the sound takeoff is in the last video i-f stage. Here the 41.25-mc sound is taken off through C_1. Of course, the 45.75-mc video signal with the composite video modulation is also taken off through C_1. The sound and video signals beat in the sound detector CR_1 to produce a 4.5-mc signal which is frequency-modulated by the sound signal and at the same time produces a composite video signal just like the signal at the output of the video detector. The 4.5-mc signal and the composite video signals are then amplified by a stage called the sound, sync and agc amplifier.

The signal is then fed through the primary of T_1 which is resonant at 4.5 mc. This induces a 4.5-mc signal in the secondary. The signal from the secondary is fed to a limiter which removes any amplitude variation that might be present; the signal is fed from there to an fm detector. At the same time a video signal will be developed across R_4. This signal is fed through R_1 to the noise filter made up of R_2 and C_4 to the grid of the sync separator. The primary circuit of T_1 is a parallel resonant circuit and hence offers a high resistance to the 4.5-mc sound signal. Most of this signal will be dropped across the parallel resonant circuit and very little will appear across R_4. However, if a small amount of the 4.5-mc signal does get through to the grid of the sync separator, it will not have sufficient amplitude to affect the operation of this stage.

The circuit of Fig. 4E is quite different from the other sync takeoff circuits. It completely overcomes the problem of having the sync separator upset the high frequency response of the video amplifier or the 3.58-mc color signal.

The sync takeoff circuit in a transistorized receiver is essentially the same as the circuits found in a vacum-tube receiver. In Fig. 5A we have shown the sync takeoff circuit used in a monochrome transistorized receiver.

In this circuit Q_1 is the first video amplifier and Q_2 is the second video amplifier. Q_1 is the common-emitter type circuit and the video signal is developed across R_2. The circuit consisting of C_3 and the primary of T_1 is resonant at 4.5 mc and sound is taken off at this point. The series-resonant trap also provides a low impedance path for the 4.5-mc signal so that the amplitude of the 4.5-mc signal between the emitter of Q_1 and ground is kept comparatively low. Meanwhile the sync signal is taken off through the combination of C_1 and R_1 and then fed through C_7 to the sync separator Q_3. The network consisting of C_1 and R_1 isolates the sync separator from the video circuit to prevent excessive loading of the video amplifier.
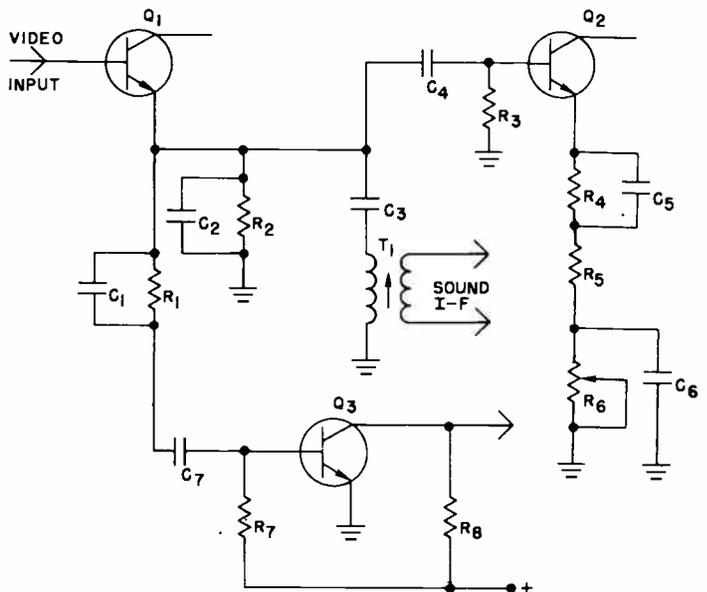
Fig. 5A. Sync takeoff from a monochrome receiver.

Fig. 5B. Sync takeoff circuit in a color TV receiver.

work. The sync signal is taken from the emitter of Q_1 through the parallel combination of R_4 and C_1, through R_5 and then through C_4 to the sync separator Q_2. Isolation between the sync separator and the video circuit is provided by R_4, C_1 and R_5.

Notice that the transistor circuits shown in Fig. 5 and the vacuum-tube circuits shown in Fig. 4 have one point in common: that is, steps are taken to prevent the sync takeoff circuit from loading the video amplifier and upsetting the performance of the video amplifier stage. Now, let us go ahead and see how the sync signal is separated from the composite video signal in the sync separator stage.

SYNC SEPARATORS

After the composite video signal is taken from the video amplifier it is fed to the sync separator. The sync separator must remove the portion of the composite television signal below the blanking level so that the only signal appearing in the output will be the sync pulses. Either tubes or transistors can be used as sync separators.

The sync separator is biased to permit the tube or transistor to conduct only on the portion of the composite signal between blanking and sync tip. If the applied signals were of a constant amplitude, this separation could be accomplished with the use of external bias as shown in Fig. 6. For example, if the applied video signal were of a constant 12-volt amplitude as

Another sync takeoff circuit, this one from a color TV receiver, is shown in Fig. 5B. In this circuit Q_1 is the second video amplifier. This stage is connected as an emitter-follower, and the entire network connected between the emitter of the transistor and ground is used as the emitter load. In other words, the composite video signal is developed across the entire net-
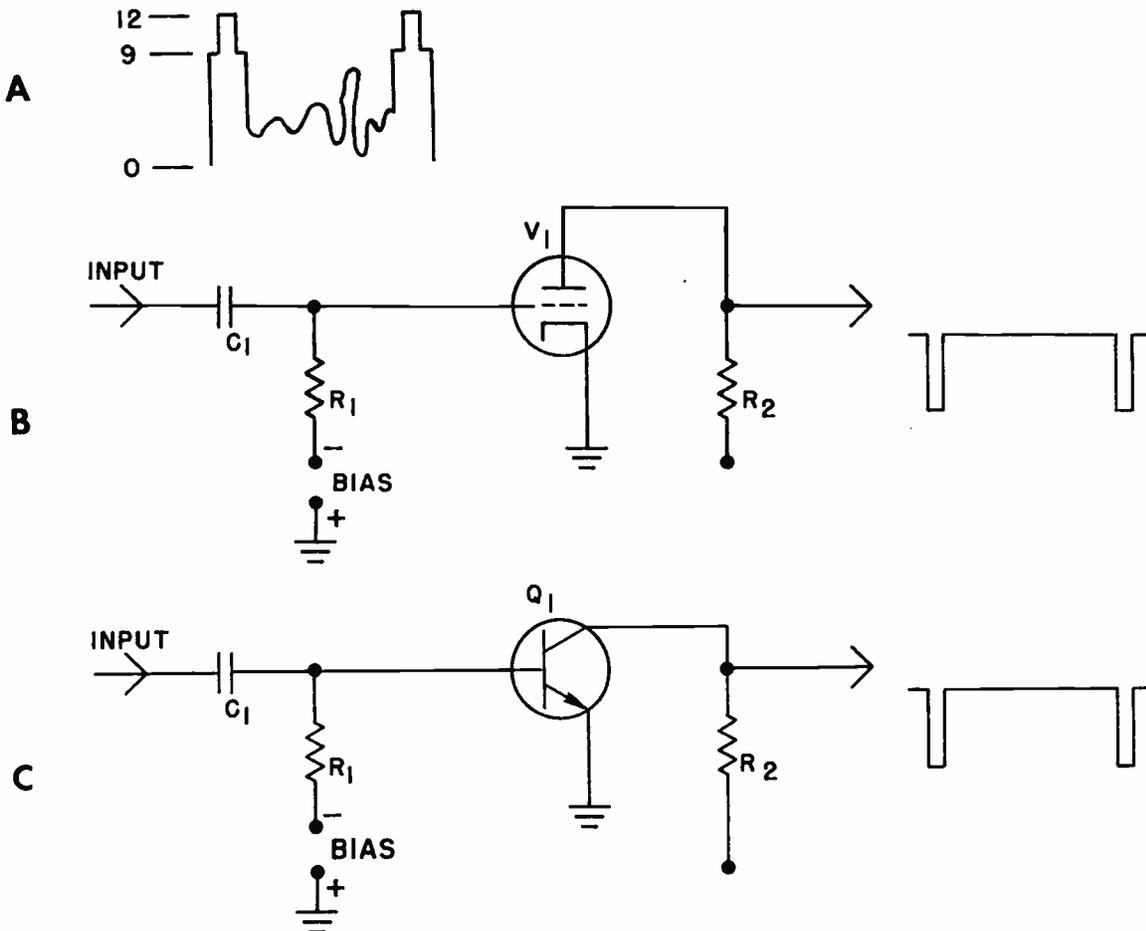
Fig. 6. Sync separators with external bias.
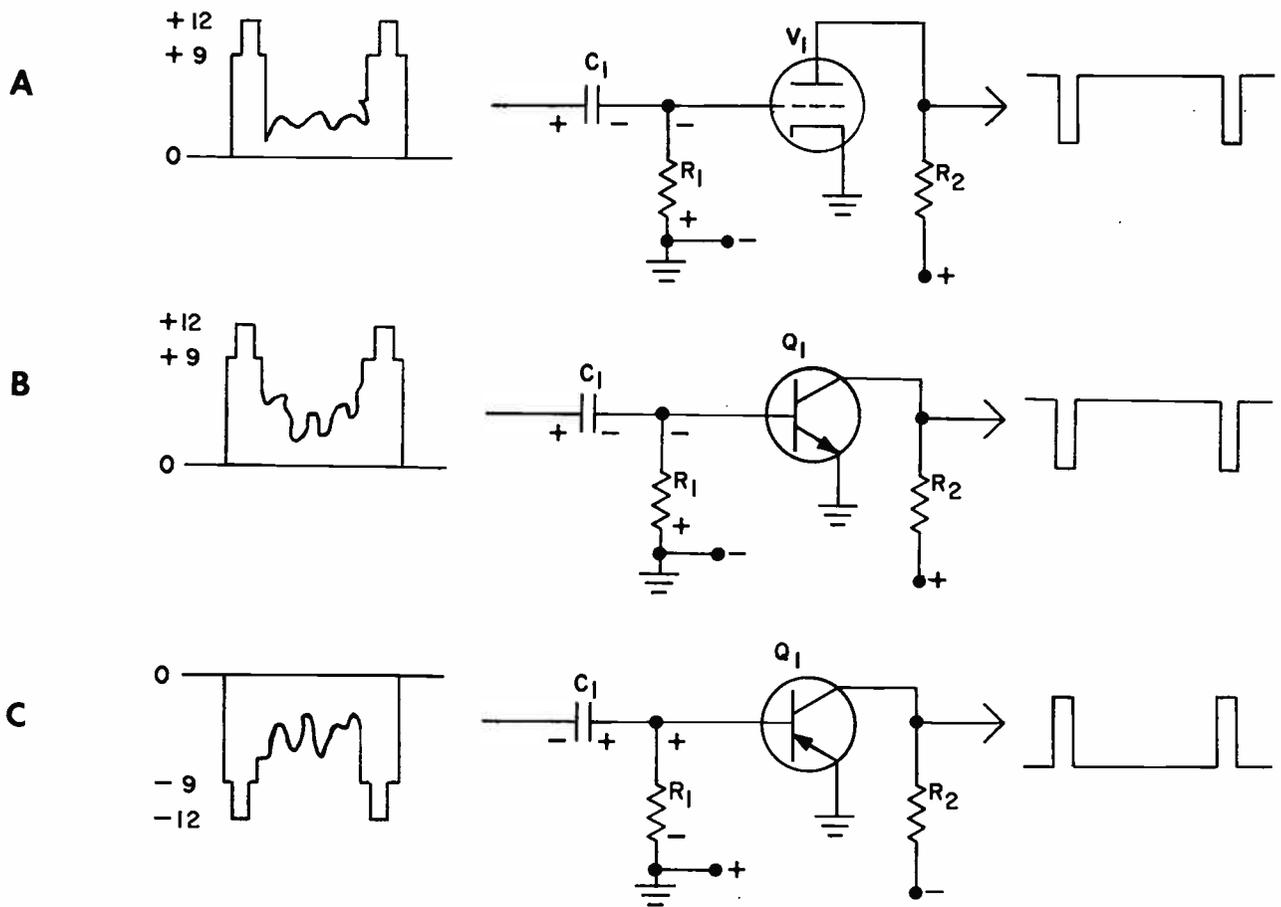
Fig. 7. Self-biased sync separators.

in Fig. 6A, and the cut-off bias for the tube in Fig. 6B were -3 volts, it would be possible to set the bias far enough beyond cut-off with a battery or another external bias source so the tube would conduct only on the portion above the blanking level. Thus, a pulse would appear in the output of the separator for each arriving sync pulse, and the other information below blanking level would not be present because the signal would not be strong enough to drive the tube into the region of plate current flow.

The transistor sync separator shown in Fig. 6C could be made to operate in much the same way. In this case, a fixed reverse bias of 9 volts would be applied across the emitter-base junction. With this reverse bias across the emitter-base junction, there will be no current flow through the transistor. However, the signal with the positive-going sync pulses such as in Fig. 6A would overcome this reverse bias. Notice that the blanking level is 9 volts. Thus the input signal as it reaches the blanking level would exactly balance out or cancel the reverse bias. Then, as the sync pulses drive the base still further in a positive direction, this would be the equivalent of placing a forward bias across the emitter-base junction. This would cause current to flow through the transistor Q_1 and through the collector-load resistor R_2 developing the sync pulses shown in the output.

However, the television signal amplitude changes in accordance with the received signal strength. Consequently, the external bias system is not able to accommodate the range of signal level variations.

Some method of signal biasing must be used to obtain true sync clipping.

When signal bias is used, the amplitude of the sync pulses sets the bias on the sync separator. In Fig. 7 we have shown three self-biased sync separators. In each of the circuits, the input signal is shown at the left, the schematic diagram of the sync separator is in the center, and the output sync pulses are at the right. In the circuit shown at A, we have illustrated a triode vacuum-tube sync separator. In the circuit shown at B, we have illustrated an NPN transistor used as a sync separator; in the circuit shown at C, a PNP transistor is used as the sync separator. Notice that there is not too much difference between the three circuits. However, we'll analyze each of these circuits in detail, starting with the vacuum-tube circuit shown in Fig. 7A.

In the vacuum-tube circuit, notice that the sync pulses are positive-going signals. The tube is operated with a low plate voltage and a comparatively large value plate load resistor. The incoming sync signal drives the grid of the tube positive. This causes grid current to flow and electrons reaching the grid of the tube flow into the capacitor C_1, charging it with the polarity shown. At the same time, some electrons will flow through the grid resistor R_1, setting up a voltage drop across this resistor having the polarity shown.

The voltage developed across the grid capacitor and grid resistor is sufficient to bias the tube to an amplitude of almost 12 volts. This will cut off the flow of plate current. The only time plate current

will flow is when the sync pulses arrive with sufficient amplitude to overcome the bias on the tube. During the interval between the sync pulses, capacitor C_1 discharges through the resistor R_1 maintaining the bias across the resistor so that no current will flow during the blanking interval or the interval when the video information is transmitted.

As a result of current flow during the sync pulse interval, the voltage drop across the plate-load resistor R_2 will increase. Therefore the plate voltage on V_1 will swing in a negative direction, producing negative-going sync pulses in the output as shown.

In the vacuum-tube circuit, unless the tube is operated with a low plate voltage there is a danger that the tube will start conducting at the arrival of the blanking pulse. For example, the cut-off voltage must be -3 volts or less. In other words, the grid cut-off voltage is -5 volts; since the amplitude of the blanking pulse is 9 volts, this would be sufficient to overcome the bias across the grid resistor and cause the tube to begin conducting. However, if the cut-off voltage is less than 3 volts, then the 9-volt signal from the blanking pulse will not have sufficient amplitude to drive the tube into the current-conducting region. The sync pulse, however, will be able to overcome the bias and cause the tube to begin conducting.

In the circuit shown in Fig. 7B, notice that we have essentially the same input signal. We have a total peaking amplitude of +12 volts and a blanking level of +9 volts. When the input signal is applied between the emitter and base of the NPN transistor, the base is driven in a positive direction and current flows from the emitter to the base of the transistor and out the base to the capacitor C_1. The capacitor will be charged with the polarity shown. The charge on the capacitor will approach 12 volts. Also, some of the electrons flowing out of the base will flow through the resistor R_1 developing a voltage drop across it having the polarity shown. In the interval between the sync pulses C_1 discharges through R_1 maintaining the bias essentially constant. Since this is a reverse bias across the emitter-base junction, there will be no current flow through the transistor. With no current flow through the transistor there will be no voltage drop across the collector-load resistor R_2, and the dc voltage level at the collector of the transistor will be equal to the supply voltage.

When the sync pulse comes along, it has sufficient amplitude to overcome the reverse bias across the emitter-base junction and place a forward bias across this junction. This will cause current to flow through the transistor. When collector current begins flowing it will flow through the resistor R_2 and cause the voltage drop across this resistor. This will cause the collector potential to swing in a negative direction; thus we have the negative-going sync pulses as shown to the right.

When the sync pulses arrive they perform another function. They also cause some additional base current to flow and this recharges the input capacitor C_1 so that it will maintain an essentially constant charge. The only thing that will cause the amplitude of the charge across this capacitor to vary is for the amplitude of the input signal to vary. If the amplitude of the signal goes down, the charge will go down and if the amplitude of the signal goes up the charge will go up. Hence the circuit is self-regulating and adjusts itself to the amplitude of the incoming sync pulses.

In the PNP transistor circuit shown at C, we have a somewhat different situation. In order for this sync separator to work, the incoming sync pulses must be negative-going signals. Notice also that the dc supply voltage that is applied to the transistor has been reversed. When the negative-going sync pulse reaches the base of the transistor the negative voltage applied to the base will attract holes across the emitter-base junction. These holes reaching the base will attract electrons from the capacitor C_1 charging the capacitor with the polarity shown. At the same time, they will also attract a certain number of electrons from ground up through resistor R_1 and develop a voltage across the resistor having the polarity shown. Thus we have a positive bias placed on the base of Q_1, and you will remember that in the case of a PNP transistor, a positive bias on the base is a reverse bias. Therefore, during the interval between the sync pulses, the reverse bias placed across the emitter-base junction prevents current from flowing through the transistor. When this happens, the maximum negative potential of the power supply is applied to the collector because there is no voltage drop across the collector-load resistor R_2. When the sync pulses arrive and drive the base in a negative direction they have sufficient amplitude to overcome the reverse bias across the emitter-base junction.

Thus the base is driven negative, and the holes crossing the emitter-base junction will once again pull additional electrons from C_1 to keep the charge on the capacitor up to its original value. Holes will also cross the emitter-base junction, cross the base and the base-collector junction and flow through the collector. These holes will be filled by electrons flowing through resistor R_2 from the negative terminal of the power supply to the collector. This will cause the negative potential on the collector to drop; in other words, the collector voltage will swing in a positive direction so we have positive-going sync pulses in the output as shown on the diagram.

During the interval between sync pulses, C_1 discharges. In order for it to discharge, electrons must flow through R_1 from ground through the resistor to the positive plate of the capacitor. When the electrons flow through the resistor in this way they maintain the positive bias on the base of the transistor and hence keep the high reverse bias across the emitter-base junction so that current flow through the transistor will remain cut off.

As in the case of the other two sync separators, the only thing that will cause the bias to vary will be a change in input signal strength. If the input signal strength increases it will cause the base of the transistor to become more positive and compensate for the stronger signal. On the other hand, if the strength of the input signal decreases, the positive voltage on the base of the transistor will decrease. The sync separator is (as the others are) self-regulating and
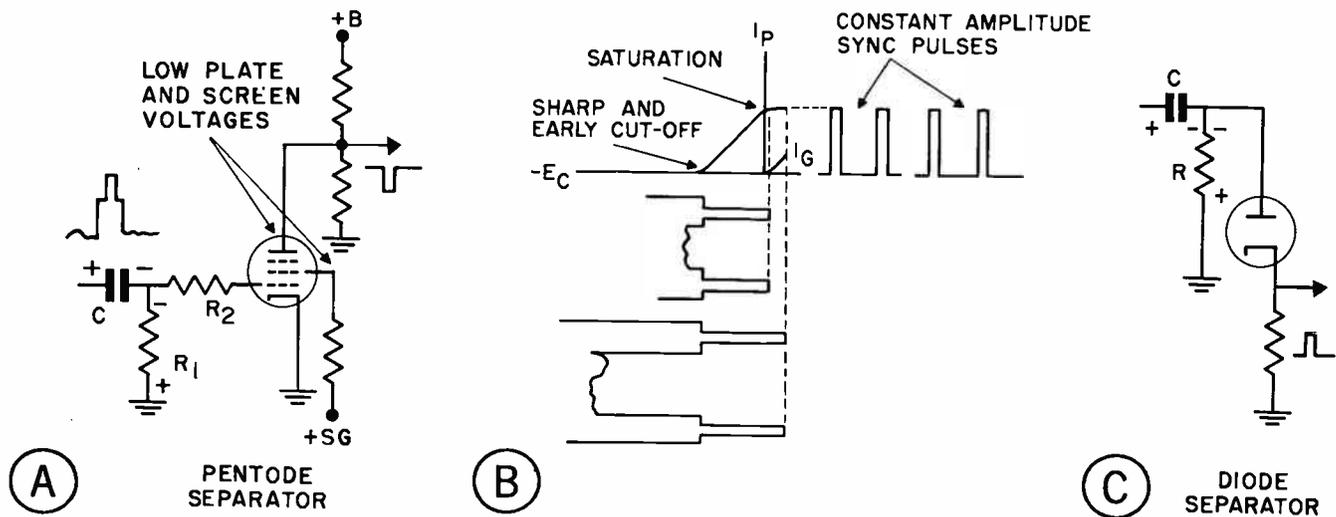
Fig. 8. Pentode separator is shown at A, pulse clipping by pentode separator at B, and diode separator at C.

adjusts for changes in input signal amplitude.

Notice the similarity between the three sync separators. They all work on the same fundamental idea of the input signal developing sufficient bias to cut off the device except during the sync pulse interval. The bias is self-regulating and increases as the signal increases and decreases as the signal decreases. In the case of the vacuum-tube separator shown at A and the NPN transistor shown at B, positive-going sync pulses must be fed to the input in order for the separator to work, and the output sync pulses will be negative-going pulses.

In the case of the PNP transistor sync separator shown at C the polarity of the video signal must be reversed so the sync pulses swing in a negative direction and the output signal will swing in a positive direction.

Pentodes can also be used as sync separators. A signal-biased pentode is shown in Fig. 8A. This stage is an excellent sync separator when the plate and screen voltages are low. Again, the grid current drawn during the sync tip interval sets the bias on the tube at the proper level to cut off all portions of the signal below the blanking level.

A pentode separator will work well because there is a narrow grid voltage range, just a few volts between cut-off and saturation. It also produces a strong output signal that is constant for a wide range of applied signal amplitudes. The sync pulse developed in the plate circuit depends on the grid voltage change between cut-off and the positive grid voltage at which grid limiting occurs. Thus, if the plate voltage is held constant, the sync amplitude in the plate circuit also remains constant, despite substantial variations in peak signal amplitude at the separator grid. In addition, the better limiting action in the grid circuit of a pentode operating with low screen and plate voltages means that any noise impulses greater in amplitude than the sync tip are clipped off, minimizing improper synchronization of the deflection generators.

The advantages of both early cut-off and early saturation are demonstrated in Fig. 8B. As you can see, the sync pulses will cause plate current flow, but reach an early saturation amplitude where any further rise

in grid voltage will cause no additional increase in plate current. Therefore any variation in sync tip level is leveled off, and the sync voltage output remains constant.

A series resistor, R_2 in Fig. 8A, is often added between the grid and the grid resistor to produce an instantaneous opposing voltage whenever very strong noise pulses reach the grid of the separator. This instantaneous opposition to grid current flow prevents the grid capacitor from being charged to an excessively high value of bias by noise bursts. Such a high bias could result in the loss of a number of the succeeding sync pulses and produce sync instability.

Even the simple diode circuit shown in Fig. 8C can be used as a sync separator (as it was in a number of earlier receivers). When the positive-going composite signal is applied to the diode plate, the sync tip peak draws maximum diode current, charging capacitor C to a peak value. Again, the charging of capacitor C is rapid because of the short time constant of the capacitor and the very low resistance of the conducting diode. Capacitor C discharges through resistor R, developing a voltage across the resistor having the polarity shown. This voltage biases the diode and prevents conduction when the signal falls below the blanking level. The only portion of the signal developed across the diode load resistor occurs when the diode is conducting. The diode conducts only for signal amplitudes higher than the blanking level, and therefore only the sync pulse itself appears across the diode load. While the circuit shown is for a vacuum-tube diode, a solid-state diode can be used just as well.

The disadvantages of the diode separator are that no amplification and only minor noise rejection are possible.

SELF-TEST QUESTIONS

(a) What function does the sync separator perform?
(b) Why is an isolating resistor usually used between the input of the sync separator and the sync takeoff point?
(c) Why is the isolating resistor R_1 used in the circuit in Fig. 4D?

(d) What two signals are produced by CR_1 in Fig. 4E?

(e) What are the advantages of the sync takeoff circuit used in Fig. 4E?

(f) What portion of the composite video signal must the sync separator remove?

(g) What is the advantage of signal bias on the sync separator over fixed bias?

(h) Why is a low plate voltage used on a triode sync separator?

(i) What is the disadvantage of a diode sync separator?

Automatic Gain Control

Modern television receivers have controls which permit the user to vary the amplitude of the output signals. For example, there is a volume control which permits you to vary the amplitude of the sound from the receiver.

In addition to a volume control there is also a contrast control. The contrast control is located somewhere in the circuitry after the point where the sound signal is taken off so that changing the contrast control does not have any effect on the amplitude of the sound signal. Changing the setting of the contrast control in effect varies the amplitude of the brightness signal fed to the picture tube. Contrast controls are used for this purpose in both monochrome and color television receivers.

In color television receivers you have another gain control, frequently called the color control. This permits you to vary the amplitude of the color signal fed to the picture tube and hence vary the color saturation of the picture. Whenever you see a color receiver where the colors are much too bright or vivid, it is because the color control has been set too high.

You might think that these three controls are all that would be necessary to control the amplitude of the three signals (the sound signal, the brightness signal, and the color signal). Indeed, if all the TV stations you could receive reached the antenna with the same amplitude then these three controls would be satisfactory. However, the fact is that it is very unlikely that any two stations picked up by your TV antenna will have the same signal amplitude. They may be close to the same amplitude and changing from one station to another might necessitate minor adjustments of these three controls. On the other hand, their amplitude might differ appreciably and this would require considerable adjustment of these three controls in order to get a satisfactory picture when going from one channel to the other.

Still another situation might exist where you are close to a very strong station and it might be impossible to prevent overloading of the receiver. Some overloading might occur ahead of the contrast control so the picture would be distorted; there is no way you can eliminate this by adjusting the contrast control. (This would cause instability in the sync circuits, among other things.) Thus, there is need for a circuit that automatically regulates the gain of the various stages in the receiver so that overloading can be avoided and also so that it is not necessary to change

the setting of the volume, contrast and color controls each time you change from one channel to another. The circuit used to regulate the gain of the receiver in this way is referred to as the automatic gain control, which we usually abbreviate "agc".

Many modern TV receivers use special noise-reducing sync circuits. However, these circuits are often tied in very closely with the agc circuit in the receiver, and therefore before looking at typical sync circuits for modern TV receivers we are going to study agc circuits so you'll know how they work and then you can see how the agc circuit and sync circuits are tied in together.

Before going ahead and studying automatic gain control circuits we are going to give some consideration of how the gain of vacuum tubes and transistors can be controlled in order to help you understand the operation of agc circuits.

HOW STAGE GAIN IS CONTROLLED

In TV receivers the voltage developed by the automatic gain control circuits is applied to the rf and i-f stages of the receiver in order to control the gain on these stages. In receivers using vacuum tubes you will find pentode tubes used in the i-f amplifier. In your study of tubes you learned that pentodes could be divided into sharp cut-off tubes and remote cut-off tubes.

In a sharp cut-off pentode, the spacing between the grid wires is constant so that the grid can cut off the flow of plate current with a comparatively low negative voltage. When a sharp cut-off tube is used in a circuit such as in Fig. 9A, the screen voltage will be held relatively constant. The bleeder R_1 is selected so that the current flow through it will be several times the screen current of the tube. With this arrangement, if a high negative voltage is applied to the grid of the tube and the screen current starts to go down, there will be some change in the voltage drop across R_2 and some small tendency for the screen voltage to increase. However, this is minimized by the bleeder current flowing through R_2 so that the screen voltage remains essentially constant. Thus the tube is cut off with a relatively low negative voltage on the grid.

With a circuit like the one shown in Fig. 9B, it takes a somewhat higher negative voltage to cut off the flow
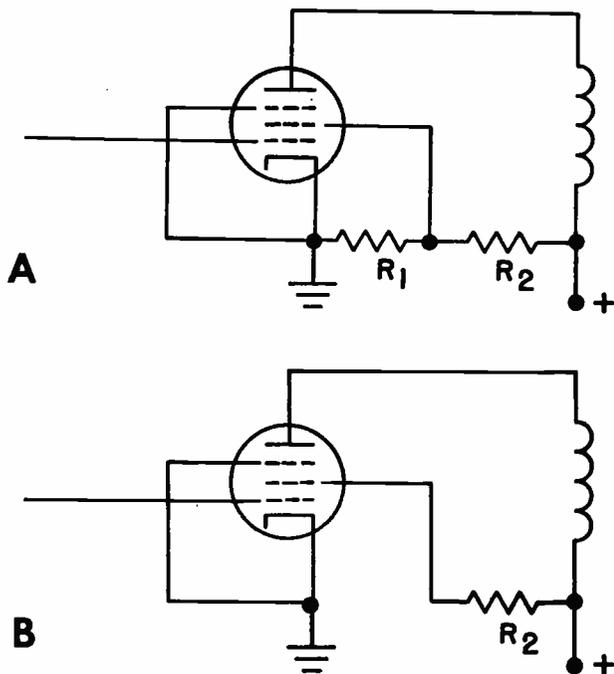
Fig. 9. Two methods of applying screen voltage.

of plate current to the tube. As the negative grid voltage is increased, the screen current decreases and this causes a voltage drop across the screen-dropping resistor R_2 to decrease. When this voltage decreases, the screen voltage increases and this tends to counteract the negative voltage applied to the grid of the tube. Thus we are able to make the tube act more like a remote cut-off tube than a sharp cut-off tube. We say that it shows semi-remote characteristics -- it is not exactly like a remote cut-off tube or a sharp cut-off tube with this arrangement.

You will remember that the remote cut-off tube is a tube in which the spacing between the grid wires varies. Thus, as the negative bias on the grid of the tube is increased the current is cut off in the area where the grid wires are comparatively close together, but current can still flow through the grid wires where they are spaced widely apart. Therefore, it takes considerably more negative voltage applied to the grid of the tube to cut off the plate current. In addition to remote cut-off and sharp cut-off types, tubes are made that are called semi-remote cut-off tubes; they have characteristics midway between the sharp cut-off tubes and the remote cut-off tubes.

The gain of a tube can be controlled by controlling the amount of plate current flowing in the tube. By increasing the negative grid voltage applied to the grid of the tube the plate current can be reduced, and this will reduce the gain of this stage. This is true of triodes as well as pentodes and is the method used to control the gain of the rf and i-f stages of a receiver.

In transistor rf and i-f amplifiers, the gain of the stage depends upon the emitter current. Thus if the agc voltage is arranged so that it reduces the forward bias on the rf and i-f stages when strong signals are received, the gain of the stage will go down. This in the case of an NPN transistor is essentially the same as in the vacuum-tube circuit. In an NPN transistor, applying increasingly large negative voltages to the base of the transistor will reduce the forward bias of the transistor and cause the emitter current to decrease. This in turn will lower the gain of the stage.

The gain of a transistor is also dependent upon the collector voltage. Therefore, gain can be controlled by varying the collector voltage. It is not convenient to vary this voltage directly, but if a large resistor is placed in the collector circuit, then the collector voltage can be reduced by increasing the forward bias on the transistor. This causes the emitter current to increase, and the increase in emitter current causes the voltage drop across the collector-load resistor to increase; this in turn reduces the collector voltage. However, notice that increasing the forward bias increases the emitter current. We already mentioned that the gain depends upon the emitter current; the higher the emitter current the higher the gain. Therefore, increasing the emitter current by increasing the forward bias has a tendency to increase the gain of the stage. Thus a large enough resistor must be used in the collector circuit so that the loss in gain due to the drop in collector voltage offsets the increase in gain due to the increase in emitter current.

In a transistor circuit where agc is applied to the transistor you can determine which method is being used to vary the gain of the transistor. If the agc voltage reduces the emitter current on strong signals, then the emitter current is being controlled to control the gain of the transistor stage. On the other hand, if the agc voltage increases the forward bias on strong signals, then the collector voltage is being controlled in order to control the stage gain.

With this brief review of how the gain of vacuum tube and transistor stages can be controlled, let us look now at some typical methods of developing the agc voltage required to control these stages.

BASIC AGC

An agc system must operate from some component of the signal that is proportional to the strength of the carrier, since it is the carrier's strength at any moment that determines what the gain of the set should be at that moment. The only part of the TV signal that meets this specification is the height of the sync pulses. You will remember that the sync pulses represent the maximum modulation of the rf carrier. The sync pulses modulate the carrier almost 100%. The modulation on the carrier from the video signal will depend upon the amplitude of the video signal (which in turn depends upon the brightness of the scene to be transmitted). The brighter the scene, the lower the percentage of modulation.

The sync pulses extend upward from the no-signal or black level pedestal by a fixed percentage of the carrier strength. This percentage may be different for different transmitters, but is always the same for one transmitter. Therefore, if the carrier strength varies, the amplitude of the peaks of the sync pulses will vary.

Of course, the sync pulses exist during only a small fraction of the whole TV signal. If the pulses are to
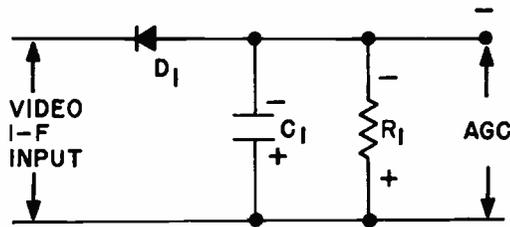
Fig. 10. A simple agc system.

furnish a controlled voltage, therefore, we must find some way to make their effects last, at least from one pulse to the next. This is easily done by using the pulses to charge a capacitor in a R-C network.

A simple agc circuit that uses the peaks of the sync pulses is shown in Fig. 10. The circuit consists of a diode rectifier with an R-C filter that has a comparatively long time constant. By this we mean that the time constant of the R-C filter is considerably longer than the period between sync pulses.

The video i-f signal is fed into the input of the circuit, and when the cathode of the diode is made negative by the rf signal, current will flow through the diode and charge the capacitor C_1 with the polarity shown. A small current will also flow through the resistor R_1. The capacitor C_1 will be charged to a value equal to the maximum amplitude of the carrier. This is the amplitude of the sync pulses. During the interval between sync pulses C_1 will discharge through R_1, to some extent, but if the time constant of the network is made long enough, C_1 will discharge very little between sync pulses.

We can use a voltage across C_1 as an agc voltage by applying it to the video i-f stages as a bias. In the case of a receiver using vacuum tubes, we apply the negative voltage to the grid circuit of the tubes so that if the signal strength increases, the negative bias applied to the grid on the i-f tubes increases, thereby reducing the gain of the stages. In a transistor receiver using NPN transistors we can feed the negative voltage to the base of the video i-f transistors. We could arrange the circuit so that the negative voltage would reduce the bias across the emitter-base junction and thereby reduce the emitter current and reduce the gain of the stage. In the case of a receiver using PNP transistors we could put sufficient resistance in the collector circuit so that the negative bias, which would increase the forward bias across the emitter-base junction, would cause the collector voltage to drop sufficiently to reduce the gain of the stage.

In transistor receivers we can also reverse the polarity of the diode and obtain a positive agc voltage. With a positive agc voltage, we can feed this directly to the base of the PNP transistors and use it to reduce the forward bias across the emitter-base junction and thereby control the gain by reducing the emitter current. If we have NPN transistors we can feed the positive bias to the base and put sufficient resistance in the collector circuit so that the increase in forward bias will reduce the collector voltage sufficiently to reduce the gain of the stage.

Selecting the proper time constant for the R-C net-

work is somewhat of a problem. There are reasons for making it short, and others for making it long. If we make it short (that is, use a value of R_1 that will permit C_1 to discharge fairly rapidly) the circuit will be able to follow more rapid fluctuations in the signal and will offer more freedom from noise interference than if we make the time constant long. On the other hand, a short time constant may make the set lose vertical sync. Let us see why this can happen.

First, suppose a sharp noise pulse that is higher than the peak of the sync pulse is received. The gain of the set will automatically be reduced suddenly by the agc circuit. If the time constant is long, C_1 will hold its high charge for several lines, during which the gain of the set will be reduced. Therefore, the use of an agc circuit having a long time constant means there will be "holes" (large blacked-out areas) in the picture when noise is present. Suppose, on the other hand, that we make the time constant quite short. Capacitor C_1 will then discharge considerably in between the horizontal sync pulses, so the average agc voltage will be relatively low. When a vertical sync pulse, which is much broader than the horizontal sync pulse, is received, however, C_1 will be charged for a much longer time than it is during a horizontal sync pulse; consequently, the average voltage across C_1 will increase during the vertical pulse. This means that the gain of the set will be reduced during the vertical pulse; in effect, it may make the set lose vertical sync.

Since synchronization is extremely important a simple agc system like the one shown in Fig. 10 is usually made slow-acting by giving it a long time constant. Such a system will compensate for signal changes like those produced by switching stations, but cannot take care of rapid fluctuations, and of course, it is far from satisfactory when noise is present.

In a circuit such as the one shown in Fig. 10, the dc voltage is applied to the i-f amplifier stages through appropriate R-C decoupling networks to prevent coupling between the stages. The signal may also be applied to the rf stage ahead of the converter, in which case some arrangement is generally used so that the bias applied to the rf stage is somewhat less than the bias applied to the i-f stages. There is usually some control on the agc network to regulate the amount of agc voltage used.

Although the simple agc circuit shown in Fig. 10 is far from satisfactory it has been used in some low-cost TV receivers. Therefore, you should understand the circuit and how it works, and also understand its limitations. Fortunately, most TV receivers use a slightly more complex agc system known as a keyed agc system. This system is far superior to the simple agc system.

KEYED AGC

The keyed agc system gets it name from the fact that the agc system is turned on or "keyed" on by pulses obtained from the horizontal sweep system. These pulses key the tube on during the horizontal

Fig. 11. A typical keyed agc system.

sync pulses only, and therefore keyed agc is unaffected by any noise or other variations that occur between the horizontal sync pulses. A typical keyed agc system using a tube is shown in Fig. 11.

The cathode of the agc tube has a positive potential somewhere between 150 and 250 volts depending on the setting of R_4 supplied to it. The positive 250-volt bias is also applied to the grid through R_2. The plate is almost at zero potential.

Obviously, with these potentials, no plate current will flow under static conditions. However, when a signal is being received, these static conditions are altered. A positive-going composite signal from the plate circuit of the first video amplifier is applied to the grid through R_1. This is the signal that controls the agc voltage. The plate is connected to a winding on the horizontal output transformer through a capacitor, C_4, so that during every horizontal retrace period, a positive voltage pulse is applied to the plate. This positive pulse is sufficient to cause the tube to conduct, if the positive-going sync pulse applied to the grid is of sufficient amplitude. The plate current flowing through the tube is controlled by the amplitude of the positive horizontal sync pulse that appears on the grid simultaneously with a positive pulse applied to the plate.

When the agc tube conducts, electrons flow from cathode to plate, charging capacitor C_4 with the polarity shown. C_4 is of relatively low value so that it has time to discharge substantially between positive voltage pulses. However, the R-C filter, consisting of R_7 and C_3, filters the pulsating voltage across C_4 so that a constant dc potential appears across C_3.

The amplitude of this voltage will depend on the amplitude of the signal applied to the grid of the agc tube.

The agc voltage developed across C_3 is fed to the grid of the first video i-f stage to control the gain of that stage. R_8 and R_9 form a voltage divider network so that the part of the agc voltage appearing across R_9 can be applied to the grid of the second video i-f tube.

The agc voltage is also applied to the grid of the rf tube. R_6 and C_2 filter the pulsating voltage at the plate of the agc tube. The voltage across C_2 is filtered further by R_5 and C_1 and then fed to the grid of the rf tube. Separate filter networks are usually used for the rf and i-f sections to avoid any feed-through from rf to i-f and also so the best time constant can be selected for each filter network.

The keyed agc circuit described here is typical of what you will see in vacuum-tube receivers, but there are a number of variations which may be encountered. The threshold control, R_4 in Fig. 11, may be in the grid circuit of the agc tube; the grid signal source may be a detector at the output of the last i-f stage as in Fig. 4E; the source of positive pulses applied to the plate of the agc tube may differ. This is sometimes simply taken off the primary winding of the horizontal output transformer, through a capacitor and dropping resistor, instead of having a separate winding on this transformer. These are just a few of the variations; however, the same principles will apply to almost any keyed agc circuit that you may encounter. We will study a few additional variations when we study noise rejection in sync circuits after we study transistor agc circuits.

Fig. 12. A transistor agc circuit.

A TRANSISTOR KEYED AGC

A transistor keyed agc circuit is shown in Fig. 12. In the receiver in which this agc circuit is used, there is sufficient resistance in the collector circuits in the first and second video i-f stages so that an increase in current through these stages will reduce the collector voltage and thereby reduce the gain of the stages. The keyed agc system shown in Fig. 12 is designed to provide an increase in the forward bias applied to the i-f and rf stages.

In the circuit shown, R_3 is the agc threshold control. It is adjusted to provide the required agc voltage. The video signal is fed to the base of Q_1. Notice that the video signal is a positive-going signal. Thus, the amplitude of the sync pulses will affect the forward bias on Q_1, which is an NPN transistor. The winding L_1 is on the horizontal output transformer. During the flyback interval, when retrace occurs and the sync pulse is being transmitted, the voltage across L_1 will have the polarity shown. Thus current can flow through the diode D_1 and a positive potential will be applied to the collector of Q_1. The amplitude of the current that will flow through Q_1 will then depend upon the amplitude of the sync pulses being fed to the base of the transistor. If the amplitude of the sync pulse increases, current through Q_1 will increase and this will increase the current flowing through R_4 and R_5. If the current through R_4 and R_5 increases, the forward bias applied to the base of Q_2 will go down. This means that the current flow through Q_2 will decrease and hence the voltage drop across R_7 will decrease. If the voltage drop across R_7 goes down, then the voltage at the junction of R_6 and R_7 will increase.

Thus the positive voltage fed to the base of the first and second i-f transistors, which are NPN transistors, will increase. This will cause the current flow through these transistors to increase and due to the large collector resistance it will cause the collector voltage on the two stages to go down, thereby reducing the gain of the two stages.

The gain of the rf amplifier is controlled by Q_3. Notice that the base of Q_3 is fed a signal from the second i-f stage. Actually, the signal is a dc voltage

which is fed from the collector circuit of the second i-f amplifier. When the signal increases in amplitude and the i-f agc causes the collector voltage on the second i-f stage to go down, the positive voltage applied to the base of Q_3 will go down. Notice that Q_3 is a PNP transistor. Therefore, if the positive voltage on the base of this transistor goes down, this is the same as saying that the forward bias across the emitter-base junction is increased. Therefore Q_3 will conduct more heavily, producing a greater voltage drop across R_{10}. This will make the junction of R_9 and R_{10} more positive and increase the positive agc voltage fed to the rf amplifier stage. The rf amplifier is an NPN transistor; increasing the positive voltage applied to it will increase the current flow through the transistor and, due to the resistance in the collector circuit, once again reduce the collector voltage. This in turn reduces the gain of the stage.

Another interesting agc circuit is shown in Fig. 13. This circuit is also a keyed agc circuit in which the agc voltage is fed only to the rf amplifier, but the change in collector voltage in the rf stage is fed to the base of the first i-f amplifier in order to control the gain of that stage also.

In the circuit shown, the agc transistor is a PNP transistor; this is the transistor labelled Q_5 on the diagram. The coil L_1 is a winding on the horizontal output transformer.

When the retrace occurs and the sync pulse is present, the voltage across L_1 will have the polarity shown on the diagram. Since the negative voltage is applied to the cathode of D_3, current can flow from B- through R_2, R_3, through L_1 and D_3 to the collector Q_5. Here the electrons arriving at the collector will fill holes in the collector. The number of holes reaching the collector will depend upon the forward bias across the emitter-base junction. This will be controlled by the setting of R_{15} and also by the amplitude of the sync pulses in the video signal being fed to the base of the transistor.

Notice that the sync pulse fed to the base of the first video i-f amplifier has a negative polarity. Notice that the first video amplifier is used as an emitter-follower circuit and the sync signal is taken from

B511-14

the emitter circuit and fed through R_{16} to the base of Q_5. There will be no phase reversal in the first video stage so the sync pulses will swing in a negative direction. The amplitude of these negative pulses will control the current flow through Q_5 and hence the voltage developed across R_2.

If the signal strength increases the voltage developed across R_2 will increase; thus a more positive voltage will be fed through R_1 to the base of the rf transistor Q_1. This will increase the current flow through Q_1, which in turn will increase the voltage drop across R_5. The drop in voltage on the collector of the transistor will reduce the gain of the rf stage.

Now notice how the i-f transistor is connected through a number of dc circuits to the collector circuit of the rf stage. The coil in the collector circuit of the rf stage takes care of the signal so that at the junction of R_5 and R_6 all we have to be concerned about is the dc potential. The transistor Q_3, which is the first i-f stage, is biased by the voltage drop across R_8. R_8 is in a voltage-divider network, with R_7, R_6 and R_5. When the voltage at the junction of R_5 and R_6 goes down, due to an increase in current through Q_1, then the forward bias across the emitter-base junction of Q_3 also goes down. The reduction in forward bias across the emitter-base junction of the i-f amplifier reduces the emitter current and hence reduces the gain of the stage.

Notice the diode D_1. This is used in a circuit to control the minimum gain of the i-f stage. Normally the junction of R_6, R_7 and R_{18} has a high enough positive polarity so that the cathode of D_1 is positive with respect to the anode. The actual positive voltage on the anode is controlled by the setting of R_{11}. This voltage is held quite constant by the Zener diode D_2. You'll notice that R_{10}, R_{11} and R_{12} form a voltage-divider network. The voltage at the junction of R_{11} and R_{12} is held constant by D_2. Thus the voltage at the anode of D_1 will be essentially constant.

When a very strong signal is received a high agc voltage will be developed. This will cause a substantial increase in current through Q_1 which will drop the voltage at the junction of R_5 and R_6 substantially. This in turn will cause the forward bias across Q_3 to drop to a very low value. To prevent the voltage from dropping below a certain minimum so that the gain of the stage would be extremely low R_{11} is adjusted to provide a minimum bias on Q_3. If the voltage at the junction of R_5 and R_6 drops very low so that the voltage at the junction of R_6 and R_7 drops low enough to let the cathode of D_1 become negative with respect to the anode, then D_1 will begin to conduct. Current will flow through R_{18}, D_1, R_{11} and R_{12} back to B+. This will tend to raise the voltage at the junction of R_6, R_7 and R_{18}, thus raising the forward bias applied to the emitter-base junction of Q_3.

In the circuit shown in Fig. 13, the agc voltage is actually amplified by Q_1. As a result, on comparatively
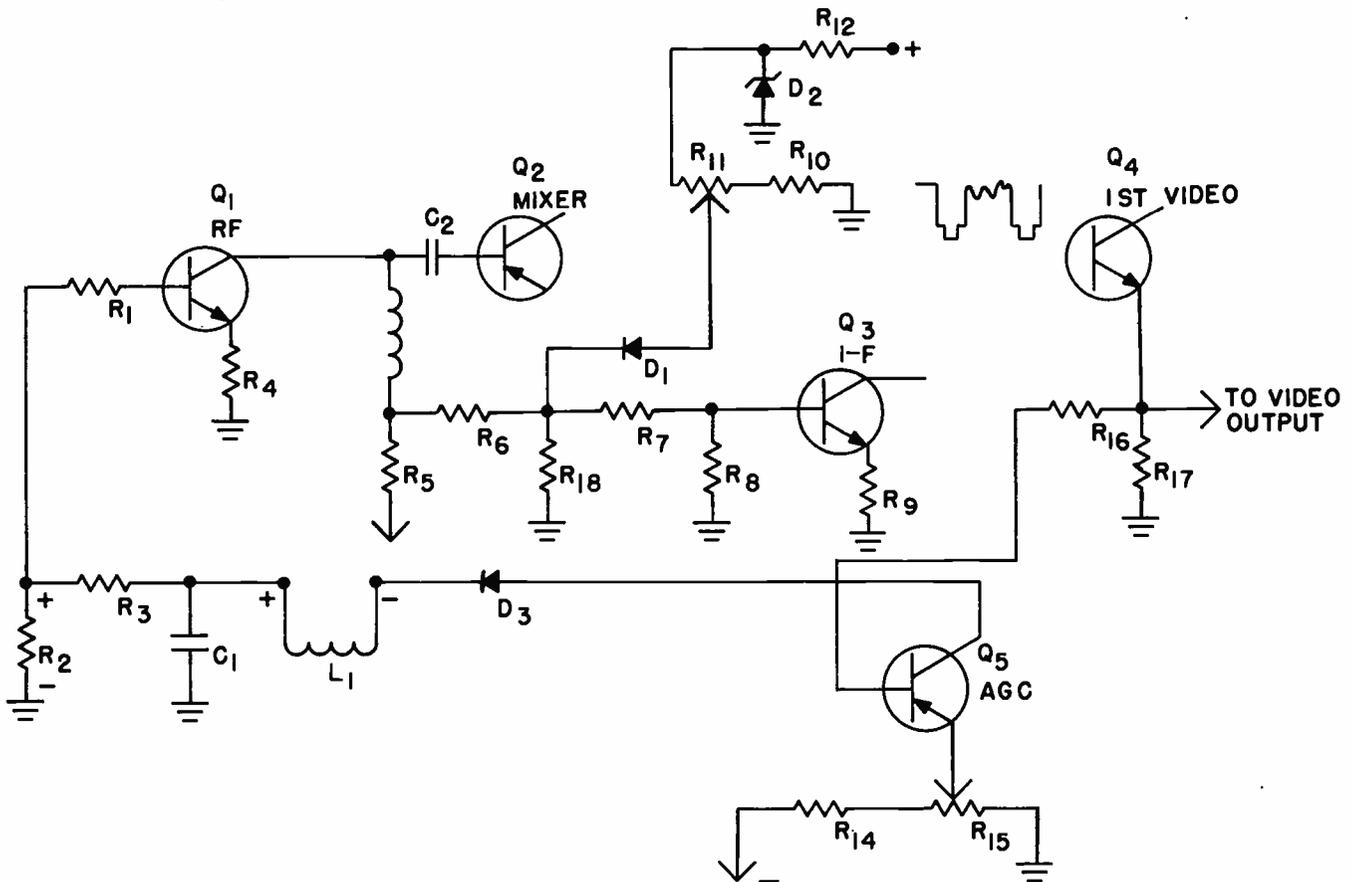
Fig. 13. An rf - i-f controlled agc system.

weak signals up to moderately strong signals, the agc voltage developed across R_2 will not be too great. However, the change across R_2 due to the change in signal strength is amplified by Q_1 and appears as a voltage change across R_5. The voltage change across R_5 will be much greater than the voltage change across R_2 and hence the gain of the i-f transistor varies considerably.

·Therefore on weak and moderate signals, there is very little reduction in the rf gain; most of the receiver gain is controlled by changing the gain of the i-f stage. However, as the strength of the signal increases, the agc voltage applied to the rf stage has more of an effect on the gain of the stage so that it begins to control the receiver gain substantially also. Eventually a point is reached where D_1 starts to conduct; when this happens any further reduction in receiver gain must be obtained by changing the gain of the rf amplifier because further changes in the gain of the i-f stage will be prevented by D_1 holding the bias on Q_3 constant.

SELF-TEST QUESTIONS

(j) What three manual controls are provided for adjusting the strength of the video, color and sound signals in a TV receiver?

(k) What part of the composite video signal is used for agc?

(l) If the strength of the video signal fed to the agc circuit shown in Fig. 11 decreases, will the voltage across C_3 increase or decrease?

(m) Should the simple agc circuit in Fig. 10 have a short time constant or a long time constant?

(n) Does an increase in signal in Fig. 12 result in an increase or decrease in the forward bias on the i-f stages?

(o) During what interval does the keyed agc tube or transistor conduct?

(p) In the circuit shown in Fig. 13, if the amplitude of the video signal drops, what happens to the forward bias on (a) the i-f transistor, (b) the rf transistor?

Noise Rejection in Sync and AGC Circuits

We have considered the source of sync takeoff and actual removal of sync information from the composite video signal. We have also seen how an agc voltage is developed to control the gain of the i-f and rf stages. Now let us consider the methods used to reduce the influence of noise in the sync separator and agc stages. Let's look at sync separators first.

Two basic techniques have been used to make synchronization less subject to noise interference. One method is to make certain that noise pulses greater in amplitude than the sync tips are clipped so that their amplitude does not exceed the amplitude of the sync pulses. This will usually prevent stray noise pulses that occur between sync pulses from triggering the sweep circuits erroneously. A second method of noise reduction uses the principle of cancellation. In this system, noise pulses are combined out-of-phase to cancel noise.

Of the two systems, the second is better because it makes it possible to almost eliminate the effect of noise on the sync system. In the first system a signal biased diode is often used. As long as the noise does not exceed the amplitude of the sync pulse, the diode does not conduct, so the noise is not affected. When the noise exceeds the amplitude of the sync pulse, the diode conducts, reducing the noise amplitude to the value of the bias across the diode. While this system was used in a few receivers, the great majority of sets that use noise rejection in the sync circuit use some form of noise cancellation.

PENTAGRID SYNC SEPARATORS

A sync separator and noise reducing system that makes use of a pentagrid tube is shown in Fig. 14. In this system, two composite video signals 180° out-of-phase are taken from two points in the video amplifier and applied to the pentagrid sync separator and noise-cancelling circuit. The actual sync separator segment uses the signal grid, which is grid number three of the pentagrid tube. A positive composite signal from the video amplifier is applied to this grid through R_1 and C_1. The high amplitude, positive-going sync pulses drive the grid positive, charging C_1 with the polarity shown. During the interval between sync pulses, C_1 discharges through R_2, developing a voltage as shown. This voltage across R_2 biases the tube beyond cut-off. The tube then amplifies only the sync pulse portion of the composite video signal. Thus, sync separation occurs without the application of any signal to the first control grid of the tube.

However, a disadvantage of a basic sync separator system is that sharp bursts of noise will place a high charge on capacitor C_1. Therefore, with strong noise, the noise pulses themselves will appear in the output of the separator. In addition, the amplitude of the desired synchronization information will be reduced, because of the high bias placed on the separator tube. In fact, with very high amplitude noise pulses, the average simple separator could be cut off, which would prevent the arrival of the sync pulses at the sweep generating circuit for an extended time, and result in loss of synchronization.

To eliminate this difficulty, every precaution is taken in modern design to lower the influence of noise before it has an opportunity to reduce the amplitude of the synchronizing information or trigger the saw-tooth generating circuits erroneously. Noise cancellation in the circuit of Fig. 14 is accomplished by applying a second, but negative, composite signal to the first grid of the separator. Except for polarity and amplitude, the two composite signals are identical. The signal applied to the first grid is a negative composite signal and is low in amplitude because it is taken from the video detector output. The signal applied to the third grid will be a positive composite signal of much greater amplitude because it has been amplified and
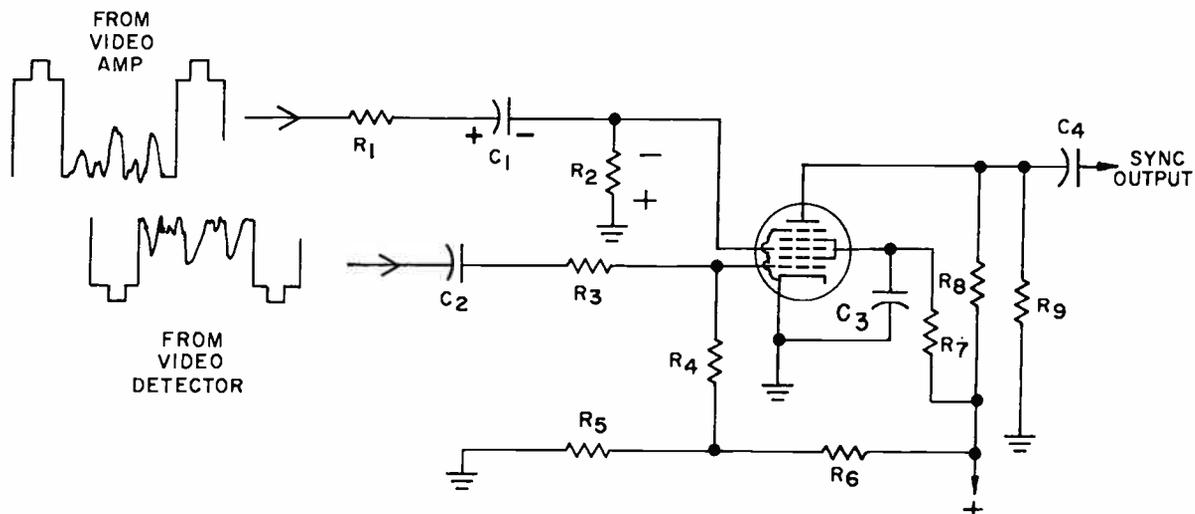
Fig. 14. A pentagrid sync separator and noise reduction circuit.

COMPOSITE VIDEO SIGNAL

CONTROL GRID 1 SIGNAL

CUTOFF

NOISE PULSE

CONTROL GRID 2 SIGNAL

NOISE REMOVED

SEPARATOR OUTPUT
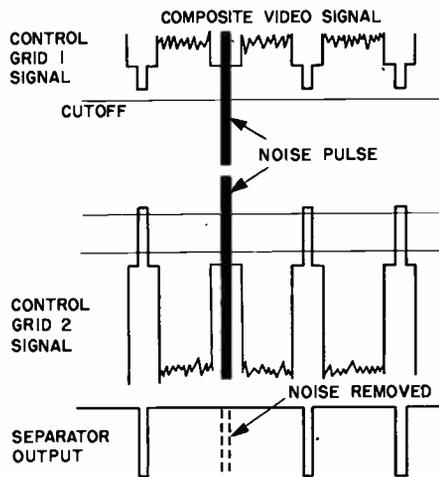
Fig. 15. Two video signals 180° out-of-phase are fed to the sync separator to produce effective noise cancellation.

inverted by the video amplifier. The stronger signal has the greater effect on plate current flow, and therefore a negative sync signal is developed in the plate circuit of the separator.

As long as there is no strong noise in the composite video signal, the signal applied to the first grid does nothing. However, the first grid is biased so that when any noise pulse that exceeds the amplitude of the sync pulse arrives, the separator tube is cut off. It is impossible for the same noise pulse arriving at the third grid to draw current and charge capacitor C_1. This circuit is called a gated sync separator.

The action of the noise-cancelling circuit is shown in the waveforms of Fig. 15. Notice in particular that the noise pulses are not just clipped, but are completely removed from the mixed synchronizing information that appears in the output of the separator, as a result of the complete cut-off of the separator during the presence of the noise pulse. Thus, if a noise impulse happens to occur immediately on top of a hori-

zontal sync pulse, as it does in Fig. 15, both the noise impulse and the sync pulse are removed. This does not upset the horizontal sync in the modern television receiver, because the horizontal synchronization depends upon the average frequency of the arriving sync pulses and not on the presence of each individual sync pulse.

In some receivers, the bias voltage applied to the bottom of the grid resistor R_4 is made adjustable so the actual cut-off level can be set with respect to the average signal strength in a given area. It can be adjusted for strong signal or weak signal reception. In a weak signal area, it would be advisable to have the cut-off occur earlier because of the much weaker composite signal applied to this grid. In a strong signal area, if cut-off occurs too soon, the actual synchronization information would be clipped or "gated" off.

The output of the sync separator in Fig. 14 will be negative-going sync pulses. In some receivers, positive-going sync pulses are required to synchronize the sweep oscillators. In these receivers, the negative sync signal from the separator output is applied to a sync amplifier. Here its amplitude is increased and it is inverted for proper application to the synchronizing circuits of the sawtooth generators. The sync amplifier is normally operated at a low plate voltage to produce early saturation and cut-off. As a result, the base line sync signal is held flat by limiting action and any instantaneous positive peak is leveled by grid conduction and early saturation. This will help maintain all the sync pulses at exactly the same amplitude.

NOISE INVERSION

If a noise signal can be developed which is 180° out-of-phase with the noise signal in the receiver, the two can be mixed and noise reduction obtained. If the original noise signal is equal in amplitude to the in-
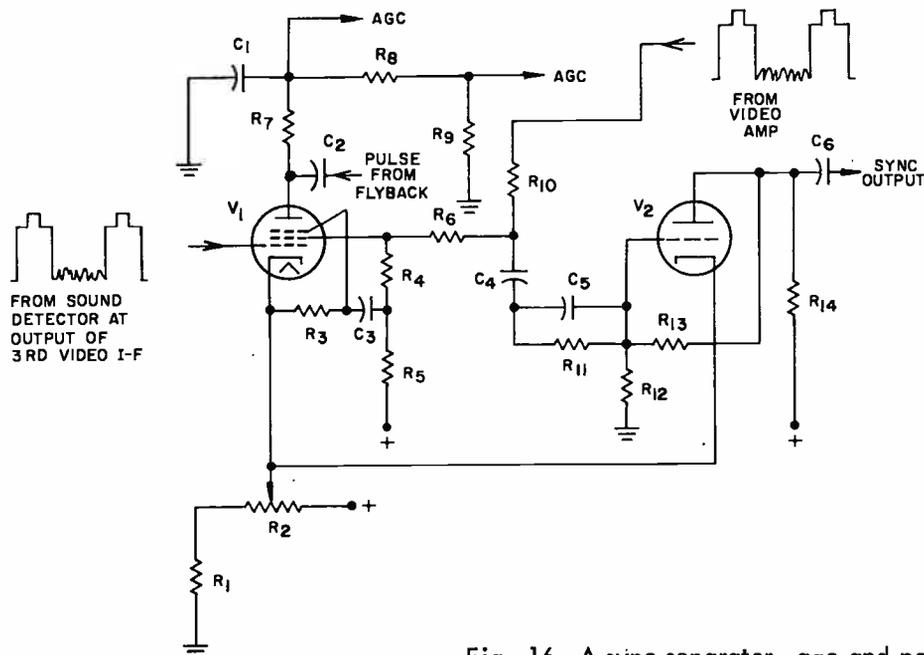
Fig. 16. A sync separator, agc and noise inverter circuit.
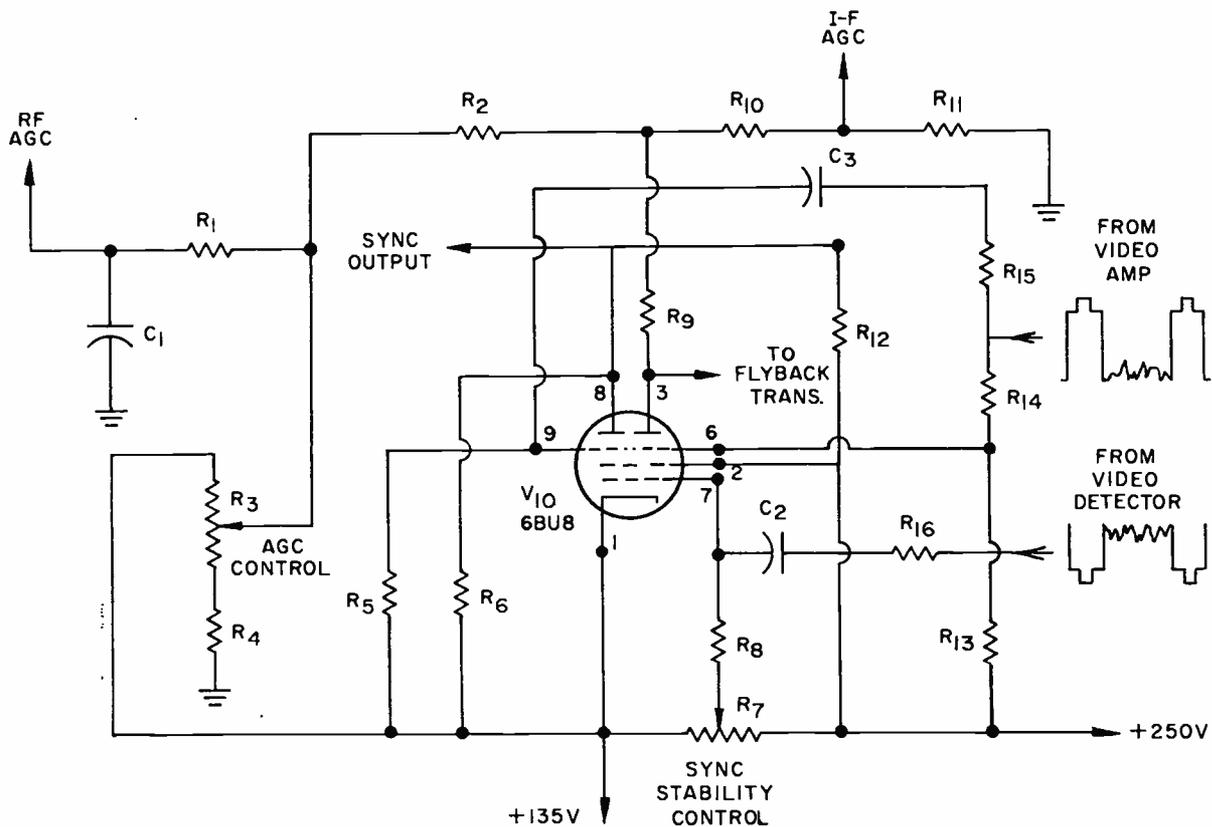
Fig. 17. Sync separator and gated agc.

verted signal, almost perfect cancellation can be obtained.

A circuit from a color TV receiver, in which one tube performs the dual function of noise inverter and agc, is shown in Fig. 16. In this circuit, V_1 is the keyed agc tube. The tube is operated with a high positive bias on its cathode; the grid is returned to ground through the sound detector circuit. The sound detector is a diode detector coupled to the third video i-f amplifier. This detector not only develops a 4.5-mc sound signal, but also a composite video signal. The detector is connected so that the sync pulses swing in a positive direction as shown in Fig. 16. When the high positive pulse from the flyback transformer is applied to the plate of the tube through C_2, the plate is driven positive. Since this positive pulse coincides with the sync pulses, the sync pulses overcome the bias on the tube and plate current flows. The amplitude of the plate current will depend on the amplitude of the sync pulses. The plate current flowing through R_7, R_8 and R_9 to ground develops a negative voltage which is used as agc. The stronger the sync pulses, the greater the agc. So far this stage is operating like any other keyed agc stage.

Now let's look at the sync separator, V_2. A high amplitude positive signal is fed from the output of the first video amplifier to the grid of V_2 through R_{10}, C_4, and the parallel combination of C_5 and R_{11}. The grid is driven far enough in a positive direction to overcome the bias on the tube, the tube conducts and negative-going sync pulses are produced in the plate circuit. Thus far, the sync separator is also operating like any other sync separator.

Notice that at the junction of R_{10} and C_4, resistor

R_6 connects to the screen grid of V_1. This means that the composite video signal is also applied to the screen of the tube. Insofar as the operation of the agc tube is concerned, this simply means that when the grid of the tube is driven positive to drive the tube into conduction, the screen is driven positive and aids the conduction. However, if a strong noise pulse arrives at the grid of V_1 and overcomes the bias on the tube, the tube will conduct.

On the other hand, if the noise pulse arrives between the sync pulses, there will be no plate voltage on the tube--but there is screen voltage! Therefore, the screen acts as the plate and a high screen current flows. This results in a large voltage drop across R_4 and R_5; in other words, a negative pulse is produced at the screen of the tube. This negative pulse is fed through R_6 to the junction of R_{10} and C_4 and reduces the amplitude of the noise pulse at this point. By careful design, the amplitude of the amplified noise pulse can be made nearly equal to the amplitude of the noise pulse arriving from the video amplifier, so almost perfect cancellation will occur.

SYNC SEPARATION AND GATED AGC

Special tubes which contain two sharp cut-off pentodes in one envelope have been manufactured, since the operations of sync separation and gated agc can be combined in the one tube. With these special tubes noise gating can be used to reduce the effects of noise on the automatic gain control system.

A circuit of this type using a 6BU8 tube is shown in Fig. 17. In this tube, the cathode and first two grids are common to both sections. Grid number one serves
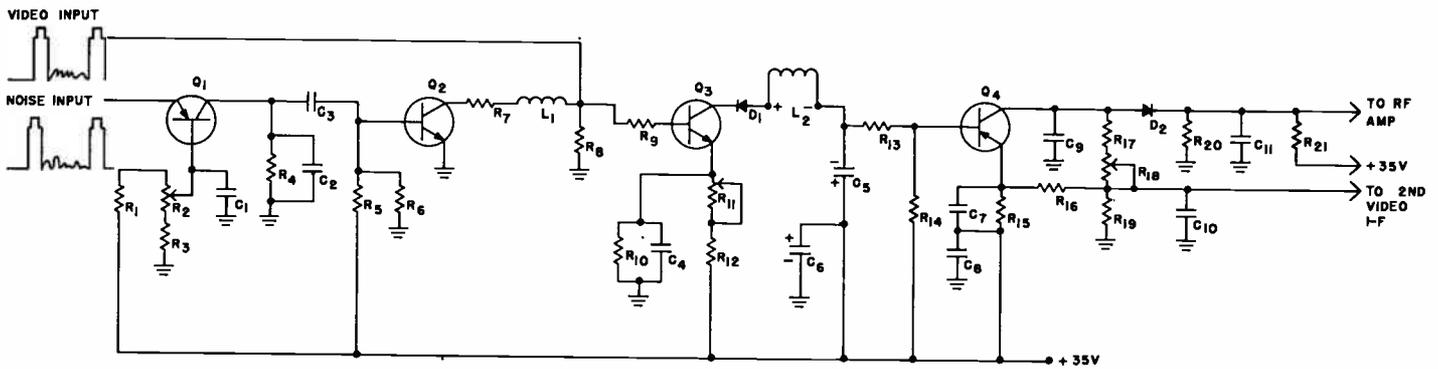
Fig. 18. A noise-cancelling agc system.

as a noise gate for both agc and sync separator, while grid number two is the screen grid for both sections.

In this circuit, pulses from the flyback transformer are applied to the plate (pin 3) of the agc section of the tube. At the same time, a composite video signal is fed from the output of the first video amplifier through R_{14} to the grid (pin 6) of the tube. During the sync pulse interval current flows through the pentode to the plate (pin 3). This current flows through R_9, R_{10} and R_{11} to ground, developing the negative agc voltage. The amplitude of this voltage will depend on how heavily the tube conducts, which in turn depends on the amplitude of the sync pulse.

In the sync separator section of the tube, the composite video signal from the output of the video amplifier is fed through R_{15} and C_3 to the grid (pin 9) of the tube. The positive-going sync pulses drive the tube into conduction, producing negative sync pulses in the plate circuit (pin 8) of the pentode. Since the video information does not have sufficient amplitude to drive the tube into conduction, only the sync pulses appear in the output and therefore the sync has been separated from the composite video signal.

Now let us consider the action of the common number one grid in the tube. A composite video signal is taken from the video detector and fed through R_{16} and C_2 to the number one grid (pin 7). The bias on this grid is adjusted by means of the sync stability control so that under normal conditions, the video signal applied to the grid does not appreciably affect the operation of either the sync separator or the agc system. However, if a strong noise pulse comes along, the noise pulse which will be negative-going will drive the number one grid to cut-off, cutting off the flow of current in both pentodes. If a strong noise pulse coincides with a sync pulse, it will eliminate the sync pulse from the output of the sync separator section, and it will prevent the agc section from attempting to develop a higher than normal agc voltage to try to compensate for the strong signal. If the noise pulse appears between the sync pulses, it will prevent the sync separator from producing a pulse in the output.

A noise cancelling agc system is shown in Fig. 18. In this circuit a positive-going sync pulse, as shown, is taken off after the first video amplifier stage and fed to the emitter of Q_1. The bias on the base of Q_1 is adjusted so that the transistor does not conduct unless a signal exceeding the amplitude of the sync

pulse is applied to the emitter of the transistor. Thus with no noise, there will be no output from Q_1. However, if a noise pulse comes along that exceeds the amplitude of the sync pulse it would drive the emitter in a positive direction sufficiently to overcome the bias placed on the base so that the transistor will conduct and an amplified noise pulse will appear in the output. Notice that Q_1 is connected in the grounded-base circuit so the phase of the noise pulse will not be inverted; in other words we'll have an amplified positive-going pulse in the output of Q_1.

The noise pulse in the output of Q_1 is fed to Q_2, which is used in a common-emitter circuit where the signal is amplified and inverted by the transistor. Meanwhile, another video output is taken from the output of the second video amplifier stage which is used in the emitter-follower circuit so that it also will be a positive-going signal. Here the negative-going noise pulse is combined with the video input fed to the junction of L_1, R_8 and R_9. The negative-going noise pulse from Q_2 will cancel the noise pulse in the video input fed from the emitter of the second video amplifier. Thus we feed a video signal to the base of Q_3 from which the noise pulse has been cancelled.

Transistor Q_3 is the agc gate. This is the transistor that develops the agc voltage. The emitter of the transistor has a positive voltage applied to it by the voltage-divider network consisting of R_{10}, R_{11}, and R_{12}. R_{11} is adjustable so that a positive voltage on the transistor may be varied to control the level of the agc output voltage.

The transistor is biased so that it does not conduct except during the positive sync pulse interval. At that time, a voltage will also be applied to the emitter through the diode D_1 by the voltage developed in the coil L_2. L_2 is part of the horizontal output transformer and this voltage is developed during the retrace interval, which of course coincides with the positive horizontal sync pulse.

When the sync pulse and the pulse across L_2 arrive simultaneously the transistor Q_3 will conduct. Electrons will flow through R_{10} to the emitter, across the emitter-base junction, across the base-collector junction and through D_1 and L_2 into the capacitor C_5, charging this capacitor with the polarity shown. The higher the amplitude of the positive sync pulse the greater the conduction through the transistor and hence the greater the voltage developed across C_5. There-

fore, we'll have an agc voltage developed across this capacitor which will depend upon the amplitude of the sync signal from the composite video signal. The diode D_1 is placed in the circuit to prevent the capacitor from discharging. The diode will conduct only when the voltage on the anode is made positive. This will occur only during the sync-pulse interval.

Q_4 is the agc amplifier. It is a PNP transistor and its conduction will depend upon the negative voltage across C_5. The higher the voltage the greater the conduction through Q_4. This will result in a positive voltage being developed across R_{17}, R_{18} and R_{19}. The voltage across R_{19} is fed to the second video amplifier. The second video i-f amplifier is an NPN transistor and the increase in positive bias applied to it causes the current through the transistor to increase. Due to the high load in the collector circuit the collector voltage drops; therefore, the gain of the stage drops.

The forward bias applied to the rf amplifier is delayed. The diode D_2 is connected so that current will not flow through it until the voltage at the emitter of Q_4 exceeds the cathode voltage on D_2. Notice that R_{20} and R_{21} form a voltage-divider network that will bias the cathode of the diode positive. Until the current through Q_4 exceeds a certain value the collector of Q_4 will not be at a high enough positive voltage for D_2 to conduct. Therefore on comparatively weak and moderately strong signals agc voltage is applied only to the second video i-f amplifier. When the signal strength exceeds a certain value and the emitter of Q_4 becomes positive so that the anode of D_2 will be positive with respect to the cathode, then D_2 can conduct and forward bias will be applied to the rf amplifier. This also is an NPN transistor and the forward bias reduces the collector voltage and hence the gain of the stage.

SELF-TEST QUESTIONS

(q) Which grid of the pentagrid converter in Fig. 14 is used for sync separation?

(r) Which grid of the pentagrid converter in Fig. 14 is used for noise cancellation?

(s) What will the polarity be of the sync pulses in the plate circuit of the tube in Fig. 14?

(t) Does the complete removal of a sync pulse as shown in Fig. 15 have any effect on oscillator synchronization? Why?

(u) On what does the agc voltage developed by V_1 in Fig. 16 depend?

(v) When a noise pulse occurring between the sync pulses causes V_1 in Fig. 16 to conduct, to what element do the electrons flow?

(w) What elements are common to both sections of the 6BU8 tube used in Fig. 17?

(x) What are two advantages of a circuit like the one shown in Fig. 17? (Not answered directly in text – try to think of two advantages.)

(y) What signals are amplified by Q_1 and Q_2 in Fig. 18?

(z) What purpose does D_2 in Fig. 18 serve?

Separating the Horizontal and Vertical Sync Pulses

The final step in the preparation of the sync information is inter-sync segregation. The segregation of the horizontal from the vertical information is accomplished with resistor-capacitor networks, referred to as differentiators and integrators. The process of segregation involves the utilization of specific segments of the received pulses. The leading edges of the pulses are used for synchronization of the horizontal deflection waveform, and the longer duration interval of the vertical synchronizing pulses is used for controlling generation of the vertical deflection waveform.

The composite sync signal shown in Fig. 19 contains three basic pulses--horizontal, equalizing, and vertical. This entire sync signal will be inverted if the sync separator produces negative sync pulses at the output. The horizontal synchronizing information is contained in the leading edges of all the pulses. It is contained in the leading edges of the equalizing and vertical sync pulses as well as the leading edges of the horizontal sync pulses. Even during the vertical retrace period, it is not advisable to lose control of the horizontal synchronization, because, as mentioned in an earlier lesson, there are a great many lines that occur during the lengthy vertical retrace period.

The six vertical sync pulses are of long duration and short spacing. At the television receiver they are blended together to form a rising waveform that will dominate all the horizontal information and control the vertical sweep generator. At the beginning and end of the six vertical sync pulses are two groups of six shorter duration equalizing pulses that are used to maintain proper vertical synchronization and interlace. These leading and trailing equalizing pulses assist the vertical sync group in firing the vertical sawtooth generator precisely, so there will be true interlace of the scanning lines.

HORIZONTAL SYNCHRONIZATION

The horizontal deflection generator is synchronized by the leading edges of all three sets of pulses: the
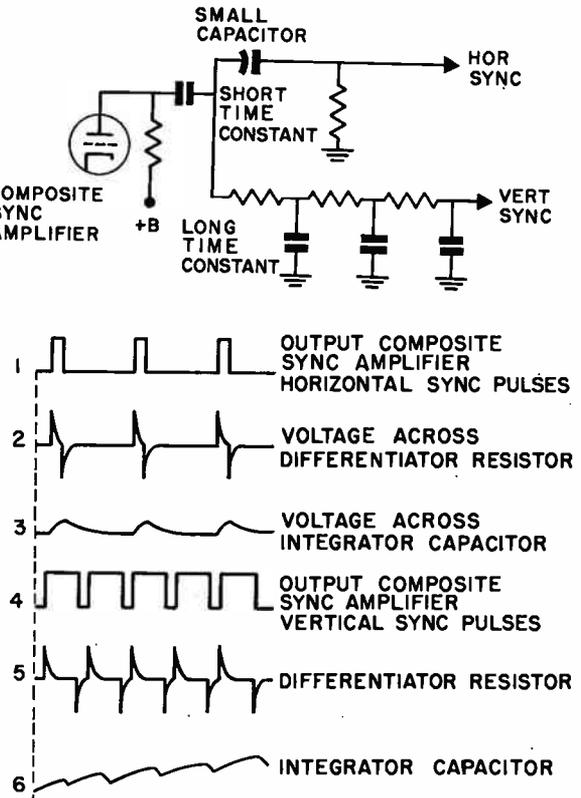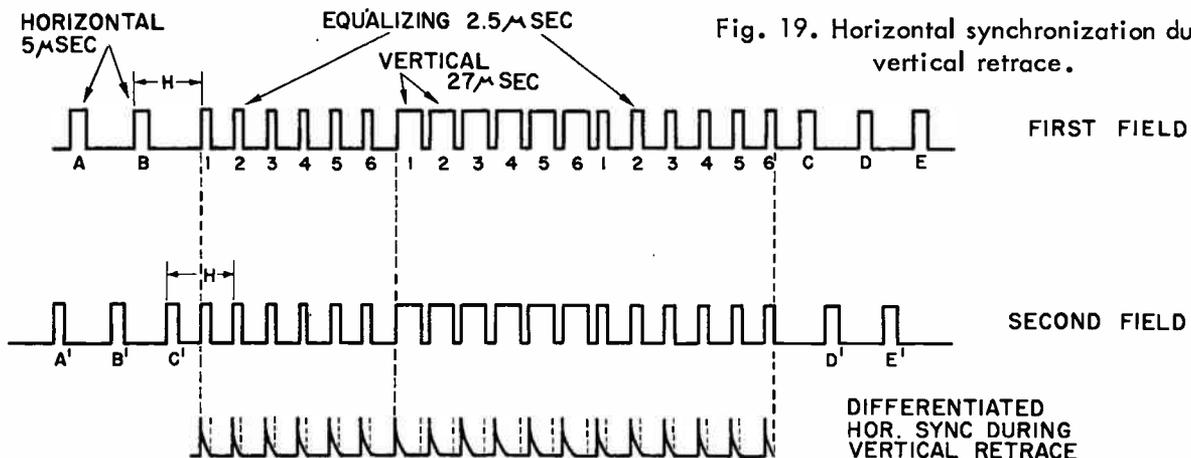
Fig. 20. Basic inter-sync separator systems.

horizontal sync pulses, the equalizing pulses, and the vertical sync pulses. When the pulses are applied to a differentiating circuit having a short time constant (small capacitor and low value resistor), the leading edges of all pulses cause a high current flow through the resistor to charge the capacitor. As the capacitor charges, the current through the resistor will decrease. This current through the resistor, of course, produces a voltage across the resistor. The leading edge of the horizontal sync pulses in Fig. 20 develops a sharp positive spike, and the trailing edge a sharp negative spike. However, the negative spike is not

Fig. 19. Horizontal synchronization during vertical retrace.

utilized and is clipped off. The positive portion is applied as synchronization to the horizontal deflection generator. During the vertical retrace interval, the leading edges of the vertical synchronizing pulses and of the equalizing pulses are also differentiated and used to maintain horizontal synchronization as shown in waveform 5 of Fig. 20.

It is important to remember that horizontal synchronization is maintained by the leading edges of all received sync pulses. During the vertical retrace interval, the leading edges arrive at twice the frequency of the horizontal sync pulses (double-line rate). This double-line rate is required in an interlaced system, because the vertical interval begins one line away from the last horizontal sync pulse at the end of one field, but only half a line away from the last horizontal sync pulse at the end of the second field, as shown in Fig. 19. Notice in the first waveform of Fig. 19 that the last horizontal sync pulse B is exactly one line away from the first equalizing pulse; equalizing pulse 3 is one line from equalizing pulse 1; and equalizing pulse 5 is one line from equalizing pulse 3. Thus, at the end of the first field, the odd-numbered equalizing and vertical sync pulses maintain synchronization of the horizontal circuits.

produced at twice the normal rate during the transmissions of the vertical sync pulse and the equalizing pulses. You might think that these extra pulses would cause the horizontal oscillator to change frequency. However, remember that the horizontal oscillator frequency is controlled by the average number of pulses arriving, rather than by one or two or any small group. During the interval of the equalizing pulses and the vertical sync pulse, there will be nine extra horizontal pulses. This is a comparatively small number compared to the 262 pulses received in one field and the 263 in the other. The extra pulses have no effect on the horizontal oscillator frequency.

In summary, the differentiating circuit emphasizes the leading edges of all received sync pulses. At the same time, the differentiator reduces the long duration of the vertical sync information and prevents it from influencing horizontal synchronization.

VERTICAL SYNCHRONIZATION

The vertical deflection circuits are synchronized by the group of six vertical sync pulses that act as a single long continuous pulse of almost 200 microseconds to trigger the vertical oscillator. When the

Fig. 21. Vertical synchronization.

The second field waveform shows the first equalizing pulse only 1/2 line away from the last horizontal pulse C^1, and the second equalizing pulse exactly one line away from the last horizontal sync pulse. Consequently, at the end of the second field, the horizontal pulse is synchronized by the leading edges of the even numbered equalizing pulses and the vertical sync pulses.

The one-line separation between the last horizontal sync pulse and the first equalizing pulse in one field, and the half-line separation between the last horizontal sync pulse and the first equalizing pulse in the next field, results from the use of interlaced scannings, for which there are 262-1/2 lines transmitted for each field. Thus, to maintain true synchronization of the horizontal circuits during the vertical retrace periods, it is necessary that these equalizing and vertical sync pulses be transmitted at double-line rate.

Horizontal control, in fact, is the basic reason for slotting the vertical sync pulse group. If it were not for the necessity of maintaining horizontal synchronization, it would be possible to transmit one long continuous pulse to establish vertical synchronization.

You might wonder about the horizontal pulses being

vertical sync pulses shown in Fig. 20 arrive at the integrating circuit, they charge the integrating capacitors slowly because of the long time constant. Between charges the very long time constant of the integrator prevents any appreciable discharge of the integrating capacitors. This means the integrator charges in steps, rising to an appreciable level during the interval of the vertical sync pulses. At a prescribed voltage level, the integrator charge has risen to a point at which it will trigger the vertical oscillator, initiating the vertical retrace as shown in Fig. 21.

The horizontal as well as the equalizing sync pulses are also present at the input of the integrator. However, these pulses are of such short duration and long spacing that they place only a very small charge on the integrator, as shown in waveform 3 of Fig. 20. Because of the long interval between arriving horizontal sync pulses, the integrator is discharged for each line. Thus the horizontal sync pulses and the equalizing pulses do not build up an increasing charge on the integrator and therefore cannot trigger the vertical oscillator.

By proper choice of time constants and arrange-
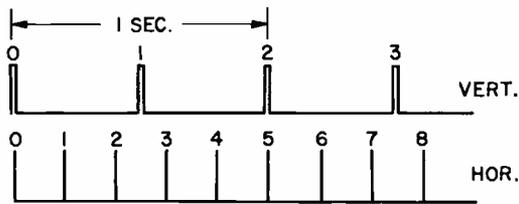
Fig. 22. Interlace is automatic.

ments of resistor-capacitor networks, it is possible to segregate the horizontal and vertical components of synchronization--the horizontal information is contained in the leading edges of the combined sync pulses, and the vertical synchronization is contained in the long duration vertical sync period.

INTERLACE TIMING

Although interlace may seem difficult to understand, it is basically simple and automatic. At times, so much emphasis is placed on the equalizing pulses that the technician assumes that they create the interlace. Actually, the interlace is automatic, because of the ratio between line frequency and field frequency. The equalizing pulses aid in maintaining the proper interlace at the receiver.

Fig. 22 demonstrates how easily interlace is accomplished. Let us assume that we have pulse repetition rates at which there are five of the bottom pulses for each two of the top pulses. In this imaginary system there are two vertical pulses per second and five horizontal pulses. The first vertical pulse will occur between the second and third horizontal pulses, and the second vertical pulse will coincide with the fifth horizontal pulse. The third vertical pulse will occur midway between the seventh and eighth horizontal pulses. In other words, we have a television system that contains 2-1/2 lines per field. For example, when the first vertical pulse arrives, the scanning line will be at the midpoint between the second and third horizontal pulses, and when the second vertical pulse arrives, the scanning beam will be at the end of a horizontal line.

In our commercial television system, the very same relationship is attained by using 262-1/2 lines per field instead of 2-1/2 as in the example. The relationship between pulses is identical except for the faster rate of pulse transmission. Consequently, with a field rate of 60, and a line rate of 15,750, there are 262-1/2 lines per field and interlace is automatic. Similarly, with the line and field rates used in color transmissions we will also have 262-1/2 lines per field.

At the receiver the problem is not to establish interlace, because that has already been done by the choice of line and field rates, but to prevent line pulses and noises from upsetting the interlace relationship. The vertical oscillator must be triggered at exactly the same time for each television field. Thus, every precaution must be taken to prevent the horizontal sync pulses, noise impulses, or any other receiver disturbances from causing faulty synchronization of the vertical oscillator.

There is one thing that could upset the interlace. At the end of one field, the start of the vertical blanking interval is one line away from the last horizontal pulse, but at the end of the succeeding field, it is only one-half line away from the last horizontal pulse. Consequently, a few lines prior to the firing time of the vertical oscillator, there is a different charge on the integrating capacitor (from the last horizontal pulse) depending on whether it is the end of the first field or the end of the second field. It is the purpose of the six equalizing pulses (of short duration and long spacing) to discharge the integrating capacitor to a fixed voltage level regardless of the charge at the start of the vertical retrace interval, so that the vertical oscillator will be triggered precisely at the same instant for each field. The trailing set of equalizing pulses discharges the integrating circuit to the same voltage level at the conclusion of the vertical sync period. Therefore, no residual charge on the integrating capacitor is carried over from one field to the next.

As you have learned, a single resistor and capacitor can function as an integrating circuit. However, in actual practice, groups of two to four resistors and capacitors are used to further emphasize the six vertical sync pulses and reduce the charges contributed
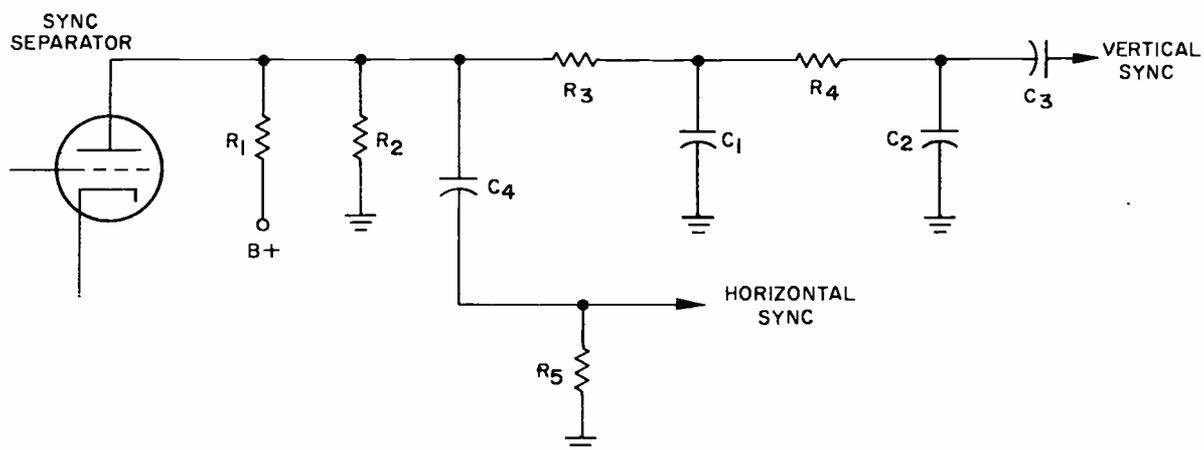
Fig. 23. Typical sync separating circuit.
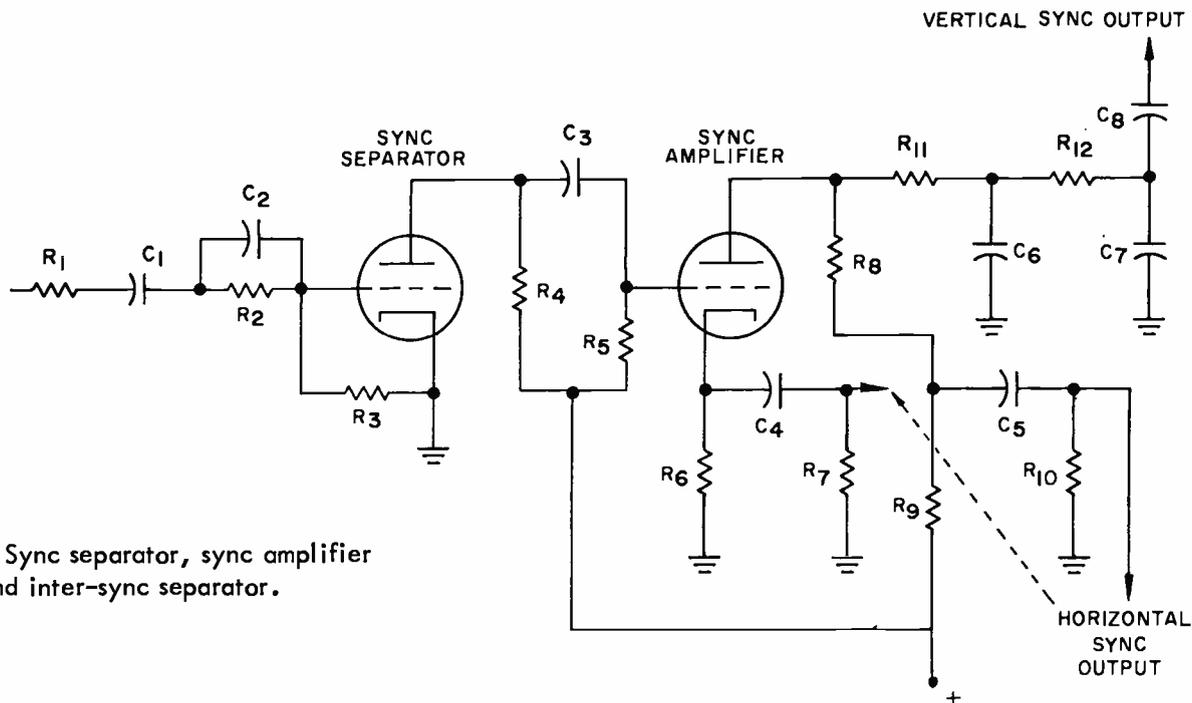
Fig. 24. Sync separator, sync amplifier and inter-sync separator.

TYPICAL CIRCUITS

Some rather complex circuits have been used to separate the horizontal and vertical sync pulses and to provide the type and kind of pulses needed to synchronize the sweep oscillators. In some sets, sync amplifiers were used after the sync separator to amplify the sync pulse and to invert its polarity. In some receivers separate amplifiers were used for the vertical and horizontal pulses. But the tendency in modern receivers is to keep the circuit as simple as possible. The simple circuits usually work as well as the complicated ones, they cost less money to build, and there are fewer parts in them to break down and cause trouble.

A typical circuit taken from a modern color TV receiver is shown in Fig. 23. The integrator consists of R_3, C_1, R_4 and C_2. C_3 is used to couple the vertical pulse to the vertical oscillator and at the same time to block the dc in the plate circuit of the sync circuit from the vertical oscillator stage. The differentiator consists of C_4 and R_5. The output is a series of pulses which can be used with a single-ended discriminator for horizontal oscillator frequency control. You'll study this circuit in the next section of this lesson.

As we mentioned earlier, sometimes an amplifier is used between the sync separator and the inter-sync separator. A typical circuit is shown in Fig. 24.

The inter-sync separator can be connected to supply either balanced or unbalanced horizontal sync output. When horizontal sync pulses of equal amplitude but opposite polarity are required, both plate and cathode outputs from a so-called phase splitter can be used to form the dual horizontal pulses required, as shown in Fig. 24.

With the negative composite sync applied to the grid of the amplifier, a negative pulse is removed from across the cathode resistor and applied to a differentiator consisting of C_4 and R_7. A positive pulse is removed from across resistor R_9, which has the same value as R_6, in the cathode circuit, and applied to another differentiating circuit made up of C_5 and R_{10}. The vertical information is removed at the plate of the phase-splitter tube and applied to the long time-constant integrating circuit made up of R_{11}, C_6, R_{12}, and C_7.

Differentiating and integrating circuits in transistor receivers are identical to those found in tube-type receivers. The purpose of these circuits is to separate the horizontal and vertical sync pulses from one another. As far as the separating action is concerned, it makes no difference whether the set uses tubes or transistors.

SELF-TEST QUESTIONS

(aa) What is meant by inter-sync segregation?
(ab) What type of circuit is used to select the horizontal sync pulses?
(ac) What type of circuit is used to select the vertical sync pulses?
(ad) What part of the horizontal sync pulse is used to maintain synchronization?
(ae) Do the same equalizing pulses maintain horizontal sync on successive fields?
(af) Why is the vertical sync pulse slotted instead of one long pulse?
(ag) Why can't the horizontal pulses or the equalizing pulses trigger the vertical oscillator?
(ah) What will be the effect of faulty synchronization of the vertical oscillator by noise or the horizontal sync pulses?

Synchronization of Sweep Generators

We have already studied sync takeoff circuits, sync separation, sync segregation, and the shaping of the horizontal and vertical sync pulses for application to the oscillators to be synchronized. The next step is to find out just how the sync pulses synchronize the deflection generator circuits.

In the vertical sweep circuits, the vertical sync pulses lock in the vertical sweep generator (blocking tube oscillator or multivibrator) directly with each arriving vertical sync pulse by initiating the retrace period of the vertical oscillator. Horizontal synchronization in most television receivers operates on a so-called "flywheel principle" in which the average frequency of the arriving horizontal sync pulses determines and synchronizes the horizontal sweep generating circuits.

The deflection oscillators in television receivers are free-running and operate continuously despite the presence or absence of sync pulses. A typical blocking oscillator used as a vertical sawtooth generator must have a free-running or non-synchronized frequency lower than the frequency at which it is locked in by the arriving sync pulses.

It is important to realize that a sweep-generating circuit can be synchronized only if the free-running frequency is brought near to the frequency of the sync pulses. The receiver has horizontal and vertical hold or frequency controls to do this. At this point the sync pulses establish control of the oscillators and lock in the scanning cycle rigidly. Let us now consider this synchronizing action.

VERTICAL SYNC SYSTEMS

You have already studied blocking oscillators and will recognize the circuit shown in Fig. 25 as a blocking oscillator. It is typical of the circuits used as the vertical oscillator in many transistor TV receivers.

Fig. 26. A is the emitter-base curve of a blocking oscillator using an NPN transistor. B is the curve showing when the sync pulse arrives. C shows how the sync pulse drives the emitter-base voltage into the forward bias region so the transistor can conduct.

The waveform of Fig. 26A is typical of the base voltage (the charge and discharge cycle of the bias capacitor C_2. The capacitor charges through the transistor and discharges through R_4 and R_5).

In synchronizing the blocking oscillator, the vertical sync pulse arrives just before the instant at which the normal free-running base waveform reaches the conduction point of its cycle as shown in Fig. 26B. Since this time of conduction could vary when the oscillator is free-running, the arrival of the sync pulse just before this time always triggers the oscillator at precisely the same time spacing as the arriving sync pulses. Consequently, the sync pulse arrives at the base and immediately places a forward bias across the emitter-base junction, driving the transistor into conduction. This initiates the feedback cycle that begins the retrace period of the oscillator. This occurs

Fig. 25. A transistor blocking oscillator used as the vertical sweep oscillator.
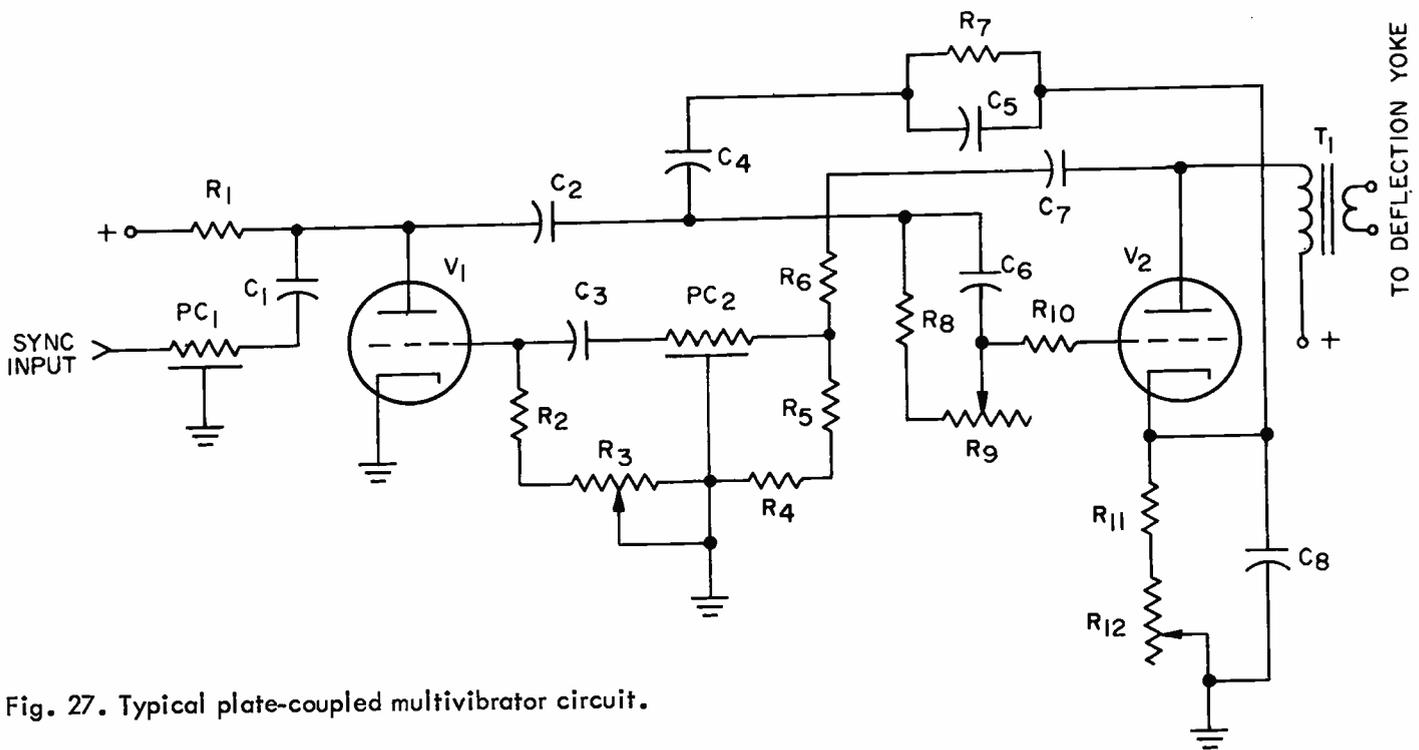
Fig. 27. Typical plate-coupled multivibrator circuit.

for each arriving pulse so that the oscillator is locked in at the pulse frequency as shown in Fig. 26C.

This very precise timing depends on the arrival time of the vertical sync pulses. If some other disturbance such as noise impulses or horizontal synchronizing components that stray into the vertical circuits arrive just ahead of the vertical sync pulses, they may cause erroneous synchronization of the vertical oscillator. This will create a momentary or continuous roll of the picture. Such a possibility emphasizes the need for the integrator circuit and the precautions that are taken in the sync circuits to minimize or cancel noise components.

A multivibrator, Fig. 27, can be synchronized in the same way with the application of a positive pulse to the grid of V_1 or a negative pulse to the grid of V_2.

With the circuit shown in Fig. 27, V_2 conducts during the sweep interval, producing the required sweep current which is coupled to the deflection yoke by T_1. During this interval V_1 is cut off. The R-C time constant of the circuit is chosen so it is slightly longer than the time required to sweep the electron beam from the top to the bottom of the picture tube.

With V_2 conducting and V_1 cut off, just before the tubes are due to switch, the negative sync pulse is fed from the integrator PC_1 through C_1 to the plate of V_1. From there the pulse is fed through C_2, the parallel combination of C_6 and R_8-R_9, through R_{10} to the grid of the tube. The negative pulse applied to the grid of V_2 produces a positive pulse in the plate circuit which is fed through C_7, R_6, PC_2 and C_3 to the grid of V_1. The positive pulse applied to the grid of V_1 causes V_1 to conduct, which produces a large negative pulse in the plate circuit of V_1. This negative pulse is fed to the grid of V_2 and cuts it off.

The R-C time constants are chosen so that V_1 conducts for a very short period and then V_2 starts con-

ducting again and generates the vertical sweep. The next sync pulse then arrives at the correct time to start the next retrace. Thus, although the plate-coupled multivibrator is actually a free-running multivibrator, its frequency is controlled by the vertical sync pulses.

Notice the integrator in Fig. 27; it is marked PC_1. This is a special component that contains both resistance and capacitance. Instead of several separate resistors and capacitors, you can consider this part as one long resistor with capacity between the entire length of the resistor and ground. The net effect is to produce a circuit with a long time constant which performs the integration function.

Fig. 28 illustrates another instance in which a negative sync pulse is used to synchronize a multivibrator. The negative-going vertical sync pulse drives the cathode negative so that the grid-cathode voltage on V501A is driven into the conduction region and plate current begins to flow through the tube.

The diode in the cathode circuit is connected so that current can flow from B- to the cathode of V501A through the diode. However, when the negative-going sync pulse reaches the cathode of V501A, it drives the anode of the diode negative. Thus the diode acts as a high impedance to the sync pulse and avoids shorting out the pulse.

HORIZONTAL SYNC SYSTEMS

Multivibrators are used to generate the horizontal sweep in modern TV receivers that use vacuum tubes. In transistor receivers, you may find either a multivibrator or a blocking oscillator as the horizontal sweep oscillator. In any case, the frequency of the oscillator is controlled by the average frequency of the horizontal sync pulses. Therefore, instead of being
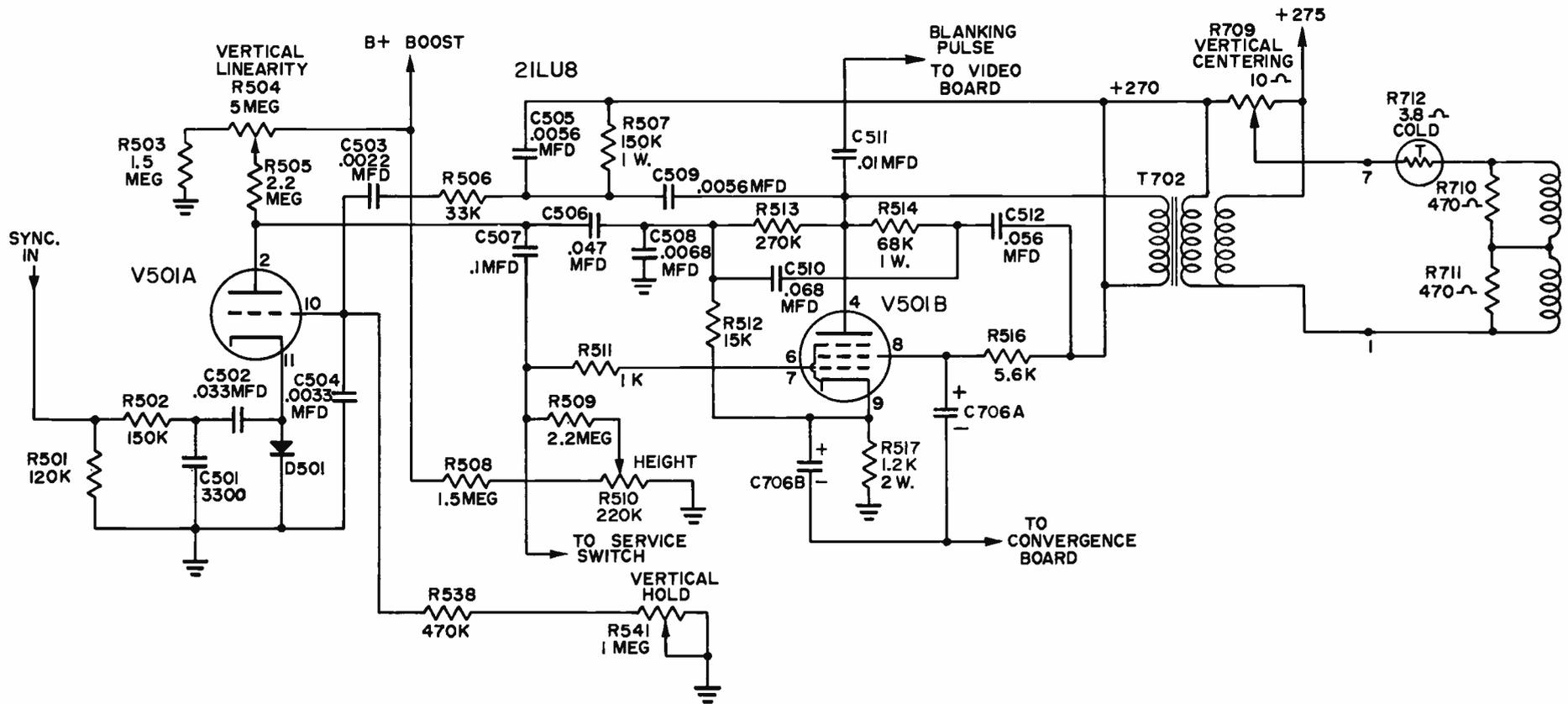
Fig. 28. Multivibrator with sync pulses fed to the cathode of the first stage.
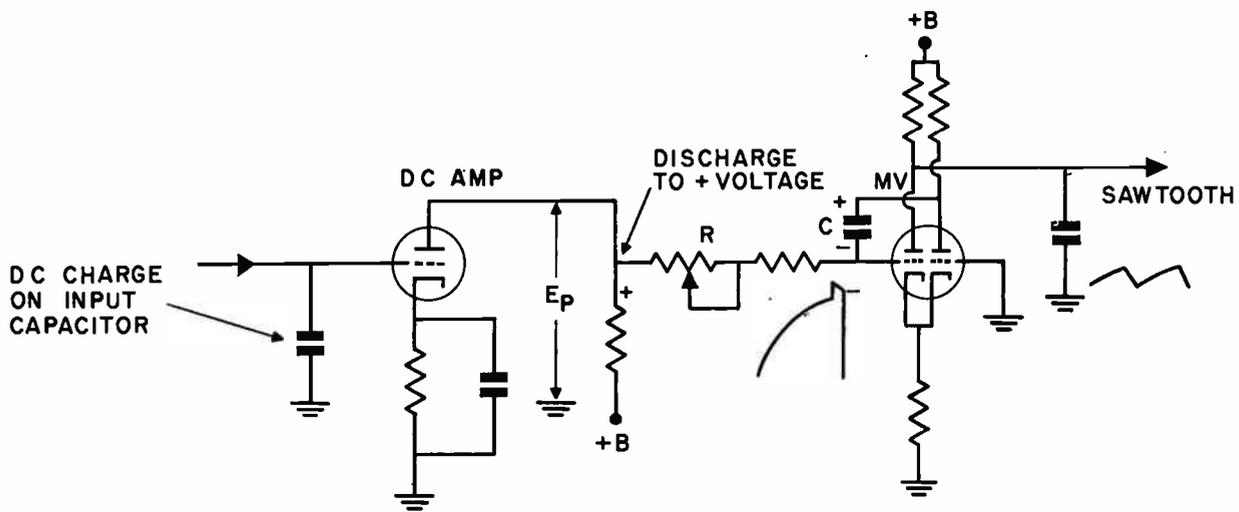
Fig. 29. A typical multivibrator and control tube used to control the multivibrator frequency.

fed directly to the horizontal oscillator, the sync pulses are fed to a separate stage where an average dc voltage is developed and used to control the oscillator frequency.

In this type of circuit, the sync pulse does not arrive at the input of the oscillator. Likewise any noises that might arrive along with the sync pulses cannot trigger the oscillator erroneously. The sync pulses place a dc charge on the input circuit of the oscillator that depends on their arrival time. As the average frequency of the sync pulses changes in relation to the oscillator frequency, the charge changes and causes the horizontal oscillator frequency to follow the frequency of the horizontal sync pulses.

A circuit of this type is shown in Fig. 29. The waveforms in Fig. 30 show how the dc potential controls the frequency of the oscillator. In the multivibrator circuit shown, the grid is returned to a positive supply potential point. The potential of this point influences the frequency of the multivibrator because it determines the voltage range through which the grid capacitor discharges. When the first section of the multivibrator conducts, grid current will flow charging C and developing a bias across the grid resistors as shown. This bias will cut off the first stage of the multivibrator. After the grid capacitor C has been charged negatively to a value of minus E_c it attempts to discharge to zero and on to some plus value through the resistors in the grid circuit, keeping the tube cut-

off. The capacitor charge never reverses during this discharge cycle, because as soon as cutoff voltage is reached, the first section of the multivibrator starts conducting and a new cycle is started.

The rate at which the capacitor discharges, or the time required to reach cutoff voltage, depends on the potential toward which it attempts to discharge, as shown in Fig. 30. You can see that the discharge slope is steeper when the capacitor discharges toward the higher supply value, so the cutoff point is reached more rapidly, and the frequency increases.
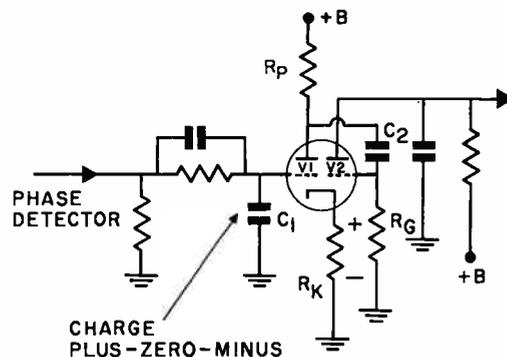
Fig. 31. The frequency of a multivibrator can be controlled by varying the dc bias applied to one section.

Since the plate voltage on the dc amplifier controls the discharge time and is, in turn, controlled by the charge on the input capacitor, the charge placed there by the sync pulses regulates the frequency of the horizontal oscillator. This permits a horizontal deflection circuit far less affected by noise impulses than a directly synchronized sweep generator.

It is also possible to control the frequency of a multivibrator with a dc bias voltage applied to the grid of one section of the multivibrator as in Fig. 31. The bias is applied to V_1, and V_2 forms the waveshape needed to drive the horizontal output tube.

This voltage at the plate of V_1 depends upon the drop across R_p. When the drop across R_p is high, the voltage at the plate of V_1 is low.

The drop across R_p depends upon the grid bias. A

Fig. 30. The waveform on the grid of the first stage of the multivibrator.

low bias increases the current through V_1 and R_p. This increases the voltage drop across R_p, and reduces the voltage at the plate. Increasing the bias reduces the current through V_1 and R_p. This reduces the voltage drop across R_p and raises the voltage at the plate of V_1.

Since the frequency depends upon the voltage at the plate of V_1, reducing the bias reduces the frequency; increasing the bias increases the frequency.

HORIZONTAL AFC SYSTEMS

It is possible to synchronize the horizontal sweep oscillator by direct application of the sync pulse as discussed previously. However, the presence of noise impulses along with the sync pulses can cause faulty synchronization. For example, a sharp noise pulse just ahead of a horizontal sync pulse could trigger the retrace period too early and displace the succeeding line of video information. Likewise, groups of noise pulses could cause improper synchronization over a number of lines and cause line displacements. This is called horizontal tearing. Nevertheless, direct synchronization of the horizontal sawtooth oscillator was used in some early TV receivers.

In the modern receiver, the horizontal sync pulses still maintain synchronization of the horizontal sweep, but they do so by indirect means. In the so-called horizontal automatic frequency control circuit, the average frequency of the arriving sync pulses over a number of lines is used to establish synchronization of the horizontal oscillator, thus preventing triggering by noise pulses.

In a horizontal afc system, shown in block diagram form in Fig. 32, there are three basic circuits--the comparison circuit, the oscillator circuit and the sweep output circuit. The sweep generators and output circuits were discussed in a previous lesson. In this lesson we will discuss the process of synchronizing the horizontal oscillator.

The locally generated signal is fed back to the comparison circuit from the horizontal output stage or from the horizontal oscillator. In the comparison circuit, the frequency and phase of this signal are compared with the frequency and phase of the sync pulses to produce a dc voltage that depends on their frequency and phase relationships. This dc voltage, in turn, regulates the frequency of the horizontal oscillator. Consequently, the horizontal oscillator is maintained on proper frequency by a dc voltage instead of by the sync pulses. When the incoming sync pulses and the locally generated signal are in phase, there is no voltage developed by the comparison stage. If the two signals deviate in phase, a voltage is developed that brings the oscillator back in phase with the sync pulses.

There are three basic methods of comparison:

1. A phase detector system that compares the incoming sync signal with the locally generated signal and produces a dc voltage that is used to control the frequency of a blocking tube or multivibrator sweep generator.

2. A pulse width system that develops a pulse, the duration of which depends on the phase relationship between the sync and the sweep oscillator signals. This pulse establishes a dc voltage to control the sweep oscillator frequency.

3. A phase discriminator system that produces a dc charge that biases a reactance tube. The reactance tube regulates the frequency of a sine wave sweep oscillator.

Of the three systems, the phase detector system is the most widely used--it is found in modern TV receivers. The pulse width system was widely used for many years and you'll probably encounter it in service work. The phase discriminator system was used in some early-model TV sets, but you are not likely to run into any of these sets. This type of circuit is used in color synchronization so we'll study it there.

PHASE DETECTORS

There are two types of phase detector systems. One type requires two signals from the sync circuit; the other, only one. A phase detector afc system that compares horizontal sync pulses of equal amplitude, but opposite polarity, with the locally generated sawtooth wave that is fed back from the horizontal output circuit is shown in Fig. 33.

The feedback voltage is initially in the form of a pulse from the horizontal output circuit, but is integrated into a sawtooth wave by the network consisting of resistor R_1 and capacitor C_3. Capacitor C_6 acts as a blocking capacitor, and resistor R_2 aids in shaping the sawtooth and provides a dc return path for the phase detector diodes. The operation of the phase detector circuit can best be understood by first considering the circuit when just one of the basic signals is applied.

With the application of a positive sync pulse to the top diode and a negative sync pulse of equal amplitude

HORIZONTAL
SYNC → COMPARISON → HORIZONTAL → HORIZONTAL → HORIZONTAL
INPUT   CIRCUIT   OSCILLATOR   SWEEP   DEFLECTION
                                        OUTPUT   COILS

LOCALLY GENERATED COMPARISON
SIGNAL FROM EITHER STAGE
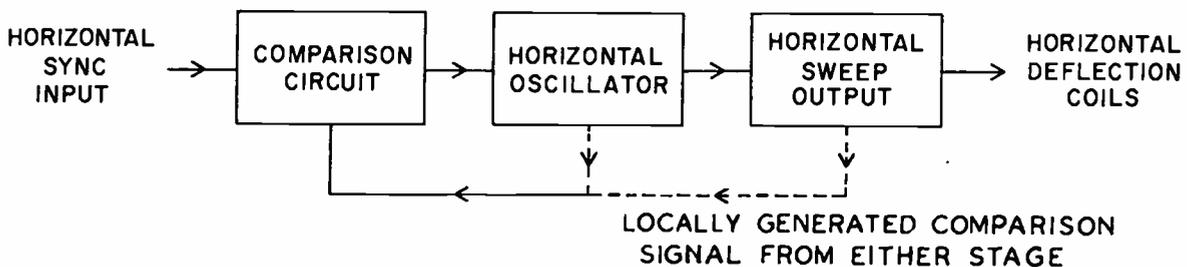
Fig. 32. Block diagram of the horizontal afc system.
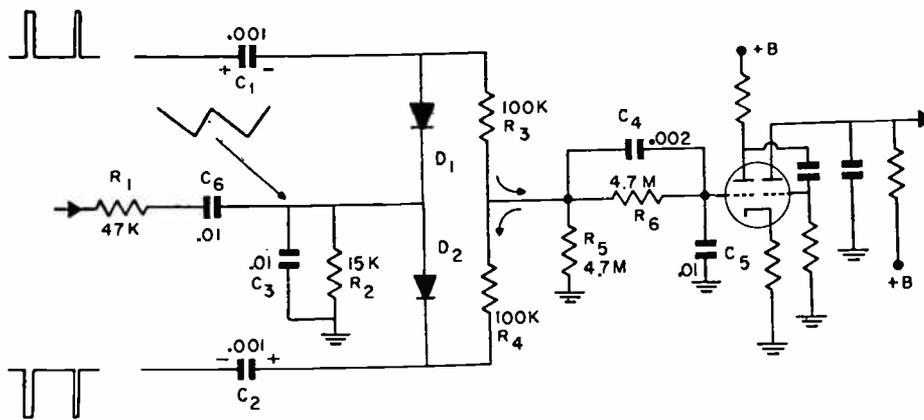
Fig. 33. A typical phase detector afc system.

to the lower diode, both diodes conduct. The diode currents flow in opposite directions through resistor R_5 in the output circuit. The positive pulse applied to the anode of diode D_1 will cause diode current to flow from the anode of D_1 through resistors R_3 and R_5 to ground, through R_2, and back to the cathode of D_1. The negative pulse applied at the same time to the cathode of D_2 will cause current to flow from the anode of D_2 through resistor R_2 to ground, through R_5, R_4, and back to the cathode of D_2. If the diode circuits are balanced, and the applied sync pulses are of equal amplitude, equal currents flow through resistor R_5 in opposite directions and there is a zero voltage drop across the resistor and a zero charge on capacitor C_5. The diode currents, however, do charge capacitors C_1 and C_2 with the polarities indicated to prevent the diodes from conducting between pulses. Thus the diodes are keyed into conduction only during the time interval of the arriving sync pulses.

If the sawtooth wave alone were applied to the phase detector, the output would again be zero and the charge on C_5 would also be zero. As the sawtooth falls below zero, it applies a negative voltage to the cathode of D_1, and the diode conducts. On the positive portion of the sawtooth cycle (positive with respect to its central or zero axis), D_2 conducts. Since the two diodes again conduct equally, but in opposite directions, the net output across R_5 is again zero.

The phase detector circuit functions only when both signals are applied simultaneously. If the sync pulses and the feedback sawtooth wave are exactly in phase, the sync pulses coincide with the center of the retrace portion of the sawtooth wave. Under this condition, as shown in Fig. 34A (assuming 5-volt pulses and a 5-volt peak-to-peak sawtooth), the pulses arrive when the sawtooth wave is going through zero. Thus
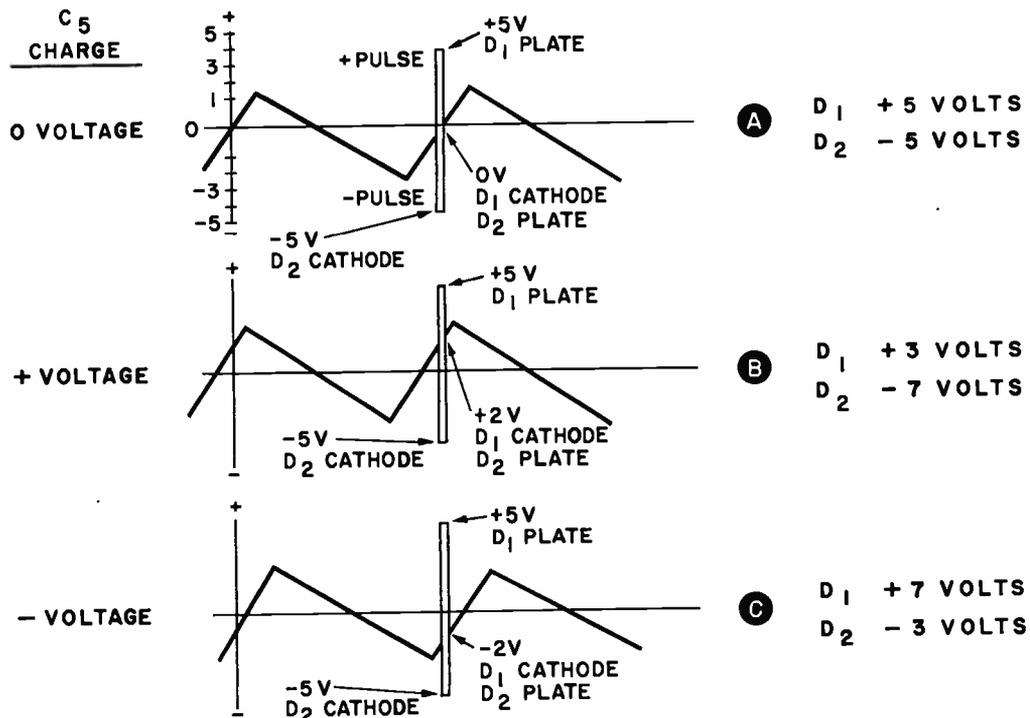
Fig. 34. A, the phase relationship between the sync pulses and the sawtooth signal applied to the phase detector when the oscillator is operating at the correct frequency. B, the oscillator frequency is high. C, the oscillator frequency is low.
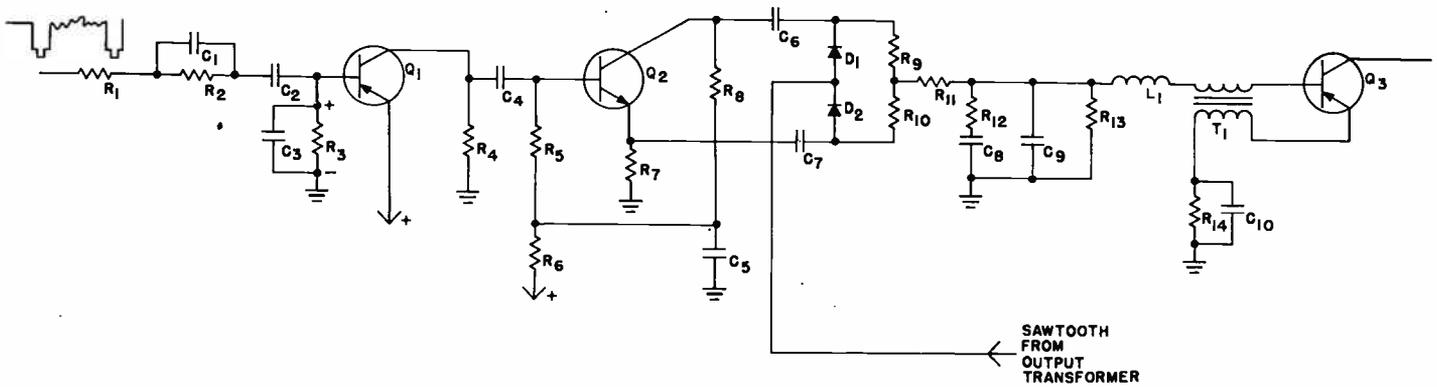
Fig. 35. Sync separator, sync splitter, afc and blocking oscillator circuits.

at the instant the diodes are triggered into conduction by the arriving sync pulses, there is a 5-volt difference of potential across the top diode and a 5-volt difference across the bottom diode. These equal potentials draw equal currents of opposite direction through resistor R_5, and the charge on the capacitor C_5 remains at zero.

If there is a change in circuit conditions that causes the frequency of the oscillator to increase, the sync pulses will move up on the sawtooth as shown in Fig. 34B. Now the sync pulses occur when the sawtooth is positive. This makes the cathode of D_1 and the anode of D_2 positive. If, under these conditions, the cathode of D_1 is 2 volts positive, as indicated, and the anode 5 volts positive, the net difference of potential across D_1 is only 3 volts. At this same instant the same positive 2 volts contributed by the sawtooth is also present on the anode of D_2 along with a 5-volt negative pulse applied to its cathode, producing a net difference of potential across D_2 of 7 volts. Consequently, D_2 will conduct a greater current through the output resistor R_5 than D_1.

The polarity of the voltage across R_5 will therefore be determined by the current through D_2, so the junction of R_3, R_4, R_5 and R_6 will be positive with respect to ground, placing a positive charge on capacitor C_5. This positive charge on the grid of the horizontal multivibrator causes the frequency to decrease to that of

the sync pulses, restoring the in-phase condition between the deflection waveform and the sync pulses.

If the oscillator frequency decreases, the sawtooth wave will be negative with respect to its zero axis when the sync pulses arrive as indicated in Fig. 34C. Under these conditions the difference of potential across D_1 will exceed that across D_2 and the current through D_1 will be greater than the current through D_2. The unbalanced currents will develop a voltage across R_5. The net voltage drop across resistor R_5 and the charge on capacitor C_5 will be negative with respect to ground and will increase the frequency of the multivibrator the proper amount.

An example of a sync system where positive and negative sync pulses are used is shown in Fig. 35. In this circuit, the video signal with negative-going sync pulses is fed to the base of Q_1, the sync separator. Q_1 is a PNP transistor -- it will conduct on the negative sync pulses applied to the base. A bias will be developed across R_3, as shown, that will prevent Q_1 from conducting, except on the sync pulses.

Amplified, positive-going sync pulses will be developed at the collector of Q_1. These pulses are fed to the base of Q_2, which is an NPN transistor. R_7 in the emitter circuit and R_8 in the collector circuit are of equal size so we have equal (but opposite polarity) sync pulses developed at the emitter and collector of Q_2. The pulses at the emitter will be positive-going;
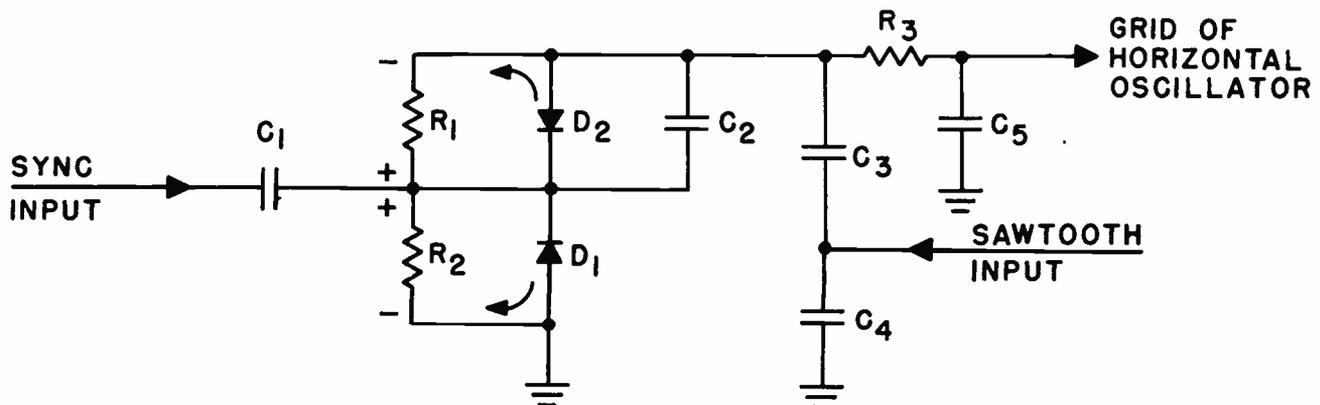
Fig. 36. A single-ended phase detector afc system.

B511-32

those at the collector, negative-going. The positive sync pulses are fed to D_2 and the negative pulses to D_1. The sawtooth is fed to the junction of D_1 and D_2. The afc circuit works just like the circuit shown in Fig. 33.

The output of the afc circuit is fed through R_{11}, L_1, and the secondary of T_1 to the base of Q_3. Q_3 is a blocking oscillator. The changes in afc voltage will affect the charge across C_9. The time constant of C_9 and R_{13}, and the charge developed across C_9, will control the oscillator frequency.

Notice that Q_3 is a PNP transistor. If the oscillator frequency is too high, a negative output voltage will be developed by the afc circuit. This is applied to the base of Q_3, causing it to draw more current and charging C_9 to a higher value. This will slow down the oscillator by increasing the time required for C_9 to discharge through R_{13}.

The circuit of a single-ended phase detector afc system is shown in Fig. 36. Here the sync input consists of negative pulses. These pulses cause diodes D_1 and D_2 to conduct as shown, developing voltages across R_1 and R_2 as shown. As long as the conduction through the diodes is equal, the voltages across R_1 and R_2 will be equal and the net voltage fed through R_3 to the grid of the horizontal oscillator tube will be zero.

A sawtooth voltage that can be taken from the horizontal oscillator or from the horizontal sweep output is applied to the junction of C_3 and C_4. This sawtooth voltage is fed through C_3 to the two diodes in series. C_2 is used to be sure that equal sawtooth voltages are applied to the two diodes.

To see how the circuit works we must consider the voltage from the cathode to the plate of each diode. When the oscillator is running at the correct frequency, the sync pulses will fall on the zero point on the sawtooth retrace as shown in Fig. 37A. Under these circumstances, the signal applied to each diode will be equal, the voltage across R_1 and R_2 will be equal, and hence cancel. The net voltage fed to the oscillator grid will be zero.

When the oscillator runs too fast the waveshapes shown in Fig. 37B will be produced. The negative voltage applied to the cathode of D_1 will be a portion of the feedback voltage plus the sync pulse. At the same time the negative voltage applied to the cathode of D_2 will be, in effect, the sync voltage minus a portion of the feedback voltage. As a result D_1 will conduct more than D_2. The voltage across R_2 will be greater than the voltage across R_1, so a positive voltage will be fed to the oscillator grid to slow it down.

When the oscillator frequency drops below the sync pulse frequency, the waveforms shown in Fig. 37C will be observed. Under these circumstances, D_2 will conduct more heavily than D_1, the voltage across R_1 will be greater than the voltage across R_2, and a negative voltage will be fed to the oscillator grid to speed it up.

A long time constant network is used at the output of a phase detector for a number of reasons. For example, the time constant must be made long enough so the instantaneous current changes do not cause the charge on capacitor C_5 (in Figs. 33 and 36) and on C_9

(Fig. 35) to vary quickly. In fact, the charge on capacitor C_5 is the average of the instantaneous changes for a number of lines. Thus, rapid instantaneous changes of multivibrator frequency, which would make the system more susceptible to noise, do not occur. Likewise, sharp noise pulses do not influence the multivibrator frequency, because they cannot change the charge on C_5 because of the long time constant of the associated circuit.

The time constant of this network, though long, is made short enough to follow the normal variations in the frequency of the sync pulses or drift in the frequency of the horizontal multivibrator. Otherwise, there would be annoying line displacements and ragged raster edges, because the horizontal oscillator could not follow sync changes quickly enough.

One of the advantages of the phase detector circuit, as compared to other types of horizontal afc circuits, is that no adjustment of the detector is necessary. The only adjustment is setting the horizontal multivibrator frequency properly, as mentioned in the preceding lesson, by setting the horizontal stabilizing circuit and the horizontal hold control, if one is used, so that the arrival of the sync pulses matches the center of the retrace period of the feedback sawtooth. This adjustment insures that the sync pulses occur during the retrace interval of the deflection waveform and that proper synchronization occurs when the customer-adjusted horizontal hold control is set at the approximate center of its range.

PULSE-WIDTH AFC

The pulse width, or 'synchroguide' circuit, consists of a blocking oscillator and a control tube as shown

DIODE 1   DIODE 2
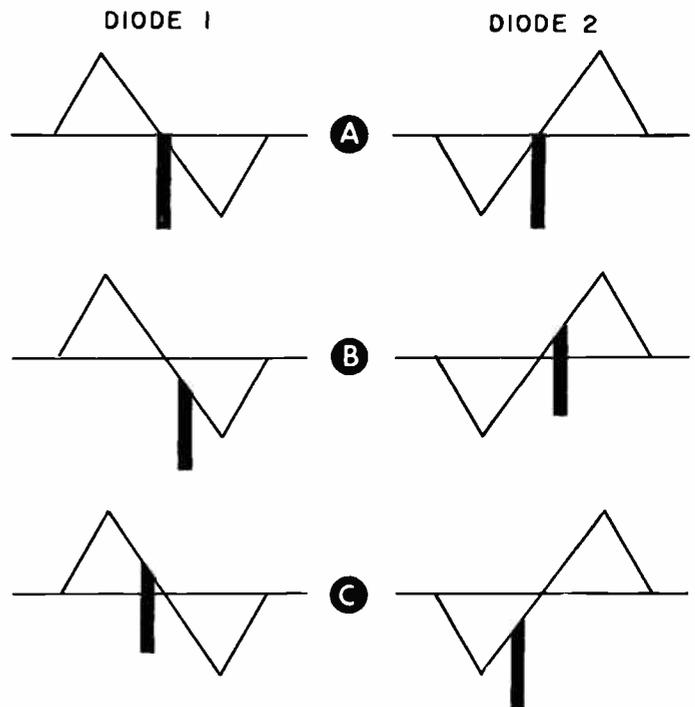
Fig. 37. Waveshapes for the circuit in Fig. 36.
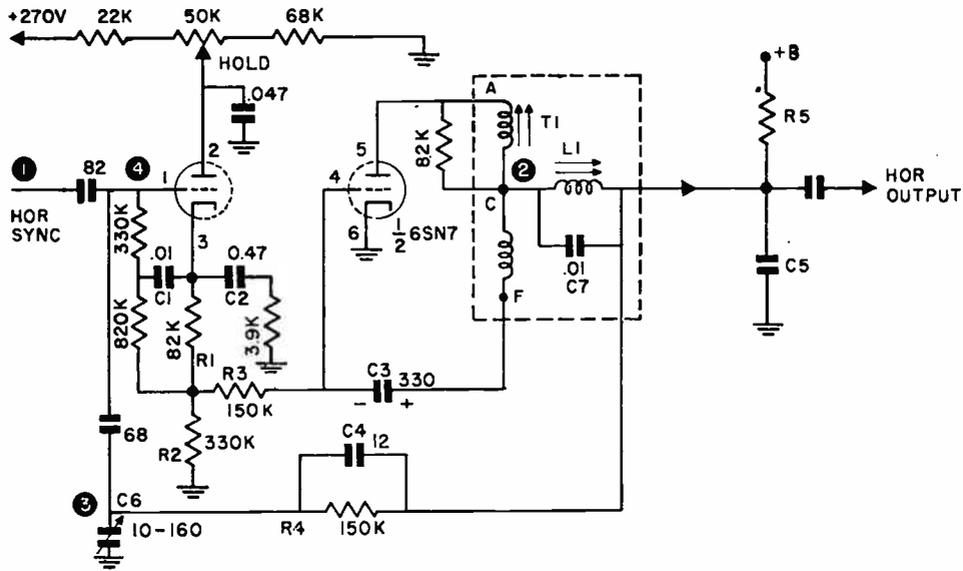
Fig. 38. A blocking oscillator and control tube.

in Fig. 38. The blocking tube oscillator uses an auto-transformer arrangement to obtain feedback between plate and grid circuits. The oscillator tube is biased near cut-off by the charge on capacitor C_3.

The frequency of the blocking tube oscillator is regulated by the dc charge placed on capacitor C_2 by the control tube. Resistors R_1 and R_2 act as a voltage divider across this capacitor, supplying the proper dc voltage level through resistor R_3 to the grid of the blocking tube. The charge placed on capacitor C_2 is governed by two things--the setting of the horizontal hold control in the plate circuit of the control tube, and the duration of the pulse applied to the grid of this tube.

The hold control determines the plate voltage of the control tube and the amount of dc current drawn by the tube and, therefore, the dc charge placed on capacitor C_2. The charge on capacitor C_2 is also affected by the duration of the pulse applied to the grid of the control tube. The duration of this pulse, in turn,

is determined by the frequency and phase relationship between the incoming horizontal sync pulses and the locally generated signal (fed back from the horizontal sawtooth generating circuits by way of capacitor C_4 and resistor R_4).

The oscillator control tube is biased so that plate current flows only during the positive peak of the signal applied to the grid. This peak occurs when the sync pulse arrives, so the sync pulse actually determines the charge placed on capacitor C_2. The charge placed on the capacitor C_2 is determined by the length of time the control tube conducts. This, in turn, depends on the phase relationship between the sync pulse and the feedback signal supplied to the grid.

The signal applied to the grid of the control tube is made up of the incoming sync pulse, the sawtooth wave developed at the output circuit of the oscillator (the sawtooth-forming circuit consists of resistor R_5 and capacitor C_5), and a sinewave component contributed by the output resonant circuit of the transformer
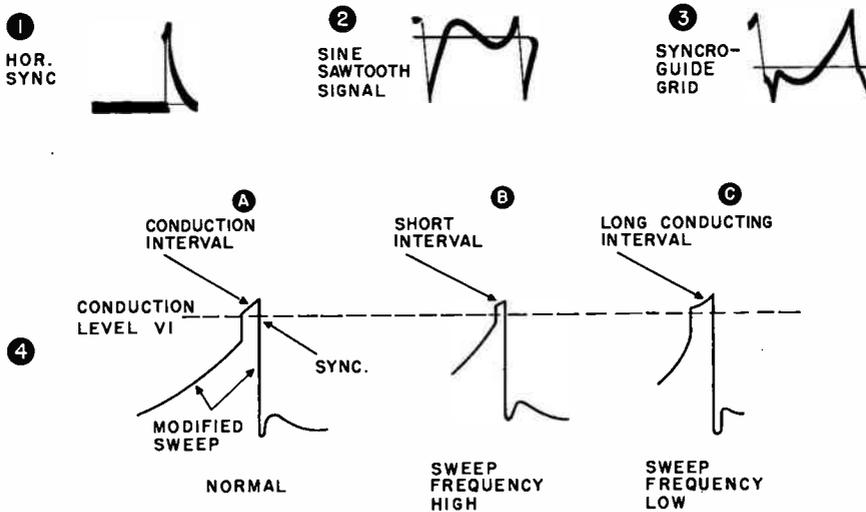
Fig. 39. Waveforms found in the pulse width circuit. The numbers on the diagram in Fig. 34 correspond to the numbers on the waveforms.

(winding L_1 and capacitor C_7). The sawtooth component is shaped by resistor R_4 and capacitor C_6 to form a partial parabolic wave that emphasizes the retrace portion of the generated sawtooth. The sine-wave component is added in proper phase by the tuned circuit, to further emphasize the retrace portion of the feedback signal. The waveform at the synchroguide grid is made up of the incoming sync waveform and the fed-back modified signal, shown in 1 and 3 of Fig. 39. The addition of waveforms 1 and 3 produces the resultant synchroguide input signals shown in 4 of Fig. 39.

The length of time the control tube conducts determines the amplitude of the charge placed on the cathode capacitor C_2. The time the tube conducts depends upon the position of the sync pulse with respect to the modified waveform (in other words, the phase relationship between modified waveform and incoming sync).

In waveform 4A of Fig. 39, the sync pulse is above cutoff for the proper length of time to charge the cathode capacitor to the proper voltage, to hold the blocking tube on correct frequency. In waveform 4B, the horizontal frequency is too high. The sync pulse therefore arrives somewhat later than in 4A, and a part of the pulse is dropped below cutoff by the sharp decline of the modified waveform which now appears slightly displaced to the left of its original position. Thus, the tube does not conduct for as long an interval, and the charge on the cathode capacitor drops; the blocking tube grid voltage decreases and the frequency decreases to the same frequency as the sync pulses.

In the waveform shown in 4C of Fig. 39 the horizontal frequency is low. The sync pulse therefore arrives too soon, drives the grid into the plate current region, and remains above cutoff for a longer interval because the drop off of the modified waveform is displaced to the right of its in-phase position. This increases the cathode charge; the blocking-tube grid voltage rises and causes a compensating increase in the horizontal frequency to match the incoming sync pulses once again.

This method of frequency control, referred to as a pulse-width system, controls the frequency by the length of the pulse duration. Again, the blocking tube frequency is controlled by a dc voltage determined by the horizontal sync pulses. It is not triggered directly by the sync pulses and is therefore not subject to erroneous synchronization by noise pulses.

SELF-TEST QUESTIONS

(ai) Must the natural operating frequency of a vertical blocking oscillator be higher than or lower than the required field rate?

(aj) What is the polarity of the sync pulses fed to a blocking oscillator (a) using a tube? (b) using a PNP transistor? (c) using an NPN transistor?

(ak) What is the polarity of the sync pulse applied to the multivibrator shown in Fig. 27?

(al) Does the sync pulse cut-off V_2 in Fig. 27?

(am) What is used to control the oscillator frequency in an afc system?

(an) What are the three basic methods of comparison used in horizontal afc systems?

(ao) How many sync signals are required for the phase detector system shown in Fig. 33?

(ap) What is the polarity of the sync pulse fed to the base of Q_2 in Fig. 35?

(aq) What is the polarity of the sync pulse at the emitter of Q_2 in Fig. 35? At the collector?

(ar) Do the diodes D_1 and D_2 in Fig. 35 conduct at all times?

(as) Will a positive voltage across C_5 in Fig. 33 cause the oscillator frequency to increase or decrease?

(at) What is the polarity of the sync pulse fed to the phase detector in Fig. 36?

(au) Why is a long time constant circuit used between a phase detector and the horizontal oscillator?

ANSWERS TO SELF-TEST QUESTIONS

(a) The sync separator separates the sync pulses from the composite video signal.

(b) An isolating resistor is used to prevent any loss of the high-frequency components of the video signal and to avoid any loss of the 3.58-mc color signal.

(c) R_1 in Fig. 4D isolates the sync separator from the video amplifier and prevents any loss of the 3.58-mc color signal. It has no effect on the video signal since it is taken from the cathode of the video amplifier.

(d) (1) A 4.5-mc sound signal and (2) a composite video signal.

(e) It eliminates any possible loss of the high-frequency video components and it prevents any loss of the 3.58-mc color signal.

(f) The sync separator must remove all components of the composite video signal below the blanking level.

(g) With signal bias, the bias on the tube automatically adjusts to the amplitude of the signal--with fixed bias any change in signal amplitude may result in faulty operation of the sync separator.

(h) To keep the spread between grid cutoff voltage and saturation voltage reasonably low--this permits better clipping and more constant pulse amplitude at the output.

(i) (1) No amplification (2) very limited noise rejection.

(j) Contrast control, color control, and volume control.

(k) The sync pulses.

(l) Decrease.

(m) Long time constant.

(n) An increase.

(o) During the sync pulse.

(p) (a) Increases; (b) Decreases.

(q) Number three grid.

(r) Number one grid.

(s) Negative.

(t) No -- because synchronization depends upon the average frequency of the arriving sync pulse and not on the presence of each individual sync pulse.

(u) The strength of the sync pulses.

(v) The screen grid.

(w) The cathode, grid number one and grid number two.

(x) (1) One tube to perform two functions. (2) Noise cancellation is obtained both in sync separator and agc stages.

(y) Noise pulses.

(z) Provides delayed agc for the rf amplifier.

(aa) Separating the horizontal sync pulses from the vertical pulses.

(ab) A differentiating circuit.

(ac) An integrating circuit.

(ad) The leading edge of the horizontal sync pulse is used to maintain synchronization.

(ae) No. If the first, third and fifth equalizing pulses maintain sync on one field, the second, fourth and sixth pulses will maintain synchronization on the next field.

(af) The vertical sync is slotted so horizontal synchronization can be maintained during the long vertical sync pulse.

(ag) The time duration of the horizontal pulses and the equalizing pulses is too short to appreciably charge the capacitors in the vertical integrator.

(ah) It will result in loss of interlace.

(ai) Lower.

(aj) (a) positive polarity; (b) negative polarity; (c) positive polarity.

(ak) Negative.

(al) No. The negative sync pulse is amplified by V_2. This produces a positive pulse in the output which is fed to the grid of V_1. V_1 amplifies the pulse and produces a large negative pulse in the plate circuit which is fed to the grid of V_2 to cut it off.

(am) The frequency of the arriving sync pulses over a number of lines.

(an) (1) Phase detector system; (2) Pulse width system; (3) Phase discriminator system.

(ao) Two -- one positive and one negative.

(ap) Positive-going sync pulses.

(aq) At the emitter, positive polarity; at the collector, negative polarity.

(ar) No, they conduct only during sync pulse interval.

(as) Decrease.

(at) Negative.

(au) To prevent the oscillator frequency from responding to instantaneous voltage changes. It must respond only to average voltage changes.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. If the composite video signal is fed to the grid of a triode sync separator, what polarity must the sync portion of the video signal have?

2. What will the polarity of the sync pulses be at the output of a PNP transistor sync separator?

3. What is the chief advantage of keyed agc?

4. If the agc voltage increases the forward bias across the emitter-base junctions of a transistor i-f amplifier, when the incoming signal strength increases how is the stage gain controlled?

5. How does the input from the 2nd i-f control Q_3 in the circuit in Fig. 12?

6. In the circuit shown in Fig. 13, if the strength of the input signal increases, what happens to the forward bias on (a) the rf stage (b) the i-f stage?

7. In the circuit shown in Fig. 18, what will the polarity of strong noise pulses be (a) at the output of Q_1, (b) at the output of Q_2?

8. What signal is fed to the vertical oscillator to synchronize it?

9. Are the horizontal sync pulses fed directly to the horizontal oscillator to synchronize it?

10. What purpose does Q_2 serve in Fig. 35?

STUDY SCHEDULE

> For each study step, read the assigned pages first at your usual speed, then reread slowly one
> or more times. Finish with a quick reading to fix the important facts firmly in your mind.
> Study each other step in this same way. Be sure to test yourself by answering the Self-Test
> Questions at the end of each major section. You'll find the answers at the end of the lesson.

SOUND SYSTEMS AND POWER SUPPLIES

You have now studied all of the sections of the television receiver that produce a black-and-white picture. The circuits you have studied will be found in both black-and-white and in color receivers. Before going on and studying the additional circuits found only in color TV receivers, we will examine two other circuits found in both color and monochrome TV, the power supplies and the sound system. We will study power supplies first in this lesson, and then sound systems.

There are two power supplies in each TV receiver: the high-voltage power supply which supplies the high voltage for the picture tube and the low-voltage power supply which supplies all the other operating voltages required by the receiver. The low-voltage power supply is low in comparison with the high-voltage supply, but in some TV receivers it generates voltages of 400 volts or more, and because of its high current capacity, it may actually be more dangerous than the high-voltage supply.

SAFETY PRECAUTIONS

The most important things to learn about TV receiver power supplies are the safety precautions that must be observed. The first safety rule is very simple --unplug the receiver before working on it. Don't be satisfied with just turning it off; this is not enough. In transformerless TV receivers, you may have the ac line voltage running all through the set even with the switch off. Even receivers that use power transformers can be hazards unless they are unplugged.

The second safety rule is to discharge the filter capacitors in the power supply before working on the set. Remember that the picture tube itself acts as a filter capacitor in the high-voltage supply; it, too, must be discharged. Failure to observe these simple precautions could result in a serious shock. It could also result in a shock that might cause you to pull your hand quickly from the set, and in so doing cut yourself. You could also strike the picture tube with something and break it -- you could be seriously injured by the flying glass.

When you have to take voltage measurements in a receiver, you must, of course, have the receiver turned on. Voltage measurements can be taken in complete safety if you observe a few simple precautions. First, connect the common or "ground" lead of your vtvm to the common or grounded side of the power supply in the receiver while you have the receiver unplugged from the power line. In TV receivers that use tubes, the common or grounded side of the B supply will be B-. In transistor receivers, either B- or B+ may be the common or grounded side of the power supply, depending on the type of transistors used. After you have connected your meter to ground, turn the set on. After it has warmed up you are ready to take voltage measurements.

When taking voltage readings, do not touch the receiver chassis or any metal hardware on the chassis, or any grounded object such as a water pipe. It's a good idea not to touch the case of your vtvm if it is metal. Make sure your meter is on a voltage range considerably higher than the voltage you expect to measure to avoid the possibility of damaging the meter. You can always switch to a lower range later to get a more accurate reading. Don't try to measure dc voltage in circuits where high-level pulses are present, such as in the sweep output stages. You may damage your meter if you try to do so.

Finally, remember that to receive a shock you must provide a current path through your body. You can reduce the chances of providing such a path by using only one hand in taking voltage measurements. Keep the other hand in your pocket so you won't carelessly touch the chassis with it. There is no reason why you should ever get a shock from a TV receiver; if you do, you have failed to follow the safety rules.

Transformerless type TV receivers are a particular hazard because one side of the power line becomes the common side of the B supply, and it is usually connected directly to the chassis. You know that one side of the ac power line is grounded. Thus if the receiver power cord is plugged in in such a way that the "hot" or ungrounded side of the line is connected to the common or grounded side of the receiver power supply, all you have to do to receive a shock is touch the chassis and any ground at the same time. Often a basement floor will provide a very good ground.

The safest way to service transformerless sets is to use an isolation transformer between the set and the power line. An isolation transformer is simply a 1:1 transformer with no direct connection between the primary and secondary windings. This will eliminate the danger of being shocked by touching the chassis and a ground. Any TV/radio technician should have an isolation transformer for use in transformerless sets.

If you are just getting started in service work and do not have an isolation transformer yet, plug the set in and turn it on. Use your ac voltmeter to measure the voltage between the chassis and ground. If you get a reading equal to the line voltage remove the power plug from the wall socket and reverse it. This should give you a zero reading and tell you the chassis is at ground potential. There is far less chance of getting a shock with the receiver chassis at ground potential.

Low-Voltage Power Supplies

The low-voltage power supply must supply the dc operating voltages required by the tubes or transistors in the television receiver. In addition, in a receiver using tubes, the low-voltage power supply must supply the low ac voltage to the tube heaters. You might at first think that the low-voltage power supply in transistor TV receivers would be simpler than those found in tube receivers, but this is not the case. Most of the transistors in the receiver will require comparatively low operating voltages, but the sweep output transistors and the video amplifiers will require fairly high operating voltages. The widely different voltage requirements complicate the low-voltage power supply.

Just as in radio receivers that operate from the power line, there are two main types of low-voltage power supplies: the transformer type and the transformerless type. Both of these are very similar to their radio receiver counterparts, but you will find that the larger number of tubes or transistors used in the television set makes some increased demands on the low-voltage supply, requiring the use of larger components, and sometimes somewhat different circuits.

TRANSFORMER-TYPE

The basic full-wave rectifier circuits shown in Fig. 1 will refresh your memory of conventional transformer type power supplies. The main difference between this basic power supply and those used in television receivers is that in the television receiver there is apt to be more of everything. The large number of stages in the television receiver requires a heavy duty rectifier to supply sufficient plate current. Because of the high current range and the necessity of good decoupling in the television receiver, more filter capacitors of higher capacity will be used. The different stages in the television set may require a number of different operating voltages. Therefore, there may be more taps on the voltage divider across the output of the power supply.

Often in TV receivers using vacuum tubes filament windings of two different current ratings are used because of the large number of tube heaters to be supplied. In many of the older TV receivers you will find one 6.3-volt filament winding for the damper tube and another 6.3-volt filament winding for the heater of the

Fig. 1. Full-wave transformer type power supplies.

Fig. 2. Typical transformer-type low-voltage power supply.

other tubes, in addition to the 5-volt winding which supplies the rectifier filament. Transistor power supplies may have additional taps on the transformer. One set of taps steps up the voltage for the sweep output and video output stage; the other set steps down the voltage for the remaining stages.

Let's examine some typical low-voltage power supplies. We'll start with the older types that were used

for many years. Even though the new receivers use a somewhat different circuit, there are many receivers still in operation today that use these older circuits. A typical low-voltage power supply used in the older TV receivers is shown in Fig. 2. Note that one plate of each rectifier tube is connected in parallel with the corresponding plate of the other tube. The same current-carrying capacity could be achieved by con-

Fig. 3. Simplified circuit of a low-voltage power supply producing both positive and negative voltages.

Remember that the voltage applied between any two elements of a stage is equal to the voltage difference between the elements. Fig. 4 shows how a vacuum tube may operate with all of the dc voltages to its various elements negative with respect to ground. It is not uncommon to find an arrangement of this sort in some of the older TV receivers, particularly when a two-stage, direct-coupled video amplifier is used. If the stage shown in Fig. 4 required a plate potential of 335 volts, it would be possible to obtain this from a power supply of the type illustrated in Fig. 3. With the -120-volt tap attached to the cathode, and the +215-volt tap attached to the plate, there would be a difference of potential between cathode and plate of 335 volts, utilizing the complete voltage output of the power supply shown in Fig. 3.

The weak link in power supplies using a rectifier tube is the tube itself. Not only do rectifier tubes burn out, but they also lose emission, resulting in a gradual degradation in the performance of the receiver. In addition, to handle the high current demand of a TV receiver, a rather husky filament is needed in the tube.

necting the two plates of each tube together and using each tube as a half-wave rectifier in a full-wave circuit; but in that case, if one tube failed, we would get half-wave rectification and greatly reduced voltage output. With the arrangement shown, if one tube fails, the other tube is somewhat overloaded, but operation is not greatly impaired until both tubes fail.

In addition to the 40-mfd and 50-mfd input filter capacitor and the 90-mfd output filter capacitor in the filter network, there are relatively high capacities shunting the various resistors in the voltage divider. These provide additional filtering action.

Some of the older television receivers have low-voltage power supplies that produce negative as well as positive voltages. A simplified circuit of such a power supply is shown in Fig. 3. Note that the overall voltage output of this supply is about the same as the one shown in Fig. 2, but its maximum voltage to ground is 215 volts. This enables the manufacturer to make some savings on components such as bypass and decoupling capacitors, that must be connected from B+ to ground, because their working voltage need not be as high as it would be if the negative side of the power supply output were connected to ground, making the positive side 335 volts. However, the full 335 volts may be utilized where necessary.

Fig. 4. This tube will conduct with negative voltages applied to all its elements, because the plate is positive with respect to the cathode, and the grid is only 5 volts negative with respect to the cathode.

This means that considerable power is needed to heat the filament. This power must be supplied by the power transformer, which increases the cost of the transformer. Also, the large amount of heat given off by the tube, because it has such a large heater, often causes the premature failure of other parts in the TV set.

Some manufacturers dispensed with the rectifier tube by switching to selenium rectifiers, particularly
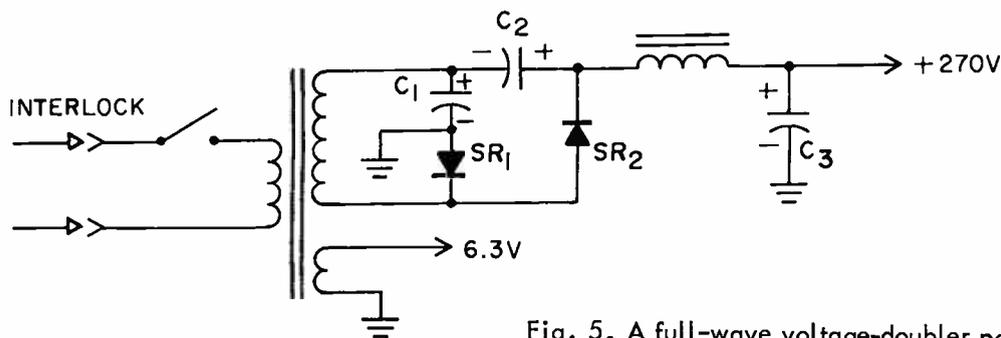
Fig. 5. A full-wave voltage-doubler power supply.
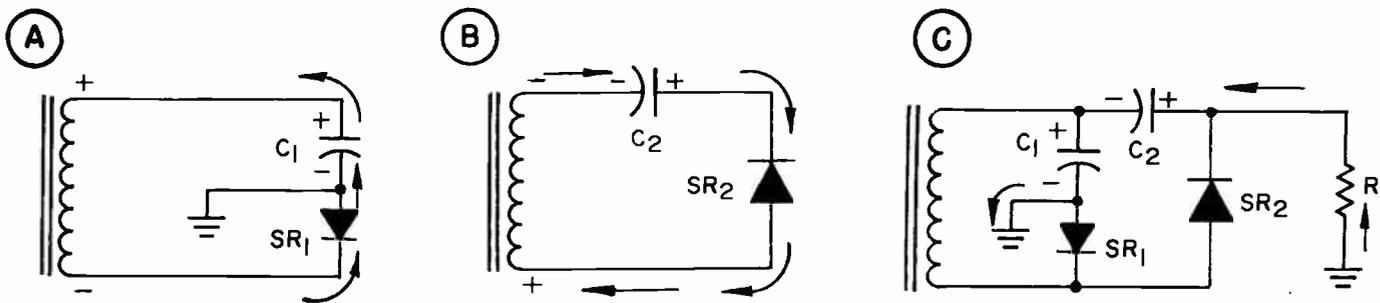
Fig. 6. Operation of the power supply shown in Fig. 5.

in smaller, low-cost sets. However, not all manufacturers used selenium rectifiers; generally they were not too much of an improvement over rectifier tubes. Eventually, low-cost, highly reliable silicon rectifiers were developed. All late model receivers use silicon rectifiers. These rectifiers are very small, give off little or no heat, and, unless they are subjected to an overload, will last indefinitely.

The schematic of a modern TV receiver power supply is shown in Fig. 5. This circuit uses two silicon rectifiers in a full-wave voltage doubler circuit. The operation of this power supply can be seen in Fig. 6. When the polarity of the voltage across the high-voltage secondary is as shown at A, electrons flow through SR_1 in the direction shown into the negative plate of C_1. Electrons flow out of the positive plate of C_1 to the power transformer.

During the next half-cycle, when the transformer voltage reverses polarity, current flows as shown at B. Electrons flow from the transformer into the negative plate of C_2. Electrons flow out of the positive plate of C_2, through SR_2 to the other side of the transformer.

In Fig. 6C, you can see that C_1 and C_2 are in series. The charge on each capacitor will be close to the peak voltage supplied by the transformer secondary. The two capacitors in series act as the dc voltage source

for the receiver. Electrons leave the negative side of C_1, and flow to ground and from there to the cathode of the various tubes in the receiver. The tubes are represented as R in Fig. 6C. Electrons flow through R, then through the filter network in the power supply, and back to the positive side of C_2. This will force some electrons from the negative side of C_2 to the positive side of C_1. The capacitors will soon discharge, but with each cycle they receive a pulse through the rectifiers to keep them charged.

A schematic diagram of the low-voltage power supply of a modern color TV receiver is shown in Fig. 7. There is not too much difference between this power supply and the one shown in Fig. 5, although at first glance they may look somewhat different. The big difference is simply in the way the schematic is drawn.

During one half-cycle when the upper end of the transformer high-voltage winding is negative, electrons flow through SR_1 into the negative plate of C_3 and out of the positive plate to the transformer, charging C_3 as shown. During the next half-cycle electrons flow through SR_2, charging C_4 as shown. C_3 and C_4 are connected in series to ground as the two capacitors were in Fig. 5.

C_1 and C_2 are simply small capacitors used to keep noise pulses out of the power supply. S_1 is the on-off switch; S_2 is a safety interlock. S_3 is a heat-operated
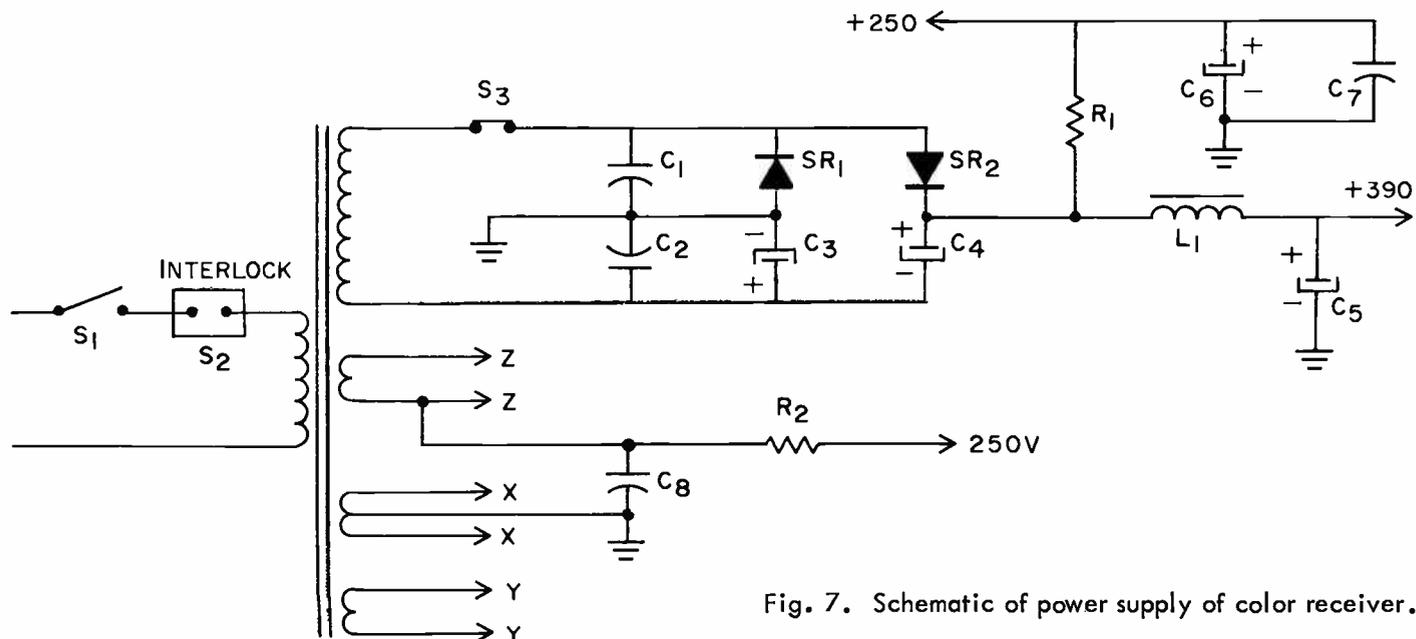
Fig. 7. Schematic of power supply of color receiver.

switch which opens if it becomes too hot. Notice that two output voltages are taken off. One is taken through L_1 to provide 390 volts, the other is taken through R_1 to provide 250 volts. C_5 and C_6 are filter capacitors; C_7 is used to provide a good rf bypass across C_6.

Notice the three separate filament windings on the power transformer. The one labelled ZZ provides the heater voltage for the tricolor tube. It is connected to the 250-volt B supply to keep the cathode-to-heater voltage on the picture tube low. The cathodes are directly coupled to the plate of the video amplifier tube and so operate at a high positive potential. By also operating the heater at a high positive potential, the chances of a cathode-to-heater short are reduced.

Heater Voltage.

The winding marked YY supplies the heater voltage for the damper tube and the shunt regulator. You'll see later in this lesson that the cathodes of these tubes are at a high positive potential. If the tube heaters were operated from a grounded heater winding, the high cathode-to-heater voltage would shorten tube life.

The winding marked XX is the high-current winding. It supplies heater current for all the other tubes in the receiver. Notice that the winding is center-tapped, and that the center tap is grounded. In most receivers, one side of the heater circuit is grounded and the center tap on the filament winding is emitted.

We mentioned previously that the low-voltage power supply found in transistor receivers is often more complex than those found in tube-type receivers. In Fig. 8 we have shown a schematic diagram of a low-voltage power supply from a monochrome transistor TV receiver. Notice that there are several windings on the power transformer T_1. First, look at the primary

winding; you'll see that it is connected to the 120-volt ac power line. The switch marked SW_1 is the on-off switch. The circuit breaker, marked CB_1 on the diagram, is designed to open if the primary current exceeds a certain value. Thus if a short develops in the receiver and causes excessive transformer current, the circuit breaker will open and protect the power transformer and any other components in the receiver that may be overloaded.

In looking at the secondary windings, first notice that there is a filament winding on the power transformer. This filament winding supplies the voltage to operate the picture tube.

Next, notice that there is a full-wave rectifier circuit using diodes D_2 and D_3. A portion of the transformer winding has a center tap and the two diodes are used in a conventional full-wave rectifier circuit like the one shown in Fig. 1B. The input filter capacitor is C_3 and the output filter capacitor C_4. The choke coil, L_1, makes up the other part of the filter network.

In transistor power supplies the electrolytic capacitors will frequently have a much higher capacity than in vacuum-tube supplies. The reason for this is that the transistors in the receiver operate at low voltages, but have considerably higher currents than the equivalent vacuum tubes. Therefore, the capacitors must be larger in order to keep the supply voltage constant with the higher current drain. In the circuit shown in Fig. 8, the input capacitor C_3 has a capacity of 500 mfd, and the output filter capacitor C_4 has a capacity of 1000 mfd.

Full-Wave Power Supply.

Notice that the output from the full-wave power supply is 38 volts. Also notice that lower voltages are obtained by means of the voltage-divider network consisting of resistors R_2, R_3, R_4 and R_5. The voltage drop across these resistors is due to the current flowing through the entire network, and also the current taken off at the various taps. In the circuit shown, the 38-volt tap is used to operate the vertical oscillator and the vertical output transistors. This tap is connected to the emitter and base circuits of these transistors; the collector is grounded – the transistors are PNP transistors. The 38-volt tap also connects to the collector of the horizontal oscillator which is an NPN transistor. The 34-volt tap provides power for the horizontal output stage, and the 32-volt tap provides the voltage for the sync separator. The 12-volt tap provides the operating voltages for the tuner, the video i-f and sound stages.

Notice that the power transformer has an additional winding that connects to the diode of D_1. The voltage between the center tap on the lower winding and the voltage from the additional winding are rectified by D_1 to obtain an output voltage of 135 volts. This voltage is used by the video output stage and also by the focus electrode on the picture tube. A power supply made up of D_1 and the associated filter network is a half-wave rectifier circuit.

The low-voltage power supply from another transistor TV receiver is shown in Fig. 9. In this power supply we have two full-wave rectifier circuits plus a half-wave rectifier circuit.
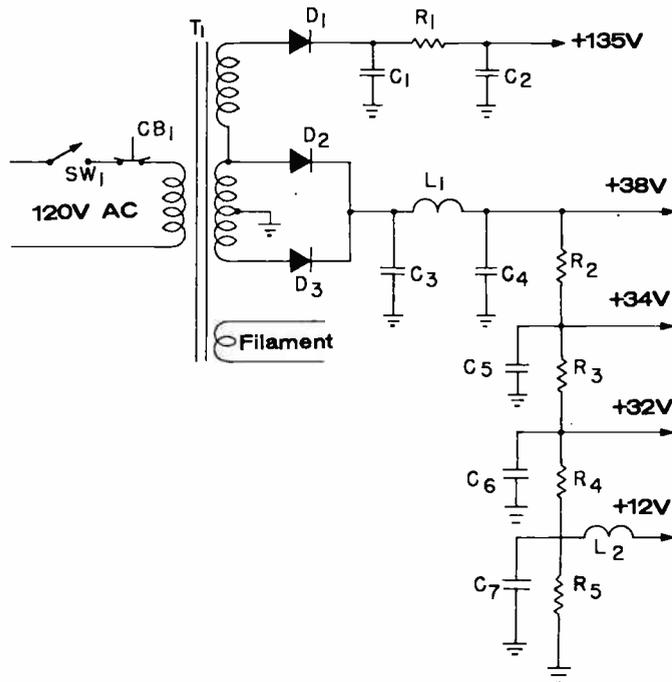
Fig. 8. The low-voltage power supply from a transistor television receiver.
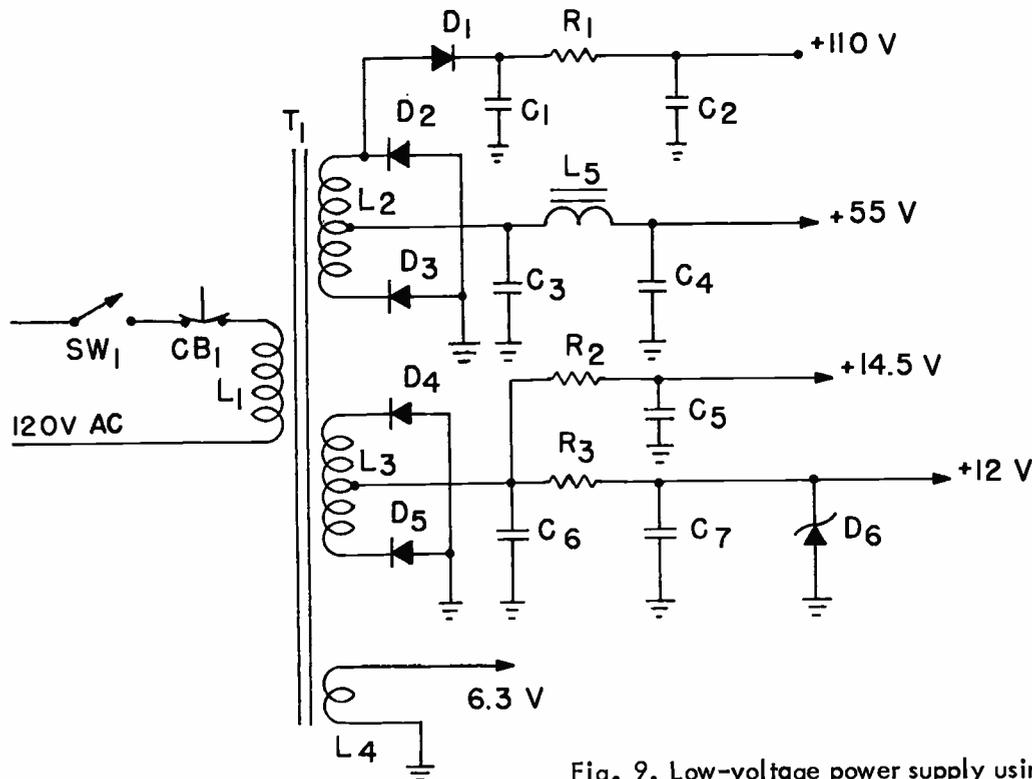
Fig. 9. Low-voltage power supply using two full-wave rectifier circuits plus one half-wave rectifier circuit.

We have labelled each winding on the power transformer separately in order to make it easier to identify. You'll notice that L_1 is the primary winding, and it connects to the power line through the on-off switch and the protective circuit breaker. L_4 is the 6.3-volt filament winding that supplies the operating voltage for the picture tube.

Winding L_3 is center-tapped and used in a conventional full-wave rectifier circuit. When the upper end of L_3 is positive, the lower end is negative. Electrons can flow from the lower end through the diode D_5 to ground, and then through the load and back to the center tap through either R_2 or R_3. When the upper end of the transformer winding is negative, electrons can flow through D_4 to ground, through the load and the resistors back to the center tap of L_3.

Zener Diodes.

Notice that in the 12-volt output we have a diode labelled D_6. This is a zener diode. A zener diode is a diode that is manufactured in a special way so that it breaks down at a certain reverse voltage. This diode is designed to break down at a reverse voltage of 12 volts. If the voltage tends to rise above 12 volts, current will flow through the diode. This will increase the voltage drop across R_3 and tend to maintain the output voltage constant. If the voltage across D_6 tends to rise still further, the current passing through it increases, thereby increasing the voltage drop across R_3 to help maintain the output voltage constant at 12 volts.

The 14.5 volts obtained from this winding are obtained simply by using a smaller value for R_2. In addition, the current taken off through this resistor is somewhat lower than the current drawn through

R_3. As a result, the voltage drop across R_2 will be less than the voltage drop across R_3, and therefore the voltage output across C_5 will be higher than the voltage output across C_7.

The second full-wave power supply is made up of the diodes D_2 and D_3 connected across the transformer winding L_2. During one half-cycle current flows through D_3 to ground, through the load and through L_5 to the center tap of L_2. During the next half-cycle current flows through D_2 to ground, through the load and L_5 back to the center tap of L_2.

In the half-wave circuit two diodes are used. When the upper end of the transformer winding L_2 is positive and the lower end negative, electrons will leave the lower end of L_2 and flow through D_3 to ground. They will flow through the lead, through the filter resistor R_1 and through D_1 back to the upper end of the transformer. Thus the full voltage of L_2 is used in developing this voltage, and we get twice the voltage we do from the full-wave rectifier, where only one-half is used at a time.

When the polarity of the voltage reverses, so that the upper end of the transformer is negative and the lower end is positive, current cannot flow through D_1 or D_3, and therefore there is no current supplied to the 110-volt supply during this half-cycle. Thus we have one pulse each cycle: in other words, we have a half-wave power supply.

Another power supply for a transistor receiver is shown in Fig. 10. This power supply is designed for use in a receiver that can be operated either from a 12-volt battery or from the power line. The power supply is regulated in order to maintain the output voltage constant at 12 volts.
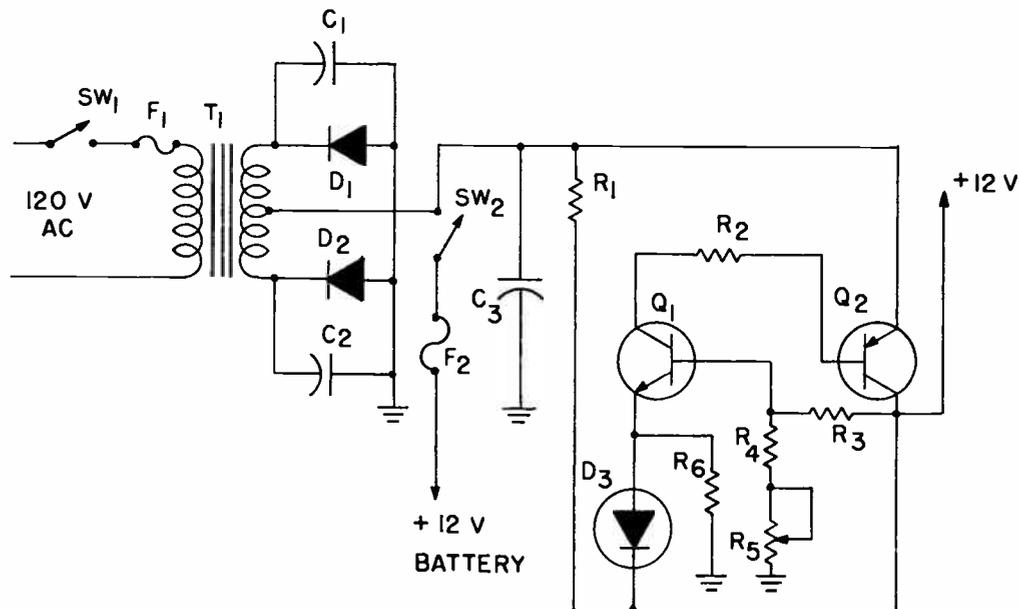
Fig. 10. A regulated transistor power supply.

In the ac operating condition, the primary winding of T_1 is plugged into the power line. The primary circuit is completed through the on-off switch, SW_1, and the fuse F_1. The fuse is put in the primary circuit to provide overload protection.

The secondary of the transformer is center-tapped and used in a full-wave rectifier circuit. When the upper end of the secondary winding is negative, D_1 will conduct; when the lower end is negative, D_2 will conduct. The power supply is designed so that the output voltage from the rectifiers (after it has been filtered by the input filter capacitor C_3) is slightly higher than the voltage from a 12-volt storage battery. Therefore, switch SW_2 can be closed when the set is operated from the power line and the storage battery recharged. With SW_2 closed and the set unplugged from the power line, the receiver operates from the battery.

The remainder of the components in this circuit are used to regulate the output voltage so that it will remain constant at 12 volts. Regulation is necessary; otherwise, the output voltage would be somewhat higher when the receiver is operated from the power line than it would be when it is operated from the storage battery.

The operation of the circuit is comparatively straightforward. In operation, the PNP transistor Q_2 acts more or less as a variable resistor. The NPN transistor Q_1 controls the resistance of Q_2 by adjusting the forward bias across Q_2 if the output voltage changes.

Notice that the voltage divider made up of R_3, R_4 and R_5 sets the base voltage on Q_1. R_5 is adjustable so that the base voltage on Q_1 can be adjusted to give the correct output voltage from the power supply. If there is any change in the output voltage, there will be a proportional change in the voltage on the base of the transistor.

The emitter of Q_1 is connected to the junction of the zener diode, D_3 and R_6. The zener diode and the

resistor form a voltage-divider network, but the voltage drop across the diode will remain constant at 6.3 volts. Therefore, if there is any change in the output voltage, the full change will be felt on the emitter of the transistor Q_1. Thus if the output voltage increases, the positive voltage on the emitter of Q_1 will increase by an amount equal to the increase in the output voltage. However, the voltage on the base of Q_1 will increase, but it will not increase by an amount equal to the full increase of the output voltage.

DIVIDER NETWORK

The increased voltage is divided by the divider network. Therefore, if the power supply output voltage increases, the forward bias across the emitter-base junction of Q_1 will be reduced. This will cause the current flowing through the transistor to go down. If the current flowing through the transistor goes down, the current flowing through R_2 and across the emitter-base junction of Q_2 will decrease. This will reduce the forward bias across the emitter-base junction of Q_2 and tend to increase the resistance of the transistor, and hence hold the output voltage constant.

If the opposite occurs and the output voltage tends to drop, then the entire drop will be felt on the emitter of Q_1, but only a portion of the drop at the base. This will increase the forward bias across the emitter-base junction, causing a higher current to flow through the transistor and through R_2. A greater voltage drop across R_2 will increase the forward bias across Q_2, which in turn will reduce the resistance of the transistor; this will tend to hold the output voltage constant.

In a portable receiver, which is designed to operate from a comparatively low voltage and which must operate from either the power line or from a battery, changes in the B supply voltage can cause a considerable change in the receiver performance. If the power supply voltage tends to increase this could

cause excessive sweep, which in turn might cause excessive current through the sweep transistors and damage these transistors. Similarly, if the voltage should drop, the picture may be narrower than it should be, hence the need for the regulated power supply.

The schematic diagram of the power supply from a transistor color TV receiver is shown in Fig. 11. At first glance this power supply looks quite complex, but actually it is merely made up of a number of circuits similar to the circuits you have already studied. Let us start at the line cord and examine the power supply in detail.

RFC Choke Coils.

First, we notice that in the primary input circuit there are two choke coils marked RFC; connected across the power line is a .15 mfd capacitor. The choke coils and the capacitor are an rf filter. They keep noise from the power line from getting into the receiver, and also they keep signals generated in the receiver from getting back into the power line. The Federal Communications Commission has imposed regulations on radiation from television receivers. One of the most common sources of radiation is signals from the receiver getting back into the power line. The capacitor and filter choke are designed to prevent this from happening. You'll find filter networks of this type in many receivers.

Next, notice the circuit breaker labelled J1-6. The circuit breaker is in the circuit to open in the event of a defect in the receiver that results in the receiver drawing excessive current.

If you trace the circuit from the circuit breaker, you come to a circuit that goes up to the filament transformer labelled T2J. Notice that the circuit goes from one side of the power line, through the circuit breaker, through the primary winding of the CRT filament transformer, and through the quick-on defeat switch, through the 770-ohm resistor and back to the other

side of the power line. With the circuit as shown, the primary of the filament transformer is always connected to the power line. Even though the primary is connected through the 770-ohm resistor, a certain current flows through the primary winding which will result in a voltage being induced in the secondary.

Although the voltage in the secondary winding will not be the full 6.3 volts required to bring the tube up to its full operating temperature, the current flowing will keep the cathodes of the tricolor tube warm. When the receiver is turned on by the line switch and the 770-ohm resistor shorted out of the circuit, full input voltage is applied to the primary of the transformer, and the cathodes of the tube will reach operating temperature very quickly. This quick-on feature can be defeated by opening the quick-on switch; then the transformer primary circuit will be open and power will not be applied to the transformer when the line switch is closed.

When the line switch is closed, the 120-volt ac power line is connected to the primary winding in the main power transformer, T1J. Current flows through the primary winding of the transformer and through the degaussing coils back to the other side of the power line. The thermistor labelled T is in parallel with the degaussing coils, but the thermistor has a high resistance when it is cold. When the receiver is first turned on the thermistor will be cold, and therefore most of the current will flow through the degaussing coil. In a short while the thermistor will begin to heat. Its resistance will drop and the current flow through it will increase; at the same time the current flowing through the degaussing coils will decrease.

Thermal-Generated Switch.

Notice the switch marked DG SW. This is a thermal-operated switch. Beside the switch there is a resistor which connects to the 6.3-volt filament winding on the power transformer. The purpose of this switch is to
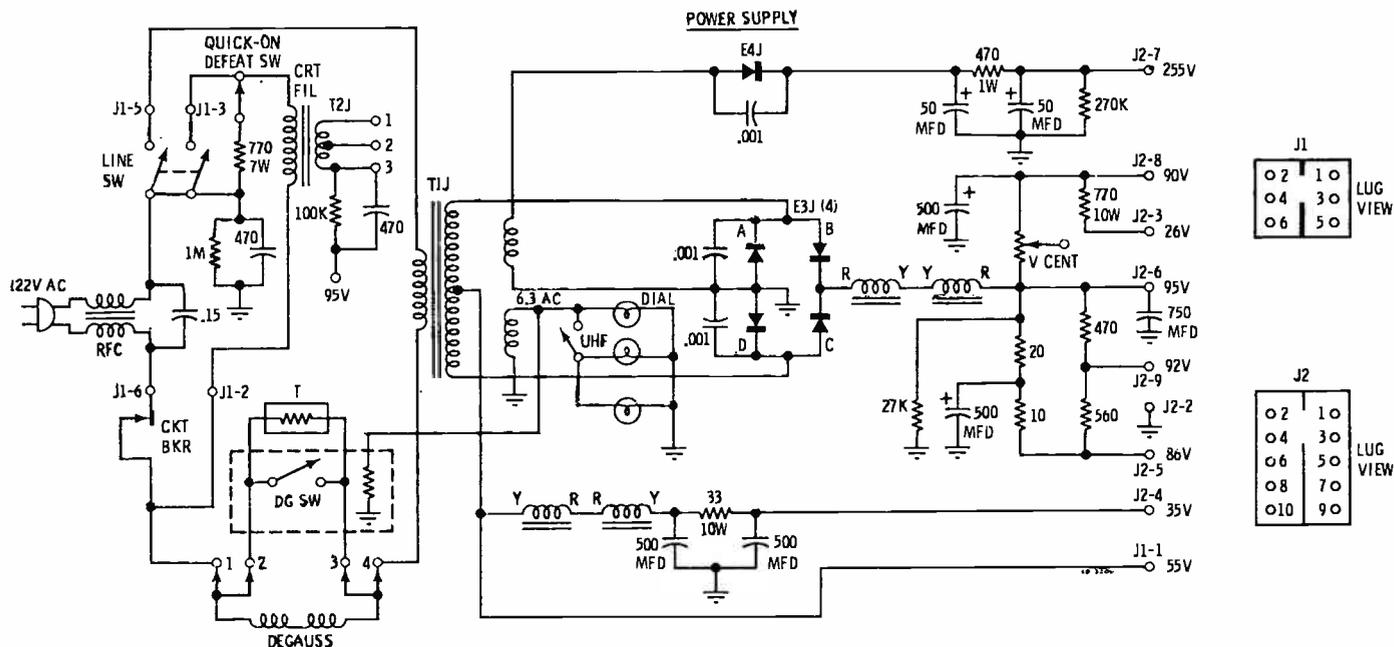
Fig. 11. Low-voltage power supply from transistor color receiver.

short out the degaussing coil. The 6.3 volts from the filament winding will cause a current to flow through this resistor which will heat the resistor. Eventually the heat will cause the switch to close, shorting out the degaussing coils and the thermistor.

The purpose of the degaussing coils is to eliminate any magnetism that may have built up on the face of the picture tube. The ac current flowing through the coils will be quite strong at first and will gradually decrease as the thermistor heats and its resistance drops. Thus we have a strong magnetic field that is continually reversing, as the power line reverses; the field gradually goes down until it eventually is eliminated completely when the degaussing switch closes. This normally will eliminate any small amount of magnetism picked up by the tube, or any purity problems encountered due to the fact that the receiver may have been moved.

Continuing with the 6.3-volt ac winding on the main power transformer, you'll notice that winding also operates a pilot light; also when the receiver is in the uhf position two additional pilot lights operate.

The main secondary winding on the transformer is center-tapped. Notice there are four silicon rectifiers in a bridge-rectifier circuit. When the bridge-rectifier circuit is used, consider what happens when the upper end of the secondary winding is positive and the lower end is negative. Electrons will flow from the lower end of the winding to the rectifier marked D to ground, through the load and back to one of the high-voltage terminals marked J2-8, J2-3, J2-6, J2-9 or J2-5. Current will then flow from there through the resistor networks, the filter chokes and then through the silicon rectifier marked B to the top of the secondary winding.

BRIDGE RECTIFIER CIRCUITS

When the polarity of the transformer secondary reverses, electrons will flow from the top of the winding through the rectifier marked A to ground, through the load to the voltage divider network terminals and then through the choke coils and the diode C to the lower end of the transformer. Thus we have a bridge-rectifier circuit in which we take advantage of the full secondary voltage.

In addition to the bridge-rectifier circuit, we also have a circuit in which the transformer voltage is used in a full-wave rectifier circuit. When this circuit is in use, if the upper end of the transformer is negative, current flows in the upper winding through the rectifier A to ground and then from ground through the load to either the terminal J2-4 or J1-1 and then back to the center tap of the transformer.

During the next half-cycle, when the lower end of the transformer is negative, current will flow from the lower end through the diode D to ground, through the load and then back to the center tap on the transformer. Thus we have two supplies actually working off the one winding on the rectifier tube. One is a conventional full-wave rectifier circuit using two diodes and the center-tapped winding where the applied ac voltage is the voltage across one-half of the secondary winding. The other is a full-wave bridge rectifier

where the full voltage from the secondary winding is used.

TRANSFORMER SECONDARY WINDINGS

In addition to the two output voltages already discussed, we also have an additional secondary winding on the transformer. In the schematic diagram this winding is shown above the 6.3-volt ac winding. This is a high-voltage winding and is used to provide the dc required by the video-output stage. Notice that one side of the winding is connected directly to ground (the winding is used in a half-wave rectifier circuit). In operation, when the lower end of this winding is negative, current will flow from the lower end to ground, through the load back to the 255-volt terminal, through the 470-ohm resistor and through the diode marked E4J back to the upper terminal of the winding. When the polarity of the winding reverses, current cannot flow through the diode and therefore there will be no current flow in the circuit.

Most of the receiver operates from the +35-volt dc line. Notice that a choke-input filter is used in this circuit to provide good regulation and to eliminate the need of any separate regulating circuit.

The capacitors shown across the various diodes in this power supply and in some of the supplies described earlier are used to eliminate surges across the silicon rectifiers and prevent interference.

The power supply shown in Fig. 11 is about as complex as any you are likely to encounter. Even though the power supply has a number of different output voltages, it is basically a simple power supply made up of a number of different simple power supply circuits that are put together to provide the various operating voltages required in the receiver. At first glance, the circuit looks very complicated, but if you take the circuits one at a time and trace them out you'll soon discover that they are not as complicated as they might at first appear.

TV receivers without power transformers have been manufactured for many years. Not only is there a saving in the cost of the receiver by eliminating the power transformer, but also there is a saving in space and weight.

TRANSFORMERLESS-TYPE
POWER SUPPLIES

The first transformerless low-voltage power supplies for television receivers were similar to their radio counterparts in principle only. In actual practice, they were considerably different from the average ac-dc radio receiver power supplies. You will recall that the transformerless radio receiver usually has a very simple filament string; the tube filaments are all connected in series across the 120-volt line. The large number of tubes used in a television set prevented such a simple arrangement when the transformerless power supply for television was first conceived; suitable tubes for transformerless TV receivers had not been developed. Early receivers made use of tubes that had been developed for use in TV sets
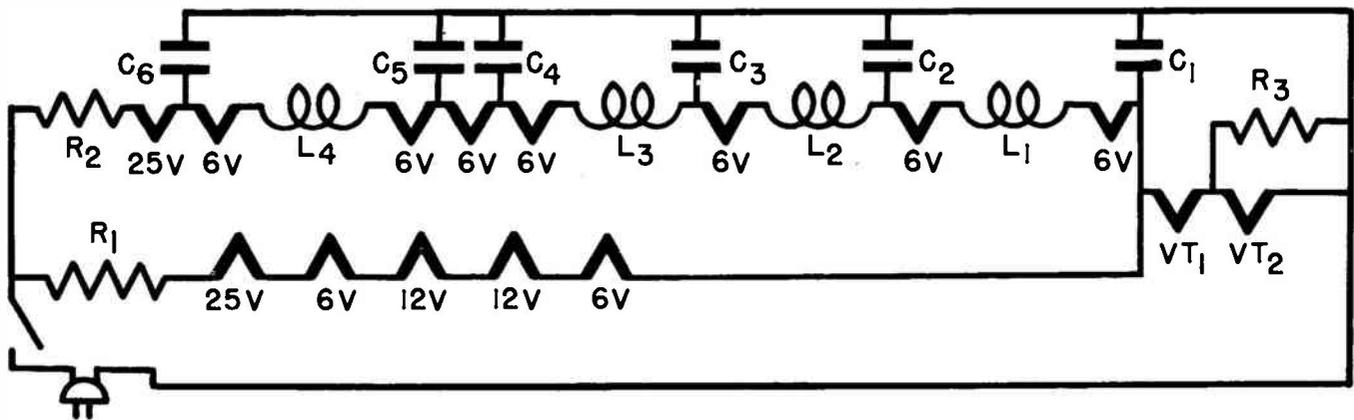
Fig 12. A series-parallel filament circuit typical of circuits used before development of special tube types for series connections.

with power transformers, along with tubes that had been developed for use in ac-dc radio receivers. However, now there are all kinds of tubes available for transformerless TV receivers, so the heater circuit in modern sets is simpler and more reliable than those used in the first transformerless TV sets.

In the first transformerless TV receivers the plate voltage requirement of the television circuits exceeded the voltage available from the simple half-wave rectifier circuit generally used in ac-dc radios. Therefore, some form of voltage multiplier that did not require a transformer was used for the plate supply circuit of the transformerless power supply. We will discuss this later in this lesson.

Filament Supply.

A typical filament supply used in the first transformerless TV sets is shown in Fig. 12. Here, five tubes in series with R_1 form one string, and eight tubes plus R_2 form another. These two series strings both pass current through tubes VT_1 and VT_2. Tube VT_1 has a current rating twice that of any tube in the series strings so that it can carry both currents. Tube VT_2 does not have as high a current rating, so it is shunted by resistor R_3, which carries the extra current.

The resistors R_1 and R_2 reduce the supply voltage to the amount required by each series string. They also usually have a ballast action to protect the tubes when the set is first turned on. The tube filaments have low resistance when cold, so a high current could flow through them until they warmed up if these resistors were not used, and the lives of the tubes would be shortened. To prevent this, the series resistors used are usually either ballast tubes or special "Globar" resistors made so that their resistances decrease as they get warm. The cold resistance of these resistors is high enough to limit the starting current to a safe value; then, as the tubes warm up, the resistance of the ballast resistors decreases enough to permit the filaments to get the proper currents. If they burn out, it is important to replace them with exact duplicates.

The bypass capacitors and rf choke coils shown act as filters on the rf and i-f tube filaments to prevent stray coupling between stages along the filament leads.

When the first transformerless TV receivers appeared, most of the tubes that had been developed for

use in TV had 6.3-volt heaters. The current requirements of the tubes varied. The tubes in the tuner, the video i-f amplifier, and sound i-f, as well as most horizontal and vertical oscillator tubes, operated on a heater current of .3 amps. The sound output tube usually required a somewhat higher heater current, usually around .5 amps, whereas the sweep output tubes along with the damper tube often required a heater current of over 1 amp.

To build transformerless TV sets with a single heater string, tubes that operated with the same heater current were required. In addition, the heater voltage of the tubes in series had to be close to the line voltage. At that time the current requirement of the picture tubes was .6 amps, so this value of current was chosen as standard for series-connected TV tubes. Since .6 amps is equal to 600 milliamperes, these tubes are usually called 600-mil tubes.

Filament Circuit With 600-Mil Tubes.

A filament circuit using 600-mil tubes is shown in Fig. 13. Many of the tubes in this series string are 6.3-volt tubes redesigned with a different heater to permit their operation in a 600-mil string. Except for their heater ratings, these tubes are the same as the equivalent 6-volt tubes. That is, the 3CB6 is the same as a 6CB6, and a 3BC5 is the same as a 6BC5; the 12AX4 is the same as the 6AX4 and the 12CU6 is the same as the 6CU6, etc. Also note that the choke coils and capacitors are still necessary in the rf and i-f tube filament circuits to prevent coupling between these stages, and a low-resistance ballast resistor is still required in series with the filaments.

While the heater circuit in Fig. 13 was much better than the one in Fig. 8, it still was not too satisfactory. It is true that the tubes all required the same heater current and after they had all reached operating temperature would have the correct heater voltage. However, the tubes didn't all reach operating temperature at the same time. As a result, some of the tubes that required a relatively small heater power, such as the 3CB6 or 3BC5, heated much faster than tubes such as the 12L6 or 12BH7. The result was that the heater resistance of the low-voltage tubes rose faster than the resistance of the high-voltage tubes. Therefore, during the warm-up period, the heater voltage of tubes such as the 3CB6 or 3BC5 would go substantially higher than
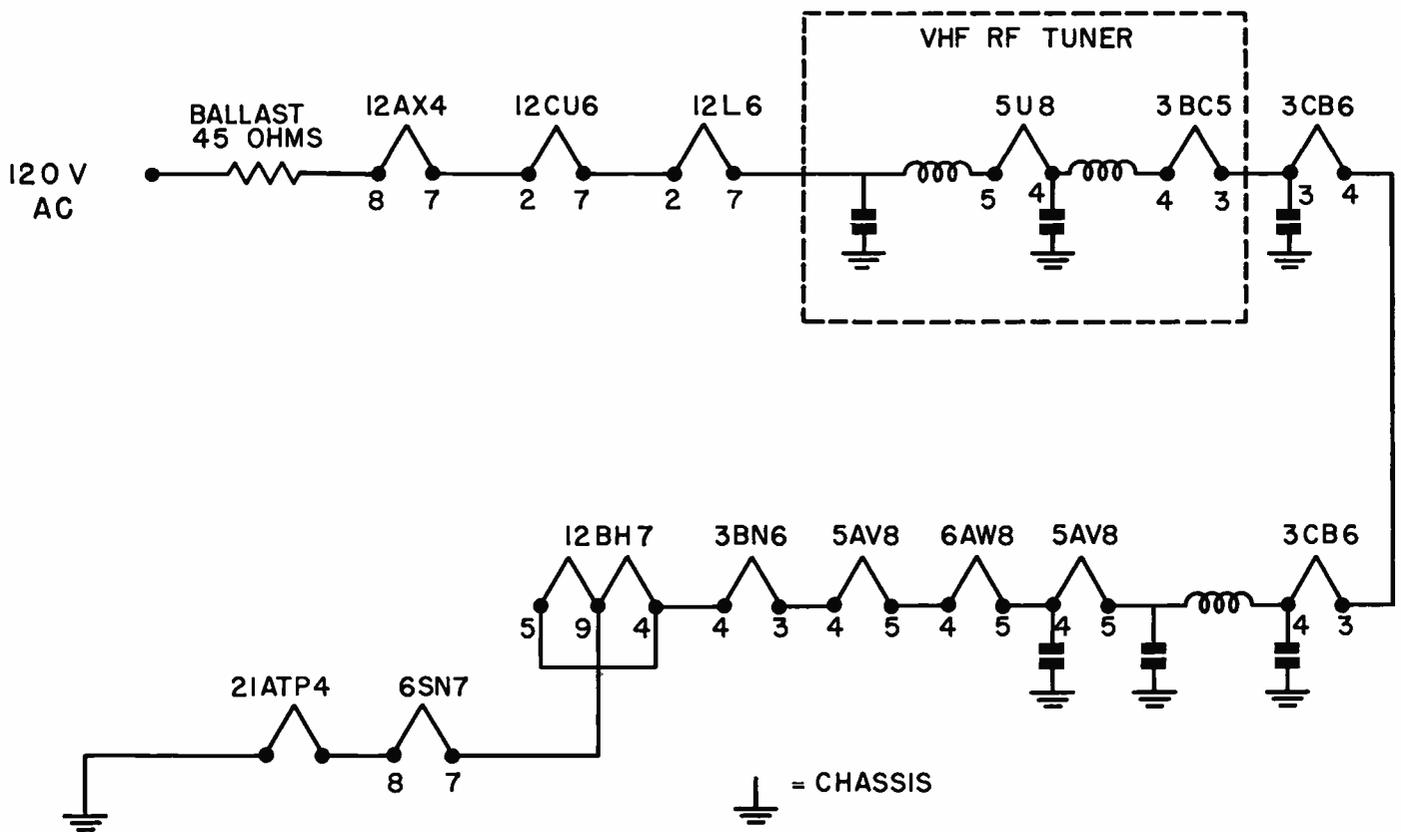
Fig. 13. Series filament string using tubes designed specifically for this type of operation.

the rated value of 3.15 volts, sometimes as high as 6 volts or more.

Needless to say, the tubes didn't last long under these conditions. The tube manufacturers had anticipated this problem so the heaters of tubes such as the 3BC5, 3BC6, 12AX4, which were originally 6.3-volt tubes, were designed with a controlled warm-up time of 11 seconds. These tubes all heated at the same time, but tubes such as the 6AW8, 12L6, 6SN7, and 12BH7 did not have a controlled warm-up time and these were the tubes that caused trouble. This trouble was soon

corrected by redesigning the tubes with a controlled warm-up heater.

Thus the 6AW8A is exactly the same as a 6AW8 except that its heater has a controlled heater warm-up period. If you have to replace a 6AW8 tube in a transformer-type set, you can use a 6AW8A; the chances are you cannot get a 6AW8 because all the 6AW8-type tubes manufactured today have a controlled heater warm-up period. Similarly, the 12BH7A has replaced the 12BH7, etc.

A later development in tube heaters is the .45-amp
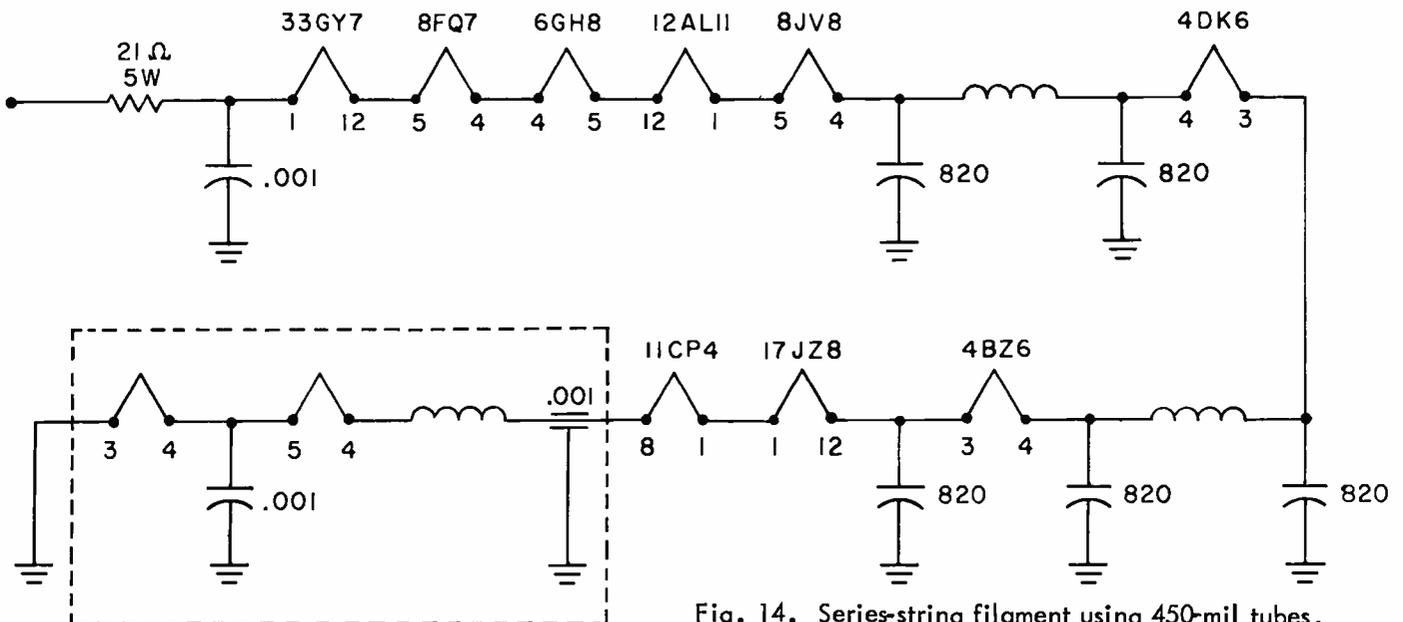
Fig. 14. Series-string filament using 450-mil tubes.
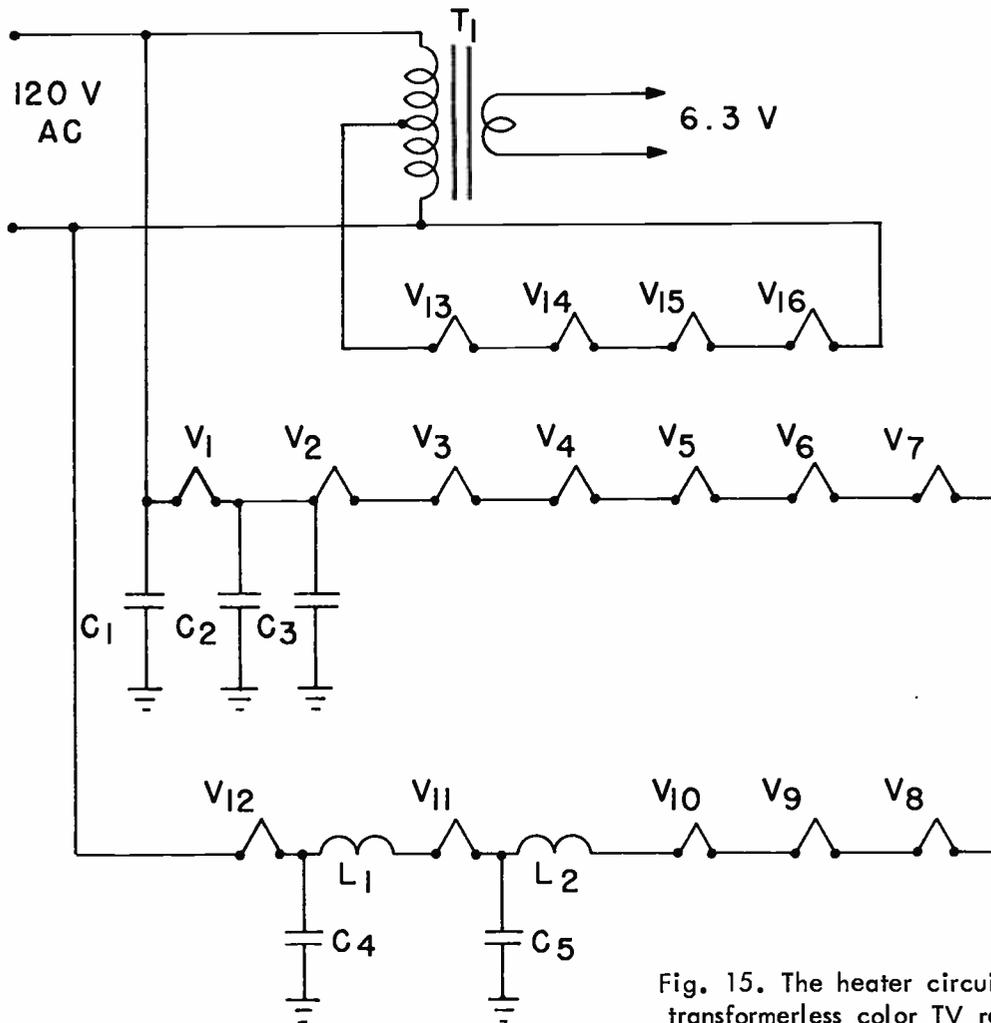
Fig. 15. The heater circuit from a transformerless color TV receiver.

or 450-mil heater. Most late-model transformerless sets use 450-mil tubes. The benefits are obvious: a 25% reduction in heater power which not only saves electricity, but more important, reduces the amount of heat generated inside the TV receiver cabinet. A series string filament using 450-mil tubes is shown in Fig. 14.

Notice that in Fig. 13 the picture tube is at the ground end of the heater string, whereas in Fig. 14 the tuner is at the ground end. In modern tuners, one end of the heater circuit is tied directly to ground inside of the tuner; therefore the tuner must be at the ground end of the string. After the tuner, the first tube is usually the picture tube to keep the potential between the picture tube heater and B- as low as possible.

When we speak of a transformerless TV receiver, what we are actually referring to is a TV receiver in which there is no power transformer used in the B supply. Sometimes there may be a power transformer used for some other purpose. An example of this type of arrangement is in the color TV receiver heater circuit shown in Fig. 15. Here we have two heater circuits like we had in the original transformerless TV receiver. The two heater circuits are needed because of the large number of tubes used in the set. The total heater voltage required by these tubes connected in series will be greater than the available power line voltage.

Looking at the circuit shown in Fig. 15, we see one heater string consisting of the tubes V_1 through V_{12} connected directly across the ac power line. All these tubes have the same heater current and the sum of the voltages required by these tubes is equal to the line voltage. Notice, also, that we have a number of bypass capacitors to prevent rf and video signals from traveling through the heater string from one tube to the other and also rf chokes located in the supply. The rf chokes have such a very low resistance that there is very little or no voltage drop across them.

Now, notice that we also have a transformer. This transformer has the primary connected directly across the power line. The primary is tapped so that it acts as an autotransformer. The total voltage required by the tubes V_{13} through V_{16} inclusive is less than the line voltage. Therefore, instead of using a dropping resistor in series with the tubes, we simply put a tap on the primary of the power transformer to provide the required voltage for these tubes. The tap could be located anywhere on the primary in a circuit of this type – the important thing is to locate it at a position where the correct voltage is obtained.

Notice also that the two heater strings are entirely independent. Therefore, the tubes in the heater string connected directly across the power line might have a different current rating than the tubes in the heater string operated across part of the primary of the power transformer. Of course, all tubes in string 1 (which is

200 MFD
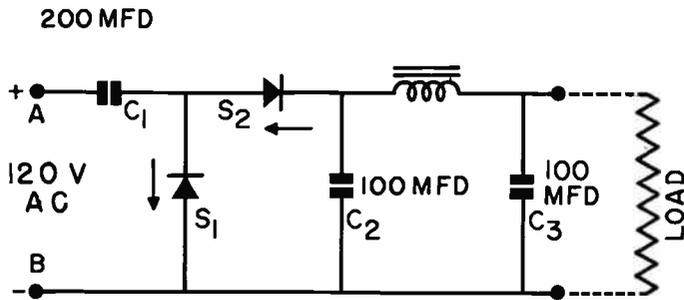
Fig. 16. A typical voltage-doubler circuit.

connected right across the power line) must have the same current rating and all tubes in the second string (which is connected across the auto transformer) must have the same current rating.

The additional advantage in using the filament transformer can be seen in the secondary winding, which provides 6.3 volts for the operation of the tricolor tube. Manufacturers are very reluctant to place tricolor tubes in a heater string because the heater requirements of the tubes are high and you have to shunt the other tubes in the string in order to pass the required current.

Even if a tricolor tube could be developed with a lower heater current, it is doubtful if it would be advisable to place it in a heater string because any defect in the string could burn out the heater in the tube. Since tricolor tubes are relatively expensive, it is worth the cost of the small filament transformer to provide the operating voltage for the tube and to provide a margin of protection for the tube.

In servicing transformerless TV receivers, you should not remove and insert any tubes in the set while the receiver is operating. It is particularly important that you do not remove a tube from an operating receiver and substitute a cold tube. This could upset the heater voltages throughout the set and burn out a tube. Also, it is not a good idea to repeatedly turn the
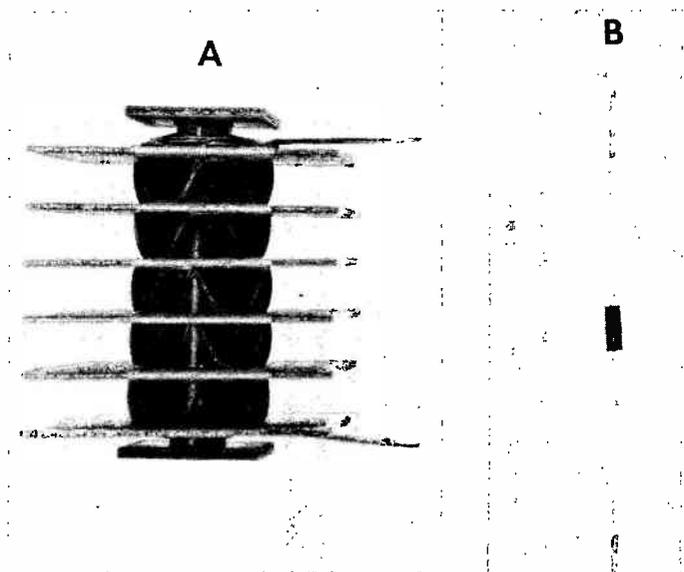
Fig. 17. Although much larger, the selenium rectifier (A) has much less current capacity than the silicon rectifier (B).

on-off switch on and off. This also can set up current surges that can cause trouble.

Plate Supply.

Since many transformerless TV receivers use tubes that were designed for use in transformer-type sets, they require operating voltages of 200 to 300 volts. The obvious solution to supplying a voltage somewhere between 200 and 300 volts to the plates of the various tubes is the use of a voltage-doubler circuit. Since one side of the power line must be connected to B- to provide the heater circuit, we cannot use a full-wave voltage doubler like the one in Fig. 5. Instead we use one like that shown in Fig. 16.

While a few sets that used this circuit were made using vacuum tube rectifiers, most use selenium rectifiers or silicon rectifiers. Selenium rectifiers consist of washers coated with selenium and selenium oxide. These rectifiers will conduct far better in one direction than in the other. Although not perfect rectifiers, they are satisfactory, and have at least one advantage over the conventional vacuum tube rectifier -- they require no filament voltage or current. A typical selenium rectifier is shown in Fig. 17A.
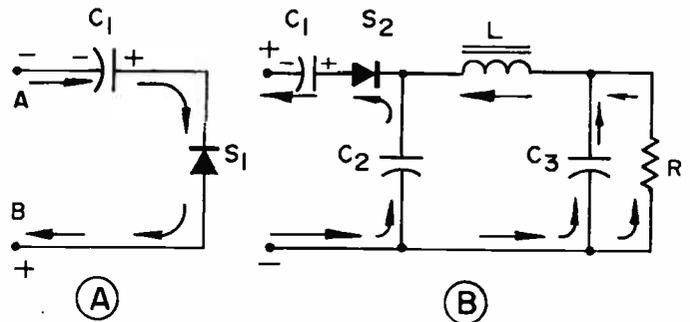
Fig. 18. In the half-wave doubler shown in Fig. 16, on the half-cycle (A) C_1 is charged; on the other half-cycle (B) the line voltage is in series with the voltage across C_1, charging C_2 and C_3 to almost twice the peak line voltage.

More modern TV receivers use silicon rectifiers instead of selenium rectifiers, as we mentioned earlier. The silicon rectifier, which is much smaller than the selenium rectifier, is a better rectifier because it offers almost no resistance at all to current flow in one direction and a very high resistance to current flow in the other direction. A typical silicon rectifier is shown in Fig. 17B.

The operation of the circuit shown in Fig. 16 can best be understood by studying Fig. 18. When the input voltage makes terminal B positive with respect to terminal A, S_1 will conduct in the direction indicated by the arrow beside it. Thus, electrons will be drawn away from the right hand plate of capacitor C_1, making that side of the capacitor positive. By the same token, electrons will collect on the left-hand plate of C_1, making it negative. Because S_1 will not conduct in the opposite direction, after a few cycles of input voltage have been applied, C_1 will be charged to the peak value of the sine wave voltage with the polarity indicated.

When the power line reverses polarity, there will be two voltages across S_1 -- the dc voltage equal to the peak value of the input sine wave, and the input
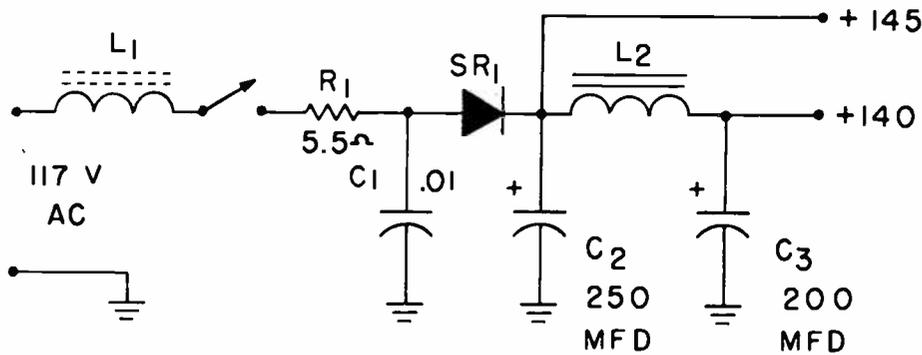
Fig. 19. Schematic diagram of a half-wave rectifier power supply.

sine wave voltage. When these two voltages are combined, the overall effect is to put the ac input voltage in series with the voltage across C_1, so that when terminal A is positive and B is negative, the voltage applied to S_2 and the input filter capacitor, C_2, is twice the peak ac input voltage.

The second half of the voltage doubler should be very familiar to you. It is nothing more than the simple half-wave rectifier circuit that you have encountered many times in ac-dc radio receivers. It consists of S_2 and a conventional filter network. The function of this section of the voltage doubler is simply to rectify and smooth out the ac voltage that is applied to the circuit. This will produce a dc output that approaches twice the peak line voltage.

The voltage doubler described in Fig. 16 is a half-wave voltage doubler, whereas the one described in Fig. 5 is a full-wave doubler. The difference lies in the fact that in Fig. 5 there is a charging pulse applied to the output during each half cycle to give 120 pulses per second from a 60-cycle power line. On the other hand, in the circuit shown in Fig. 16, one pulse charges C_1 and the other is applied to the output. Thus there are only 60 pulses per second in the output from a 60-cycle power line. Since there are twice as many pulses to the filter network in Fig. 5, smaller filter capacitors can usually be used in this circuit than in the one shown in Fig. 16.

Many late model TV receivers, particularly sets with small size picture tubes, use tubes developed to operate on B supply voltages of approximately 140 volts. This value of B supply can be obtained directly

from a half-wave rectifier. This simplifies the power supply, permitting the elimination of one rectifier and the voltage doubling capacitor. It also permits the use of lower voltage bypass capacitors throughout the receiver.

A typical low voltage power supply using a single rectifier is shown in Fig. 19. Notice that there are two output voltages, the 140-volt output which is well filtered by L_2 and the output filter capacitor C_3. The 145-volt output which is not filtered as well is used for the plate of the sound output tube. This does not cause any hum because the sound output tube is a pentode and its plate current depends on the screen voltage rather than its plate voltage. Taking the sound output tube voltage from this point reduces the current through L_2 and hence the voltage drop across it.

B Supply Distribution.

Distribution of the operating voltages in a TV receiver using a half-wave power supply presents no special problems. However, in sets that use doublers some of the tubes must often be operated at voltages considerably less than the output voltage. Since the current available from any voltage multiplier circuit is rather limited, it is common practice not to use voltage-dropping resistors but to arrange the tube circuits, if possible, so as to use the full output of the B supply. If some stages are to operate at lower voltages, the stages may be connected so as to divide the voltage between them, as shown in Fig. 20. Here, the stages numbered 1, 2, 3, and 4 are connected directly across the full B supply. Stages 5 and 6, however, are in series across the supply. This arrangement is per-
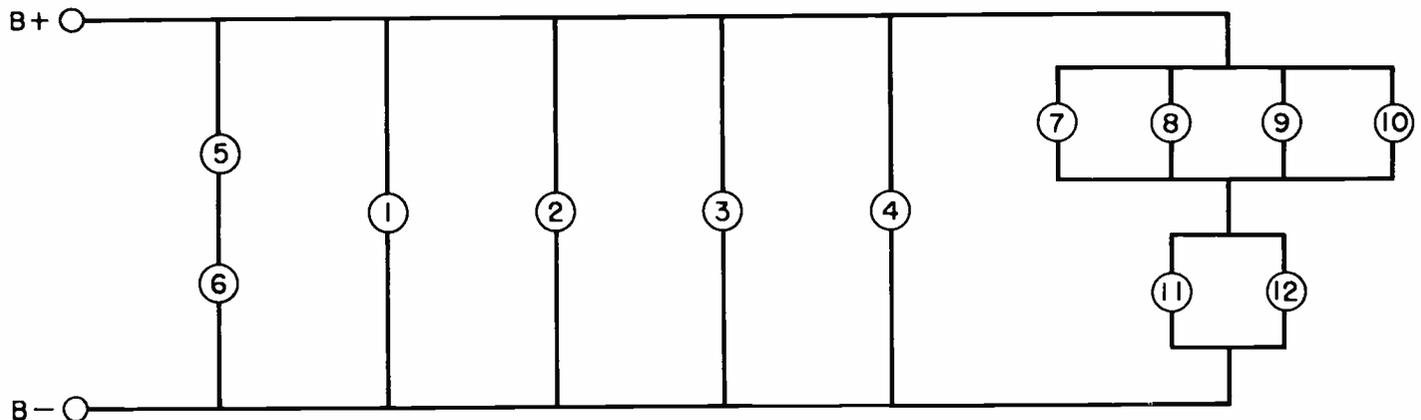
Fig. 20. A B+ voltage-distribution system used with a transformerless supply.
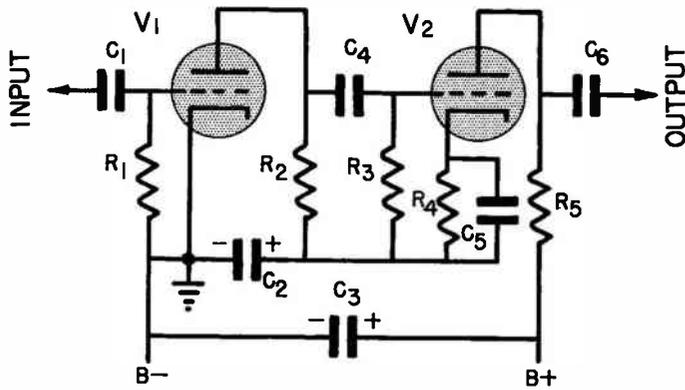
Fig. 21. Two tubes connected in series across the B supply.

missible if the two stages are to operate from half the total supply and draw identical currents.

In the rest of the circuits, stages 7, 8, 9, and 10 are in parallel, and their currents flow through stages 11 and 12. In this case the plate current sum of the first four must equal that of the last two to give the proper voltage division.

Fig. 21 shows how two tubes may be connected in series across the power supply. In this case the dc path, starting from B-, goes to the cathode of V_1, then through this tube and its load resistor R_2 to the cathode bias resistor R_4 of V_2. From here, the path goes through tube V_2 and its load resistor R_5 to B+.

The power supply circuit shown in Fig. 5 also lends itself to receivers where two operating voltages are required. By taking voltage from across C_1, as shown in Fig. 22, a voltage equal to about half the total output voltage can be obtained. To compensate somewhat for the current taken from across C_1 and to try to balance the supply so that the voltages across C_1 and C_2 are as close to being equal as possible, C_1 may be somewhat larger than C_2.

The circuits we have shown using transformer B supplies have all been for monochrome receivers using vacuum tubes. Transistor receivers do not use this type of power supply because many of the tran-

sistors operate at comparatively low voltages. Therefore, a step-down transformer is required to get the low voltage needed. If we tried to obtain the voltage directly from the power supply using a voltage-dropping resistor, the resistor would have to dissipate a large amount of power which would generate considerable heat inside the receiver cabinet.

One of the advantages of using transistors is that we can get rid of considerable heat in the set since transistors do not require a heater. Therefore we would lose one of the main advantages of using transistors if we were to try to reduce the voltage by means of a voltage-dropping resistor. In addition, with normal current changes in the transistors due to changes in agc voltage and variations in current through the individual transistors, the voltage from the power supply would probably vary considerably. This could result in poor performance from the receiver; it is possible that the voltage might actually climb high enough to destroy one or more transistors.

Transformerless Power Supply.

A transformerless power supply from a color TV receiver is shown in Fig. 23. The power supply actually consists of two separate power supplies, one using the silicon diode D3 in a half-wave rectifier circuit to obtain an output voltage of -140 volts, and the other containing a half-wave doubler circuit using the diodes, D_1 and D_2, to obtain an output voltage of 275 volts.

In the circuit the two chokes RFC_1 and RFC_2 are used to prevent radiation from the TV receiver from getting into the power line. The capacitor C_1 is also an rf bypass. The circuit breaker CB_1 is designed to open if the current drawn by the power supply exceeds a certain safe value. In the half-wave rectifier circuit, when the upper side of the power line is negative, current can flow through the diode and through the filter resistor R4 to the -140-volt terminal. From there it flows through the lead back to the lower side of the power line which will be positive at that time.

The half-wave voltage doubler works like those described previously. D_1 charges the doubler capacitor C_5 with the polarity shown and this voltage is placed

Fig. 22. A modified version of the power supply of Fig. 5 showing how two operating voltages can be obtained.
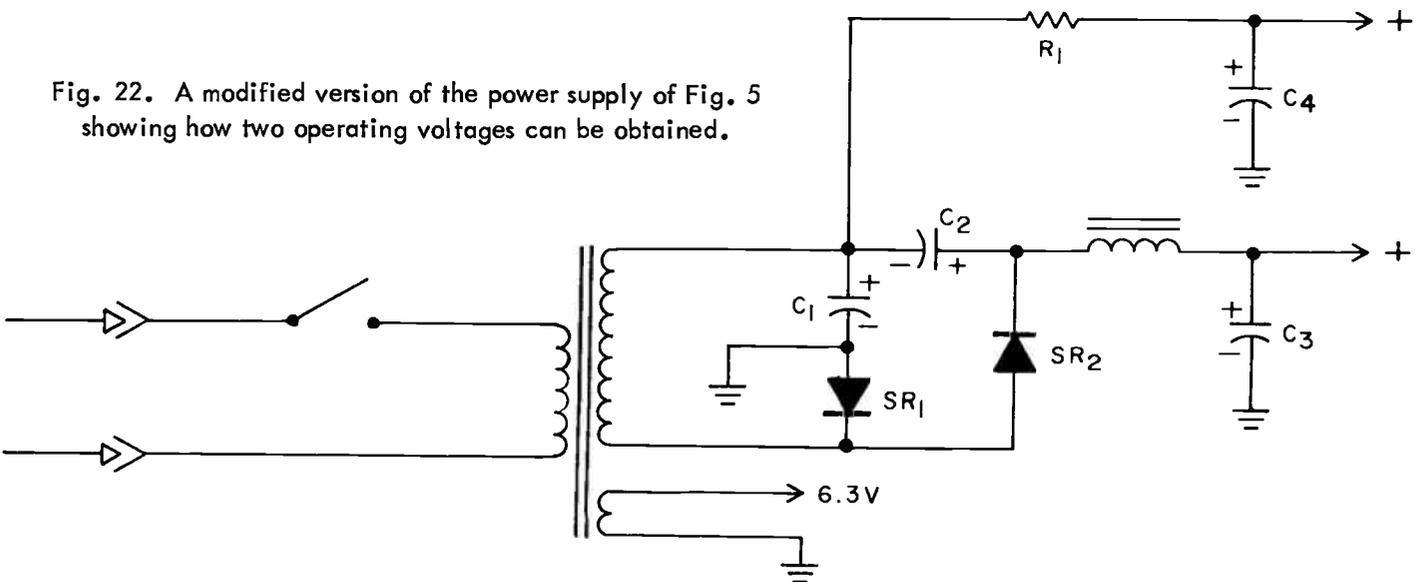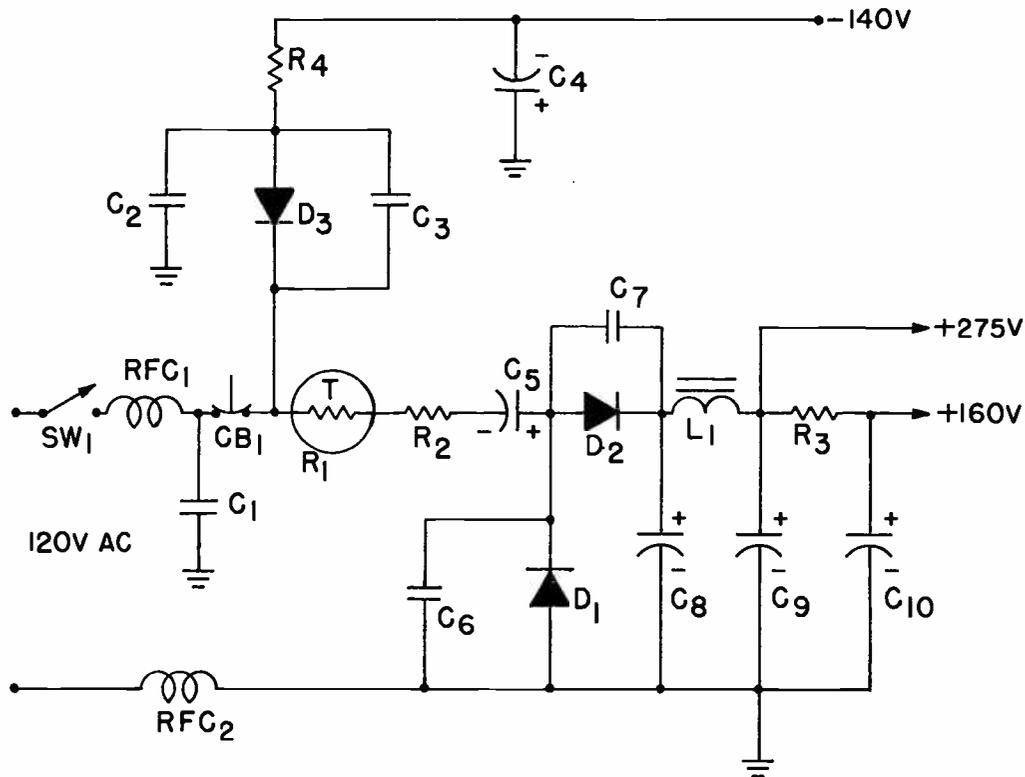
Fig. 23. A transformerless low-voltage power supply from a color TV receiver.

in series with the power line voltage, so that when D_2 conducts the input filter capacitor C_8 is charged to a value equal to approximately twice the peak line voltage. L_1 is the filter choke and C_9 the output filter capacitor. R_3 is used as a voltage-dropping resistor to obtain a lower dc output voltage of approximately 160 volts.

The resistor R_1 is a thermistor. This resistor has a resistance of approximately 120 ohms when cold. When the receiver is first turned on, the thermistor will be cold and will offer maximum resistance, thus limiting the charging current through the diodes D_1 and D_2. As the thermistor heats, the resistance drops to a low value so that, essentially, the full line voltage is available to charge C_5 and C_8.

The resistor R_2 is a 3.9-ohm resistor. It is put in the circuit to provide some protection to the diodes in the event the set owner should have the receiver operating; with the resistance of R_1 at a low value, turn the receiver off and then turn it back on quickly before R_1 has a chance to cool. Without R_2 in the circuit the charging current through D_1 would be so high that the diode would probably burn out. Similarly, there is a possibility that D_2 would burn out also. The resistor R_2 would limit the current to a safe value so these diodes would not burn out.

This power supply is designed for use in vacuum-tube type receivers; as we mentioned previously, transistor receivers use a power transformer because of the lower operating voltages required by transistors.

B+ Boost.

Often in TV receivers voltages higher than those readily available from the power supply are needed. This is particularly true in transformerless receivers.

You will recall from your lesson on sweep systems that at the end of each line the horizontal deflection circuit goes into oscillation. This oscillation is damped after 1/2 cycle by a damper diode. It is possible to obtain an additional high voltage from the action of the damper tube in the horizontal sweep system.

The circuit shown in Fig. 24 is the damper circuit used in a modern color TV receiver. The damper circuit consists of the diode circuit D_2 and the capacitor C_1. The coils L_1 and L_2 are also part of the damper circuit, but they are put there simply to prevent rf oscillation of the damper stage.
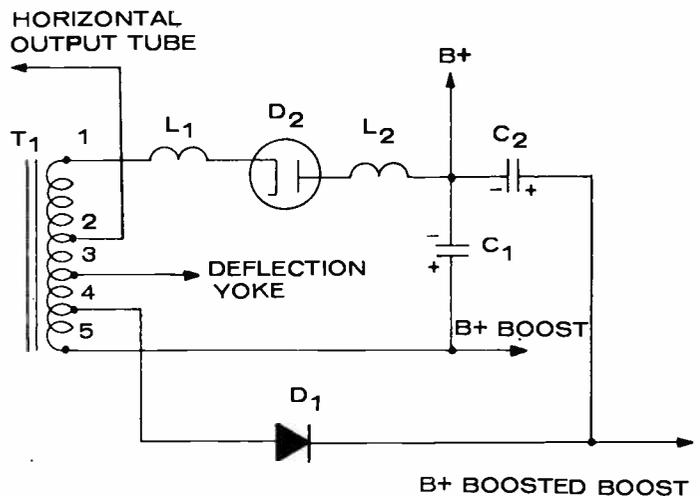
Fig. 24. Boost and boosted boost output in damper circuit.
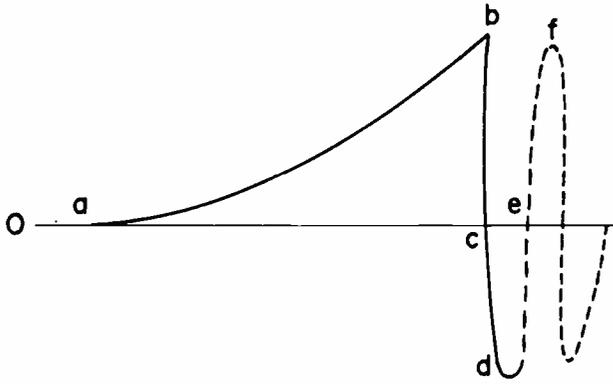
Fig. 25. Ringing in the transformer and yoke.

When the electron beam is swept across the face of the picture tube by the horizontal output stage, the current through the deflection coils increases from 0 at point a in Fig. 25 up to a maximum value represented at b in the same figure. At point b, the current at the output stage is suddenly cut off and the deflection coil begins to oscillate. The current drops from b to c, or 0, and then begins flowing in the opposite direction, reaching a maximum value at d.

Meanwhile, the voltage across the deflection coils will lead this current by 90° (or almost 90°) because the coils are primarily an inductive load. Therefore, when the current reaches point d, the voltage across the coils will be at point e, and swing positive. The deflection coils are connected across part of the secondary of the horizontal output transformer. They are connected between terminals 3 and 5. When we say the voltage across the deflection coil starts to swing positive, we are referring to the end of the coil which connects to the plate of the tube. In this case this is the end connected to terminal 5 of the transformer, which connects to the plate of D_2 through C_1. The end connected to terminal 3 will swing in a negative direction; this will drive the cathode of the damper negative, and the anode positive, and the damper D_2 will begin to conduct.

When current flows through the damper it will flow from the cathode to the plate, through the coil L_2, and into the negative side of C_1. Electrons will leave the positive side and flow to terminal 5 of the transformer, through the transformer winding to terminal 1, and through the coil L_1 back to the cathode. The current flow through the diode tube and around this circuit will charge the capacitor C_1 with the polarity shown. This charge across the capacitor is in series with the B supply and hence the total voltage available between B- and the positive side of C_1 is considerably higher than the B-supply voltage. Normally G_1 would be charged up to several hundred volts; therefore, in a receiver where we have a 300-volt B-supply we have a total of 500 volts available at the positive terminal of C_1. This voltage is referred to as the B+ boost.

In some receivers, such as in the circuit shown in Fig. 24, we have an additional circuit where the B supply is boosted even higher. The damper circuit charges C_1. During the next portion of the sweep, terminal 4 will become positive with respect to ter-

minal 5. Now if we examine the circuit from terminal 5 to C_1 and through C_2 to the cathode D_1 and then from the anode of D_1 to terminal 5, we see that we have a situation where the voltage between terminals 4 and 5 plus the voltage across C_1 is placed in series. This causes a current to flow from terminal 5 to the positive plate of C_1. Electrons flow out of the negative plate into the plate of C_2, charging it with a negative polarity. Other electrons leave the positive plate of C_2 and flow through D_1 back to terminal 4 on the transformer. During this action, C_1 will be discharged slightly, but it will be recharged the next time the damper conducts.

Meanwhile, C_2 will be charged to a value even higher than C_1 because the charging voltage is the voltage across C_1 plus the voltage across the transformer winding between terminals 4 and 5. Since the voltage across C_2 is boosted even higher than the voltage across C_1 we refer to this voltage as the B+ boosted boost. In a receiver where the B supply is 300 volts and the B+ boost is in the vicinity of 500 volts, the boosted boost may be as high as 700 volts or more. The boosted-boost supply usually cannot be loaded too heavily, but it can often be used to provide a high voltage to one or more elements of the picture tube.

The damper circuit and the B+ boost circuit from a transistor TV receiver are shown in Fig. 26. This circuit is taken from a portable TV receiver and is designed to operate from the power line or from a 12-volt battery. When the set is operated from the power line, the voltage is stepped down so that the output voltage from the power supply is only 12 volts. (The low-voltage power supply is shown in Fig. 10.) Thus it is essential that a somewhat higher voltage be available for such applications as the first accelerating anode of the picture tube and also for operation of the video amplifier where a fairly high video signal voltage is developed.

In this circuit the horizontal output transistor current flows through the primary winding of T_1 to the terminal of the transformer connected to B+. When the electron beam reaches the extreme right of the tube the beam is suddenly cut off. When this happens, the current through the primary winding of T_1 must
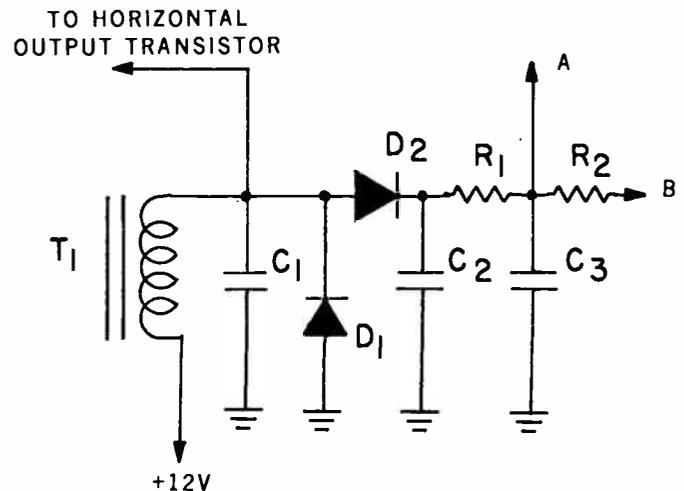
Fig. 26. Damper and boost circuit in a transistor TV.

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collapse instantly. Remember from Lenz's Law that a voltage will be induced that will tend to keep the current flowing; this means that there will be a high positive voltage appearing at the top end of T_1. This will cause the anode of D_2 to be positive; the diode will conduct and charge C_2 to a value of about 90 volts. The voltage across C_2 is filtered by R_1 and C_3.

When the electron beam reaches the extreme left edge of the picture tube, after the retrace interval, the cathode of D_1 will swing negative. This will cause D_1, which is the damper diode, to conduct. Conduction through the damper will result in a linear movement of the electron beam from the left edge of the center of the screen.

In the circuit shown in Fig. 26 we have a somewhat different situation than the one shown in Fig. 24. In the circuit shown in Fig. 24 the damper diode develops the boosted B voltage. In the circuit shown in Fig. 26 the damper diode is used solely to damp out the oscillation in the deflection coil. The boosted B voltage is developed by a separate diode.

Replacing Selenium Rectifiers.

We mentioned earlier that silicon rectifiers are used in late model TV receivers rather than selenium rectifiers. The reasons for this are that silicon rectifiers are better than selenium rectifiers; they are smaller and since they have been made in large volume, cost less than selenium rectifiers. The result of this is that most manufacturers have stopped making selenium rectifiers suitable for use in TV receivers, and if you have to replace one you'll probably have to use a silicon rectifier.

Silicon rectifiers have a lower forward resistance than selenium rectifiers, and therefore in a transformerless type of power supply can pass a very high current when a set is first turned on. You can limit this current by connecting a 5-ohm, 25-watt resistor in series with the silicon rectifier as in the circuit shown in Fig. 19. Therefore, if you have to replace a selenium rectifier with a silicon rectifier in a transformerless power supply, put a 5-ohm resistor in series with the rectifier. In a transformer type supply, this is not necessary in most cases, because the resistance of the transformer winding will usually limit the current to a safe value.

SELF-TEST QUESTIONS

(a) What is the advantage of connecting rectifier tubes as in Fig. 2?

(b) What is the maximum output voltage available from the power supply in Fig. 3?

(c) What are the chief advantages of selenium rectifiers over vacuum-tube rectifiers?

(d) What are the chief advantages of silicon rectifiers over selenium rectifiers?

(e) Why do we call the voltage doubler circuit in Fig. 5 a full-wave voltage doubler?

(f) What type of rectifier circuit is used in the power supply in Fig. 7?

(g) Why is R_2 used to connect the heater winding ZZ, on the transformer in Fig. 7, to 250V?

(h) In what type of rectifier circuit is D_1 in Fig. 8 used?

(i) How many rectifier circuits are there in Fig. 9?

(j) What is D_3 in the circuit shown in Fig. 10?

(k) Why is it important to replace resistors, such as R_1 and R_2 in Fig. 8, with exact duplicates?

(l) What is meant by "a 600-mil tube"?

(m) What is a tube with a controlled warm-up heater?

(n) What is the advantage of the 450-mil tube over the 600-mil tube?

(o) Why is the circuit shown in Fig. 16 a half-wave voltage doubler rather than a full-wave doubler?

(p) If R_5 in the plate circuit of V_2 in Fig. 21 opens, would you expect the plate voltage on V_1 to increase, decrease or drop to zero? (Use effect-to-cause reasoning; this question is not answered in the text.)

(q) In the power supply shown in Fig. 22, which will be higher, the voltage across C_4 or the voltage across C_3?

(r) Why should you put a 5-ohm resistor in series with a silicon rectifier when you use one to replace a selenium rectifier in a transformerless TV receiver?

High-Voltage Power Supplies

In the early days of TV there were a number of different types of high-voltage power supplies tried, including 60-cycle high-voltage supplies, rf oscillator supplies and pulse-type supplies. However, these types did not last long--all modern TV receivers use the flyback type of high-voltage supply.

THE FLYBACK SUPPLY

You have already been introduced to the flyback power supply in your study of sweep circuits. Therefore, much of the material here will be a review. However, we will study here only those sections of the horizontal sweep system pertinent to producing the high acceleration voltage required by picture tubes.

Fig. 27 is a schematic diagram of a flyback high-voltage supply. V_1 is the horizontal output tube, the output of which is connected to the primary of T_1. T_1 acts as a combination horizontal output transformer and high-voltage transformer. The two secondaries of T_1 are the winding for the high-voltage rectifier filament supply, and the winding that supplies a sawtooth current to the horizontal deflection yoke. When considering this transformer as the high-voltage power supply transformer, the secondary acts as the primary and vice versa. The high voltage is not derived from the output of V_1, but from pulses which originate in the transformer and the horizontal deflection coils due to the rapid collapse of deflection coil current.

From your study of sweep circuits you will recall that when the horizontal deflection coil current collapses, an oscillation is set up, one half-cycle of which is utilized to move the electron beam rapidly from the right side of the screen back to the left side. The rapid collapse of the magnetic field in the deflection coils and the horizontal output transformer induces a high voltage in the primary winding of the horizontal output transformer. The induced voltage at the plate of the horizontal output tube is usually between 2000 and

Fig. 28. A high-voltage power supply with an auto-transformer type of horizontal output.

3000 volts. The winding to which the plate of the high-voltage rectifier, V_2, is connected has several times as many turns as the one that is connected to the output tube. The exact turns-ratio is determined by the required voltage. Usually a voltage of 12,000 to 15,000 volts is used on black-and-white picture tubes and a voltage of around 25,000 volts on color tubes. These high-voltage pulses are rectified by V_2 and filtered by C_1. In old receivers C_1 was a separate high-voltage capacitor, but in modern receivers it is the picture tube itself. The pulses are at the frequency of the line repetition rate, slightly over 15 kc.

This is a very economical type of high-voltage supply, because it utilizes parts that are essential for the sweep circuits so that no special oscillators are necessary. The power supply is created simply by adding a few more turns to the primary of the horizontal output transformer and a high-voltage rectifier with a filament winding on the transformer. The only completely new parts added are the rectifier tube and its socket and the filter capacitor, if one is used.

Besides being very inexpensive, this power supply has the advantage of operating only during retrace time when the screen is dark. If anything happens to the horizontal sweep oscillator circuit that makes the sweep fail, the high-voltage pulse will not be generated, and, therefore, there will be no high voltage applied to the picture tube. If high voltage were applied while the sweep was inoperative, the stationary electron beam would burn the face of the picture tube.

Fig. 27. Schematic of a flyback high-voltage supply.

The modified version of the flyback power supply shown in Fig. 28 is more commonly found in late model receivers. The principal difference between this and to one shown in Fig. 27 is that an autotransformer is used instead of a conventional transformer with primary and secondary windings. However, the principle of operation is the same if you consider for power supply purposes that the segment that is between 2 and 3 is the primary and the segment between 1 and 3 is the secondary. Voltage pulses of about 2500 volts appear across the segment of the winding between points 2 and 3. Through transformer action, this voltage is stepped up across the full winding from points 1 to 3 to required value.

These high-voltage pulses are then rectified by the high-voltage rectifier and appear at the picture tube as a dc potential. You will note in the output of the rectifier tube that there is no separate filter capacitor shown. In this type of supply you will not find a separate filter capacitor. The filter consists of the capacity between the inside and the outside coatings on the picture tube. The high voltage is connected to the inside coating, which acts as an acceleration anode, and the outside coating is grounded. The capacity thus formed with the glass of the tube as a dielectric serves as the filter for the high-voltage power supply.

The power supply just described is the one that you will most frequently encounter in TV service work. You might service older sets that use the flyback circuit shown in Fig. 27, but it is unlikely that you will ever run into a set that uses a 60-cycle, a pulse type or an rf type of supply. The sets that used these supplies were built in the late 1940's and are obsolete. Parts for these sets are no longer available.

Some of the first large-screen TV receivers used voltage doubler circuits in the high-voltage power supply. This particular type of doubler supply is no longer used because the improved design of horizontal output transformers and horizontal output tubes and transistors makes it possible to get a high enough voltage for large tubes (even color tubes) without resorting to doublers. However, there are many sets in use using high-voltage doublers, so you might run into them in service work. Also, some portable TV receivers designed for operation from the power line or a battery power supply use voltage doublers.

The first type of voltage-doubling circuit is shown in Fig. 29. Transformer T_1 is the output transformer and supplies pulses for the high-voltage supply. The resistance, R_1, is the low-voltage bleeder; it serves only to complete the circuit from C_1 to T_1 insofar as the high-voltage supply is concerned. Here is how the circuit works:

On the first pulse, rectifier V_2 charges capacitor C_1 to the full output voltage of T_1. When the pulse cuts off, there is a relatively long period (during the horizontal trace time) in which there is no voltage pulse. C_1 is always connected across C_2 through paths consisting of R_2 on one side and R_1-T_1 on the other. During the time that V_2 is off, C_1 discharges somewhat, charging C_2 with the polarity shown. (After several cycles of operation, the voltage across C_2 becomes practically equal to that across C_1.)

Now, on the next forward pulse, when the upper end of transformer T_1 is positive, V_2 again conducts to recharge C_1. At the same time, voltage is applied to V_3. The voltage applied is the sum of the pulse voltage across T_1, plus the voltage across C_2, and minus the voltage across C_1. Since the voltages across C_1 and C_2 are equal and hence cancel each other, the
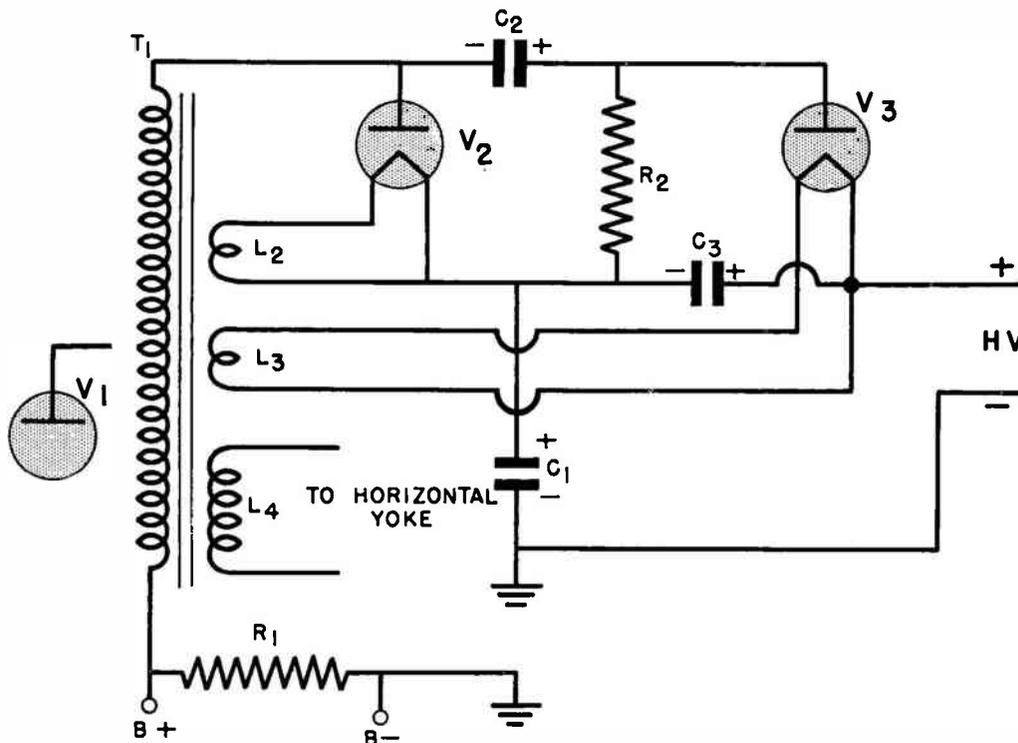
Fig. 29. Voltage doubler used with a flyback high-voltage supply.
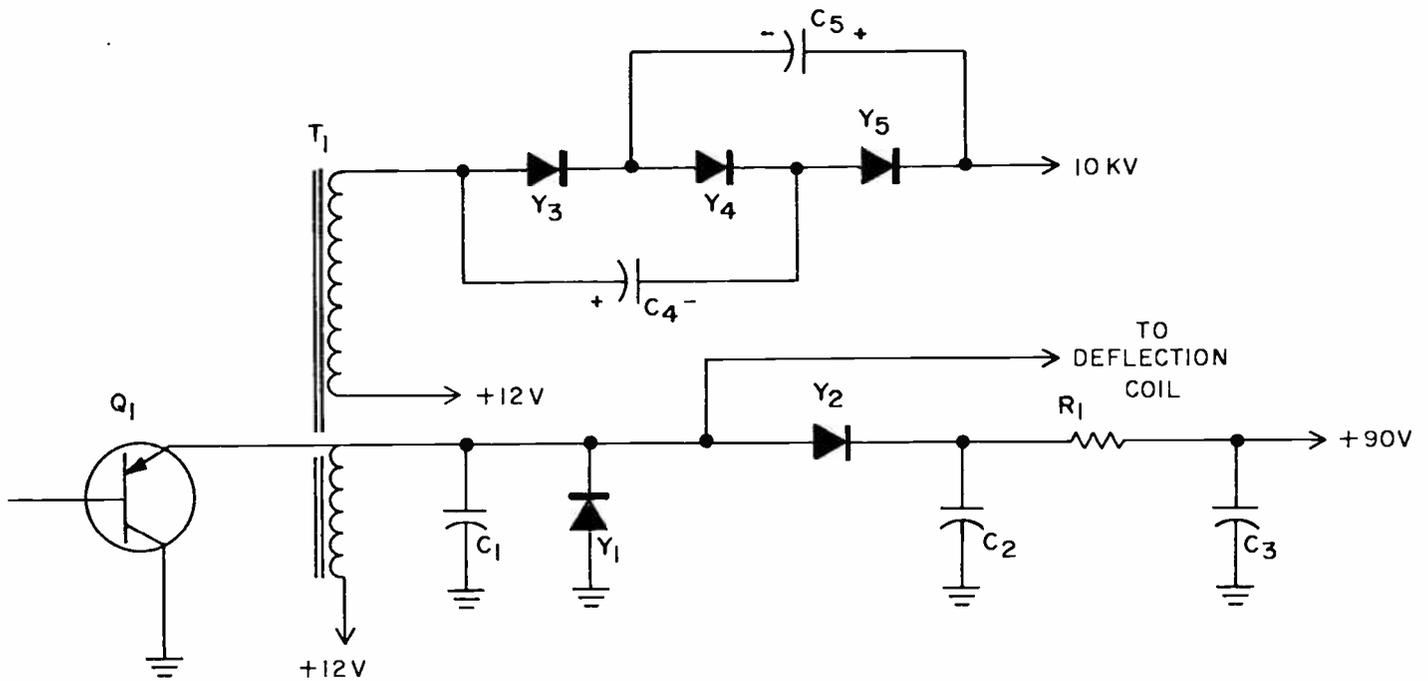
Fig. 30. High-voltage power supply of a transistorized TV.

voltage developed across T_1 is what is applied to V_3. This tube then conducts, allowing the full T_1 voltage to be applied to C_3. As a result, C_3 is charged to the same voltage as C_1.

The high-voltage output is the voltage across C_1 and C_3 in series. Hence, each capacitor supplies half the voltage. If the output is, let us say, 20,000 volts, the voltage across C_1 is 10,000 volts, and the voltage across C_3 is likewise 10,000 volts. Hence, neither of these capacitors has to have an extremely high voltage rating, which means they can be relatively inexpensive. That is an important feature of this circuit; in some other voltage-doubling circuits at least one capacitor has to be able to withstand a higher voltage.

A high-voltage power supply from a transistorized portable TV receiver is shown in Fig. 30. You may recognize the damper and B+ boost circuit from this receiver as the circuit already described in Fig. 26. Y_1 is the damper diode and Y_2 is the B+ boost diode.

The high-voltage power supply in this receiver is actually a voltage-doubler circuit. It is somewhat difficult to see the action of the power supply from the schematic diagram in Fig. 30; however, we have redrawn it in Fig. 31. By following this circuit it will be much easier to see what happens.

Let's consider the first half-cycle, when the upper end of T_1, that is, the end that connects to Y_3 and C_4, is positive and the lower end is negative. This is shown in Fig. 31A. When this happens, current will flow from the lower end (which is B+) through the power supply to the cathode of the picture tube. The internal resistance of the picture tube is represented by the resistor R_T and the capacitance is represented by C_T. Current will flow through the picture tube which is represented by the current flowing through R_T. At the same time, a charge will be built up on the picture tube capacity represented by C_T.

The current that flows through R_T will then come to the junction of Y_5 and C_5. The electrons reaching the cathode of Y_5 will find an easy path through this diode, then through the diode Y_4, then to the diode Y_3 and back to the positive side of T_1. Thus in the first half-cycle, the current flow is through the three diodes in the series and neither capacitor C_4 nor C_5 is charged; however, a charge is built up across the picture tube.

During the next half-cycle when the polarity of the voltage across the winding of T_1 reverses, the upper end will be negative and the lower end will be positive. This is shown in Fig. 31B. Now current flows from the negative or upper end of the transformer to the junction of C_4 and Y_3. Current cannot flow from the anode to the cathode of a diode so there is no current flow through Y_3. Instead, electrons flow to one plate of C_4 and out of the other, charging the capacitor with the polarity shown. The electrons then flow from the cathode to the anode of Y_4; they can flow through the diode easily in this direction. There will be no current flow through Y_5 because the electrons cannot flow from the anode to the cathode.

Electrons leaving the anode of Y_4 will flow into the negative plate of C_5 and out the positive plate, charging this capacitor with the polarity shown. Now the electrons will flow into the positive side of C_T and out of the negative side, discharging the picture tube slightly. Electrons will then flow back to the positive side of T_1. There will be no current flow through R_T, the resistance represented by the picture tube, because this would mean that electrons would have to flow from the anode of the picture tube to the cathode and this is, of course, impossible.

Thus on this cycle we have the two capacitors, C_4 and C_5, charging in series. The charging voltage will be the voltage across T_1 plus the voltage across C_T.
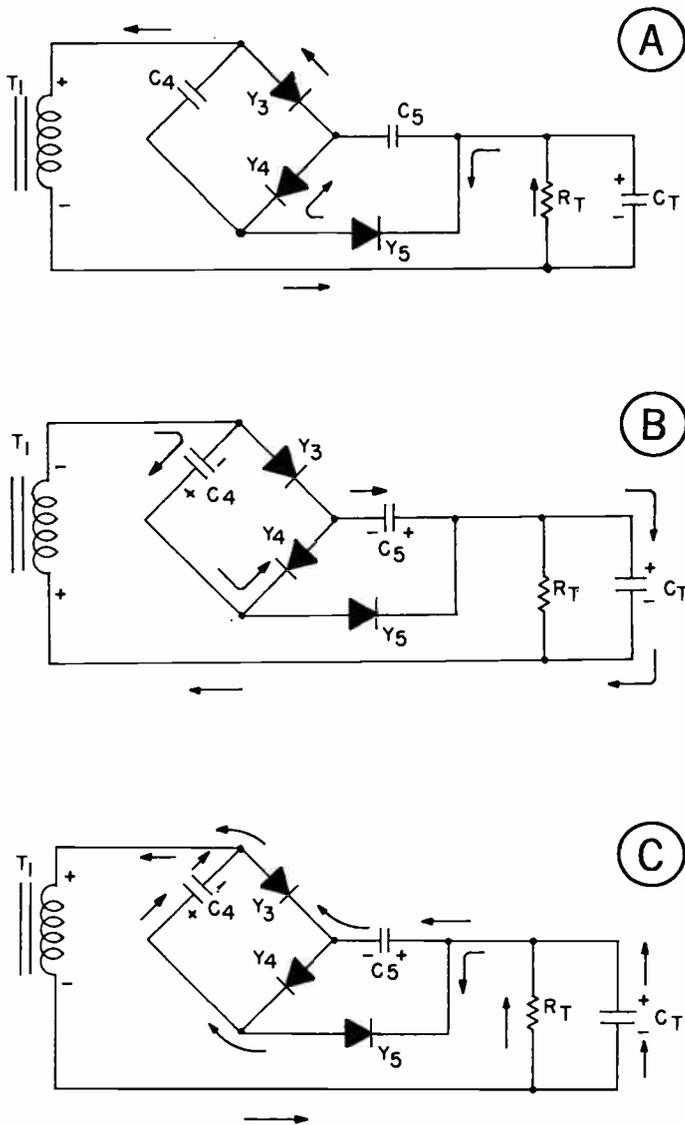
Fig. 31. Action of high-voltage doubler power supply.

The voltage across T_1, when the polarity is as shown in Fig. 31B, will not be as high as it is when the polarity is as shown in Fig. 31A. However, the total charging voltage will be somewhat higher than the voltage across C_T. Since C_4 and C_5 charge in series, then the voltage across each should be somewhat greater than half the voltage across C_T.

Now in the next half cycle, the upper end of T_1 will be positive and the lower end will be negative. Electrons leave the lower end of the transformer and flow through R_T. They recharge C_T and then reach the junction of C_5 and Y_5. Now if we trace from C_5 to Y_3, we see that the negative side of C_5 is connected to the cathode of Y_3 and the anode of Y_3 is connected to the positive terminal of the transformer. When electrons are traveling in the direction shown, Y_3 acts practically like a short circuit so in effect the voltage across C_5 is in series with the voltage of the transformer. Also, look at the other current path through Y_5. With electrons traveling in the direction shown, Y_5 acts as a short circuit, so C_4 is placed in series with the voltage across T_1.

Thus we have a situation where C_4 and C_5 are essentially in parallel, and the parallel combination is in series with the voltage across T_1. This charges C_T to a higher voltage than on the first cycle in Fig. 31A, and the voltage available on the output of the power supply is about twice the transformer voltage.

In Fig. 31C we see that there will be no current flow through Y_4. Notice that the anode of this diode is connected to the negative side of C_5. The cathode is connected to the positive side through Y_5 so that the voltage applied across Y_5 has the opposite polarity from that needed to permit the diode to conduct.

Actually we have shown how the capacitors charge in only three cycles. In effect it takes many more cycles than this for the capacitors to reach their charge. On the first cycle C_T may be charged to a value almost equal to the peak voltage across T_1. However, during the next half-cycle the voltage across T_1 will be comparatively small. As a result, the charge placed on C_4 and C_5 will not be too high. However, during the third cycle, this charge is placed in parallel and then added to the voltage across T_1 so that the charge built up across C_T increases somewhat. Then we go through the second cycle again of charging C_4 and C_5. This time C_T will be charged to a somewhat higher voltage and so the voltage across C_4 and C_5 will build up. Eventually we'll reach a situation where the voltage across C_4 and C_5 will be approximately equal to the peak voltage across T_1. When the upper end of T_1 is positive these capacitors will be in parallel with each other and the parallel combination will be in series with T_1. Under these circumstances, the voltage applied to C_T will be double the transformer voltage and hence the power supply will be performing as a voltage-doubler.

In some of the earliest color receivers, voltage triplers were used in the high-voltage power supply. However, these sets were not too satisfactory; there were only a limited number manufactured, so it is not likely you'll run into one for servicing. If you should, you'll recognize it immediately because it will have three high-voltage rectifier tubes.

COLOR HIGH-VOLTAGE SUPPLIES

The high-voltage power supply for a color TV receiver must be built to more exacting standards than for black-and-white TV receivers. Some variation in the high-voltage in a monochrome receiver is not likely to cause too much trouble, but in a color receiver it can cause convergence or purity problems.

Voltage variations in the output of a high-voltage supply can be caused by changes in beam current in the picture tube. Thus the high voltage may be considerably higher during a dark scene when the picture tube beam current is low than during a bright scene when the beam current is high. In a color tube where we have three beams to consider, the loading on the power supply during a bright scene is much greater than in a monochrome receiver.

There are three methods in use to minimize high-voltage variations due to changes in picture tube beam current. The first, which we will study now, is to regulate the high-voltage by means of a regulator tube.
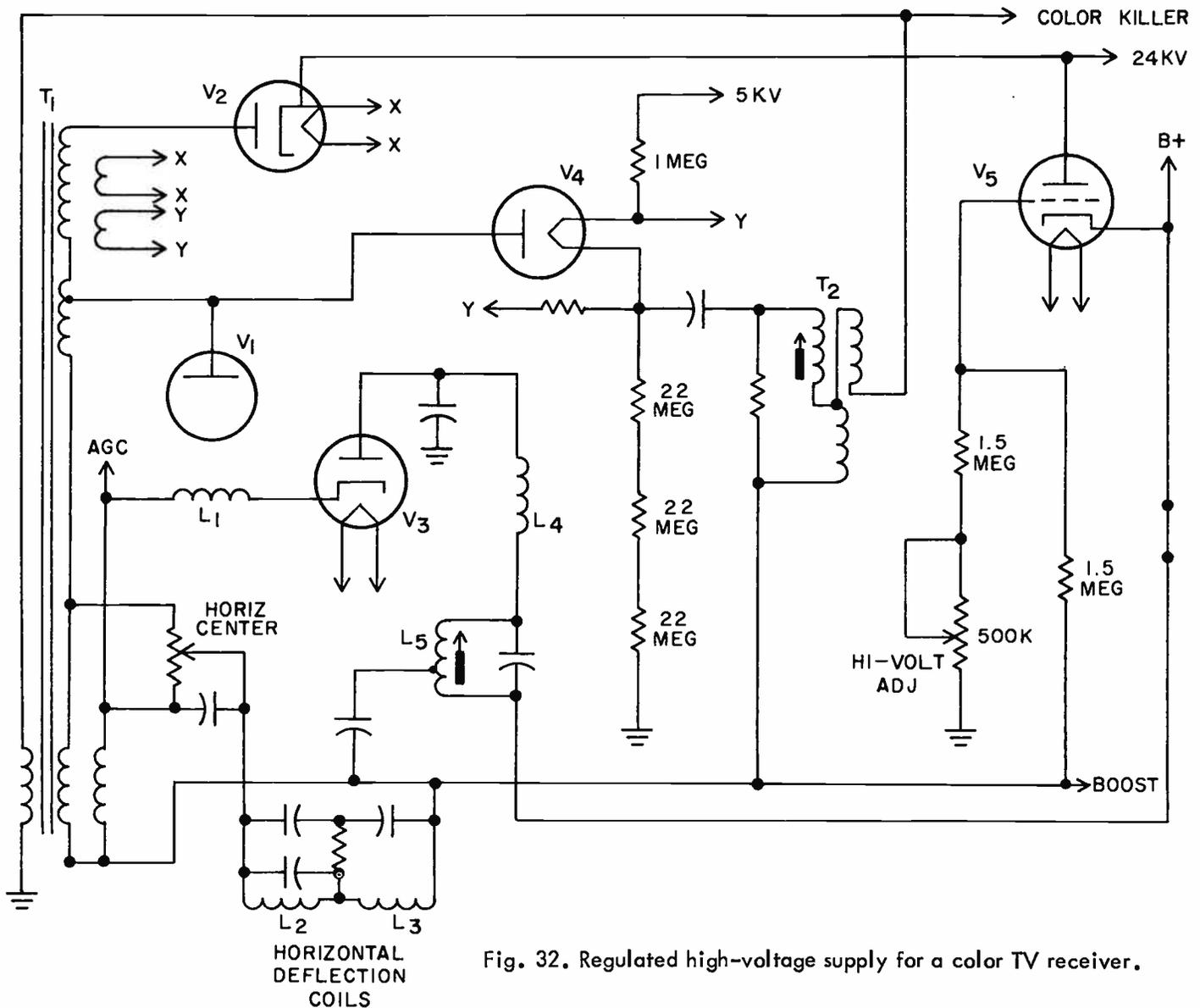
Fig. 32. Regulated high-voltage supply for a color TV receiver.

A typical high-voltage power supply using a regulator tube is shown in Fig. 32. V_1 is the horizontal output tube and T_1 the horizontal output transformer. V_2 is the high-voltage rectifier tube, V_3 the damper, V_4 the focus rectifier tube and V_5 the shunt high-voltage regulator tube.

The basic operation of the high-voltage power supply is the same as the operation of the flyback supply described for black-and-white receivers. The high voltage is developed by the collapsing deflection yoke field and is stepped up by the horizontal output transformer T_1. The high voltage is rectified by V_2 and applied to the second anode of the tricolor tube and to the plate of V_5, the shunt regulator.

The focus voltage required on the focus electrode of the tricolor tube is about 5000 volts. There is no way we can get such a high voltage from the receiver low-voltage power supply, so we obtain it by means of a separate focus rectifier operated from a tap on the horizontal output transformer. The three 22-megohm resistors connected from the filament of the focus rectifier to ground provide minimum load on the focus

supply. T_2 can be adjusted to provide best overall focus.

The high-voltage shunt regulator is connected across the high-voltage power supply. The grid voltage on the tube is set by the series network consisting of the 500K-ohm high-voltage adjustment potentiometer, the 1.5-megohm resistor connected from the potentiometer to the grid of the tube, and the 1.5-megohm resistor connected from the grid to the B+ boost. The grid voltage can be adjusted by adjusting the setting of the 500K-ohm potentiometer. This in turn varies the current through the regulator tube, which changes the loading on the high-voltage supply.

The potentiometer is set to give a high-voltage of 24 KV. If the load on the high-voltage power supply decreases because the scene is dark, the high-voltage will start to rise. However, the decrease in loading on the high-voltage supply reduces the load on the high-voltage output transformer T_1. This will cause the B+ boost voltage to rise. When the boost voltage rises, the voltage applied to the grid of the regulator tube V_5 will rise. This will cause the regulator to

draw more current, which will tend to keep the output from the high-voltage supply constant.

If the load on the high-voltage power supply increases due to increased picture tube beam current, the increased load on T_1 will lower the B+ boost voltage and hence the voltage on the grid of V_5. This will cause the regulator tube current to decrease and tend to keep the high voltage constant.

The coil, L_5, which is in the plate circuit of the damper tube, V_3, is called an efficiency coil. It varies the wave shape of the current flowing in the damper circuit. The wave shape of this current affects the total current flowing in the horizontal sweep output tube, V_1. In setting up the horizontal oscillator and the high voltage, the cathode circuit of V_1 is opened and a milliammeter is inserted in the circuit. Coil L_5 is then adjusted for minimum cathode current through V_1. In the circuit shown in Fig. 32, this current must be kept under 200 ma to avoid overloading V_1.

The power supply shown in Fig. 32 uses four tubes: the high-voltage rectifier, the focus rectifier, the damper, and the regulator tube. Some color TV receivers use a silenium rectifier in place of the vacuum tube rectifier, V_4, as the focus rectifier. High-voltage, low-current selenium rectifiers are reasonably priced and since they require no filament power, they reduce the drain on the horizontal output transformer.

You'll notice that both the high-voltage rectifier tube and the focus-rectifier tube in Fig. 32 get their filament power from filament windings on the horizontal output transformer. In receivers where a selenium rectifier is used as a focus rectifier, there will be only one filament winding on the horizontal output transformer.

Horizontal Output Tube.

The second method of regulating the high-voltage in a color TV receiver is to regulate the current through the horizontal-output tube. Since the high-voltage will depend primarily on the current through this tube, controlling this current will maintain the high-voltage essentially constant. A circuit in which this method is employed is shown in Fig. 33. The regulator tube is V_1 and the horizontal output tube is V_2. Let's see how this circuit works.

The drive from the horizontal oscillator tube is fed to the grid of the horizontal output tube, as shown, through R_7. The bias on the horizontal output tube is developed primarily across R_5. This bias is controlled by the plate current flowing through V_1.

Notice that there is a winding connected between terminals 10 and 11 on the horizontal output transformer. Terminal 11 of this winding is grounded and terminal 10 is fed back to the plate of V_1. When the signal across this winding swings in a positive direction, current will flow through V_1. The amount of current that will flow will depend upon the bias on V_1.

In the cathode circuit of V_1 there is a neon bulb. This bulb is used because neon bulbs maintain an essentially constant potential across them, regardless of the current through them. Therefore, the cathode voltage on V_1 will remain essentially constant. The cathode voltage will vary slightly with changes in cathode current because of R_4, but most of the voltage developed in the cathode circuit is developed

Fig. 33. A regulated high-voltage power supply for a color TV receiver.

across LP_1. When a positive pulse is applied to the plate of V_1, current will flow through the tube and a potential of between 50 and 60 volts will be built up in the cathode of the tube depending on the exact voltage at which the neon bulb fires. This voltage will be held constant because C_1 will charge and keep the voltage constant even though the current flowing through the tube flows through in pulses.

Divider Network.

The amount of current that will flow through the tube will depend on the setting of R_2. A divider network consisting of R_1 and R_2 takes the pulse which is fed to the plate of the tube, and divides it and feeds part of the pulse to the grid of the tube. The higher the setting of R_2, the greater the positive pulse fed to the grid of the tube. This in turn will cause a higher current to flow through the tube. V_1 plate current flows through R_5 to ground. The current flowing through R_5 develops a voltage across it having a polarity such as shown on the diagram. The amplitude of the voltage across R_5 depends on the amplitude of the current through V_1. This negative voltage is fed through R_6 and R_7 to the grid of the horizontal output tube. The higher the negative voltage fed to the grid of V_2, the smaller the current that will flow through V_2 and the lower the negative voltage fed to the grid of V_2, the higher the current that will flow through V_2.

The potentiometer R_2 is adjusted to give the required output voltage from the high-voltage rectifier V_3. Normally, the control is adjusted to give an output voltage of 22,000 volts. Once R_2 is set, V_1 will regulate the bias on V_2 to keep the high voltage essentially constant.

Regulating High Voltage.

Let's consider what happens when there is a particularly bright scene being viewed. When this happens the current through the picture tube will increase. This will load the high-voltage rectifier and in turn will load the horizontal output transformer T_1. When this happens, the amplitude of the positive pulse fed back to the grid and plate of V_1 will decrease. When the plate and grid voltages on V_1 decrease, the current flowing through R_5 decreases and the negative voltage applied to the grid of V_2 goes down. This permits V_2 to pass a higher current so it picks up the additional load on the high-voltage power supply.

On the other hand, if we are viewing a particularly dark scene, where the load on the high-voltage rectifier is very low, the voltage may tend to rise. The reduced load on V_3 will reduce the load on the horizontal output transformer T_1. This in turn will permit the positive pulses fed back to the grid and plate of V_1 to increase. The increased pulses fed to the grid and plate of V_1 will cause the tube to conduct more heavily and the voltage drop across R_5 will increase. This means that the negative voltage applied to the grid of V_2 will increase, the current flowing through the tube will go down, and the high voltage output from the rectifier tube will be held essentially constant.

Notice that this is the circuit that we discussed previously with the boosted-boost circuit. Also notice that the focus voltage in this receiver is obtained by

means of a selenium rectifier, D_1. The potentiometer R_{12} controls the voltage fed to the focus rectifier and hence the amplitude of the focus voltage.

A third method of regulating the high voltage in color TV receivers is by controlling the picture brightness. This involves limiting the amplitude of the color signals fed to the picture tube. You'll go into this type of circuit later, when you study color circuitry. The circuit is usually referred to as automatic brightness limiting and is usually abbreviated ABL. You'll find this circuit interesting since it keeps the high-voltage constant by limiting the maximum current drawn from the high-voltage power supply.

DANGER OF X-RAYS

Color picture tubes operate at voltages considerably higher than similar-sized black-and-white tubes. When such high voltages are produced there is always the danger of producing dangerous X-rays. Therefore, when a manufacturer instructs you to adjust the high-voltage power supply for a certain output voltage it is essential that you adjust the high-voltage power supply to give you exactly that voltage. Do not set up the high-voltage power supply to give a higher voltage than that recommended. If you have to deviate from the recommended value, set the voltage a little lower than that recommended. If you exceed the high voltage value recommended, there is the danger that there will be excessive X-rays produced and radiated from the receiver.

Some tubes in the high-voltage power supply such as the high-voltage rectifier tube and the high-voltage regulator tubes can easily produce X-rays. Usually these tubes are placed inside of a shielded compartment in order to keep any X-rays produced in them inside of the compartment where they can't go out and cause any harmful effects. Therefore, in servicing a receiver, if you have to remove any of the shielding around any of the high-voltage components, make sure that you put all of the shielding back in place. Leaving part of the shielding off may permit some of the X-rays to escape.

Replacing High-Voltage Tubes.

If in servicing a color TV receiver you suspect any defect in the high-voltage rectifier tube or in the high-voltage regulator tube it is a good idea to replace them. Not only are these tubes under considerable strain due to the very high voltages they must handle, but also the chances are considerably greater that the defective tubes will produce excessive X-rays. Therefore, it is a good idea to play it safe. Don't hesitate to tell your customer what you are doing and why you are doing it and that with the shielding in place and the set operating at the correct high voltage there is no danger from it.

If you have difficulty bringing the high voltage up to the value recommended by the manufacturer, remember that the high voltage is affected by the horizontal output tube as well as the damper and high-voltage rectifier tube. Therefore, if you can't get the voltage up to normal you should check all three tubes, preferably by substitution. In transistor color receivers,

the high voltage is affected not only by the rectifier, but also by the transistors used in the horizontal output stage. If everything else appears to be normal and you still can't get the voltage up to where it should be, chances are that the horizontal output transistors may be defective.

SELF-TEST QUESTIONS

(s) What is the frequency of the pulses applied to the high-voltage rectifier in a flyback type of power supply?

(t) Other than economy, what is a major advantage

of a flyback type of power supply?

(u) Why is voltage regulation necessary in the high-voltage power supply of color TV receivers?

(v) Why is the focus voltage taken from the flyback supply in Fig. 32 rather than from the low-voltage power supply?

(w) How is the high-voltage output in the circuit shown in Fig. 32 adjusted to the correct value?

(x) How is the high-voltage regulated in the circuit shown in Fig. 33?

(y) What method, other than those used in Figs. 32 and 33, can be used to regulate the high-voltage in a color TV receiver?

Sound Systems

Almost all the material contained in this section is a review. In your study of video sections of the TV receiver, you became familiar with the various methods of sound take-off. In earlier studies of FM broadcast receivers you became familiar with FM i-f amplifiers and detectors. Audio amplification is an old story to you. All of these things will be reviewed in this section and, perhaps in some cases, embellished with facts that you have not learned before.

In previous lessons we have traced the video signal from the antenna to the picture tube, and we learned that, through a large part of its route, the video signal is accompanied by the sound signal. Our principal concern with the sound signal at the time was to see that it did not produce interference in the picture. Here we are concerned with finding out how the sound signal proceeds through the various stages of the television receiver and is faithfully reproduced at the speaker.

THE TUNER

The response of the tuner is generally broad enough so that it treats sound, video and color signals impartially, and nothing unique happens to the sound signal in this section of the receiver. However, since the frequency relationship between the sound and video

Fig. 34. When the television signal is converted in the mixer-oscillator section, the relative positions of the sound, color, and video carriers are reversed.

carriers is reversed, a brief review of what happens in the tuner is worthwhile.

Fig. 34 is a graphic illustration of what happens to the television signal in the tuner. You will recall that in monochrome TV broadcasting, the television transmitter sends out an AM video signal along with an FM sound signal. In color broadcasting a 3.58-mc color subcarrier is superimposed on the video carrier. The sound carrier is always 4.5 mc above the video signal carrier and the color subcarrier is always 3.58 mc above the video carrier. The response of the rf amplifier is sufficiently broad to amplify all three of these signals. The amplified video, sound, and color signals are delivered from the rf amplifier to the mixer-oscillator section of the tuner. In the mixer-oscillator section, the sound, color, and video signals from the rf amplifier are beat against a signal produced by the oscillator, the frequency of which is higher than all three.

The output of the mixer-oscillator section is the difference between the sound, video, and color signals from the rf amplifier and the oscillator signal against which they are beat. Since the sound carrier output of the rf amplifier is 4.5 mc higher than the video carrier output, there will be less difference between the sound carrier and the oscillator signal than there will be between the video carrier and the oscillator signal. For this reason, in the output of the mixer-oscillator section, the sound carrier will be 4.5 mc lower in frequency than the video carrier, instead of 4.5 mc higher as it was in the transmitted signal.

Similarly, the color i-f subcarrier will be 3.58 mc lower in frequency than the video i-f carrier. This is the most important fact to remember about the action of the tuner on sound and color signals. To fix this fact firmly in mind, let us go through an example with actual frequencies as they would be treated in a typical receiver. Since we are primarily concerned here with the sound section of the receiver, we will consider a monochrome transmission. Remember, however, that the color subcarrier is reversed in the same way.

Let's say that a modern television receiver is tuned
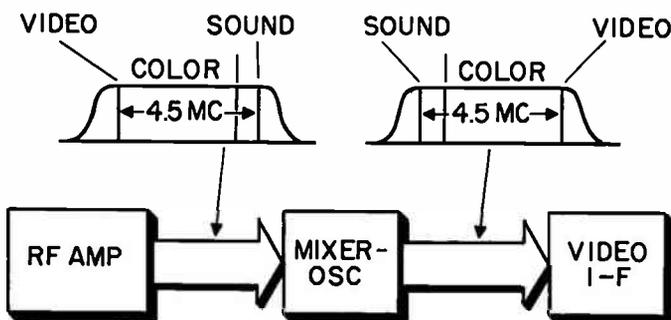
to Channel 2. You will recall that Channel 2 covers a 6-mc band from 54 to 60 mc. This complete band will be amplified by the rf amplifier. The picture carrier frequency within this band is 55.25 mc and the sound carrier frequency is 59.75 mc. In most modern receivers the local oscillator frequency will be 101 mc. In the mixer section of the receiver, the picture carrier frequency of 55.25 mc is beat against the 101-mc local oscillator signal producing an i-f picture carrier, the frequency of which is 45.75 mc. The 59.75-mc sound carrier frequency will also be beat against the 101-mc oscillator signal, producing an i-f sound carrier frequency of 41.25 mc. Thus, at the output of the mixer section of the tuner, we have a sound carrier which is 4.5 mc lower in frequency than the picture carrier.

I-F SYSTEMS

Except for the tuner, early television receivers were actually two receivers: one for the picture signal and the other for the sound. In these receivers the sound signal was picked off the output of the tuner and amplified through two or three sound i-f stages; then it was detected, amplified in an audio amplifier, and delivered to the speaker.

In modern TV receivers, the sound signals accompany the video signals through the video i-f amplifier. In monochrome receivers the sound and video i-f signals are both fed to the video detector. In the video detector a beat frequency of 4.5 mc is produced by beating the sound carrier against the video carrier. This frequency becomes the sound i-f, which is taken off either immediately after the video detector or after the video amplifier. When this system, which is called the intercarrier sound system, is used, we need only one sound i-f stage in most receivers. The economy of this system is one reason why it has displaced the old system of separating the sound and video signals at the tuner output.

In color TV receivers, the 41.25-mc sound signal is prevented from reaching the video detector. Instead of letting the sound and video signals beat together in the video detector, sound and video i-f signals are taken off from the last video i-f stage by means of a small capacitor. The small capacitor is used to keep the loading on the last i-f stage as small as possible. The two signals are then fed to a separate diode where they beat together and produce the 4.5-mc sound signal. The reason for preventing the 41.25-mc sound i-f signal from reaching the detector is that it will beat with the color subcarrier, which has a frequency of approximately 42.17 mc, and produce a 920-kc beat. This 920-kc beat signal will show up as an interference on the face of the picture tube.

The sound i-f is tuned to 4.5 mc regardless of the video i-f carrier frequencies. This 4.5-mc signal with its complex modulation is amplified by the sound i-f and then fed to an FM detector. Here any amplitude modulation is wiped out, with the result that only the frequency modulation produces an audio signal. (Of course, if any stage in the chain handling the 4.5-mc signal is overloaded by this or any other signal, cross-modulation products will be set up, with the result that some of the video modulation may cause a hum from the loudspeaker.)

Intercarrier Beat.

The FM detector is supposed to remove all amplitude variations from the i-f beat signal produced in the intercarrier system. To make it easier for the detector to do so, the amplitude modulation in the beat signal is kept as small as possible. This is done by taking advantage of two facts:

1. When two signals are allowed to beat together, and one signal is very much weaker than the other, the amplitude of the beat signal is approximately equal to the amplitude of the weaker signal and practically independent of the amplitude of the strong signal.

2. If either of two beating signals is frequency-modulated, the complete frequency modulation appears in the beat signal.

These characteristics of beat signals are made use of in the intercarrier system by reducing the strength of the sound carrier, so that it is far weaker than the video i-f carrier when the two signals are applied to the video demodulator. As a result, the amplitude of the 4.5-mc beat signal, which is frequency-modulated by the sound, depends upon the amplitude of the sound i-f signal.

The sound i-f carrier can be reduced to the desired strength (about 5% or 10% of the video i-f carrier strength) in an intercarrier set by using video i-f stages having the response shown in Fig. 35A. Notice
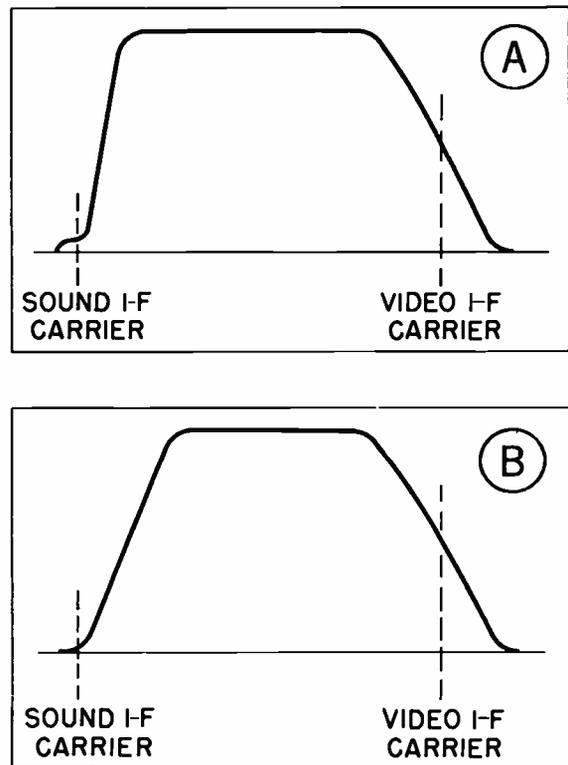
Fig. 35. The ideal video i-f response of an intercarrier set (A). Often used is the response shown in (B).
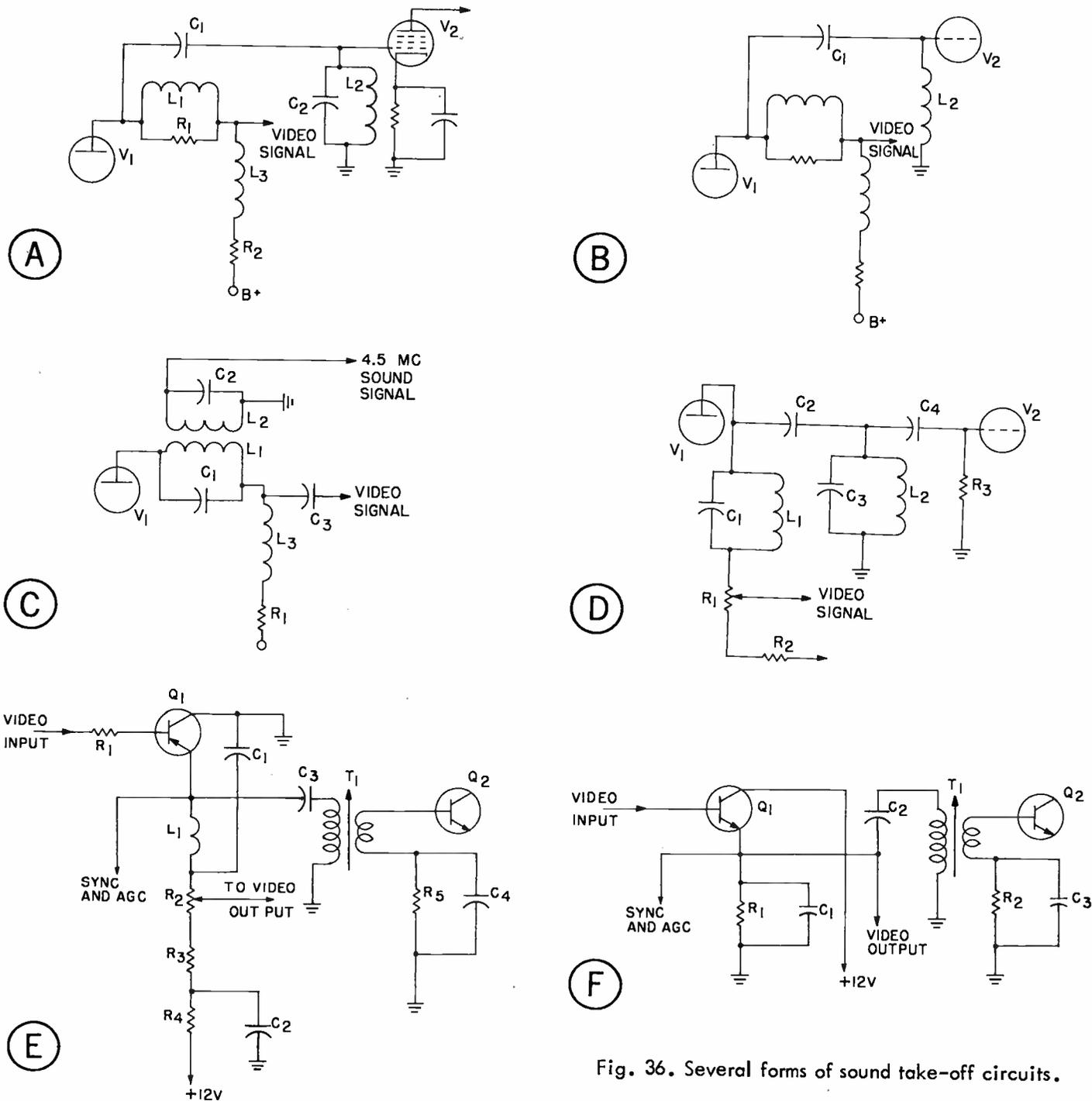
Fig. 36. Several forms of sound take-off circuits.

that this response has a small flat plateau around the sound i-f carrier frequency; as a result, there is little possibility of slope detection of this carrier and consequently little chance of cross-modulation. The shape and amplitude of the response at this frequency are determined by the alignment of the i-f amplifier and by the judicious use of traps.

Because of the difficulty of securing the response shown in Fig. 35A, the one pictured in Fig. 35B is used. There is no plateau at the sound-carrier frequency in the latter; instead, the response is made low at the sound i-f frequency by some type of trap tuned to 41.25 mc.

Since the sound i-f carrier is held at a fairly low value in passing through the video i-f section of the TV receiver, most of the amplification it is to get must be received in some later section. In color TV receivers, all the additional gain needed before the sound detector must be obtained in a separate 4.5-mc sound i-f amplifier. In a monochrome receiver, the video amplifier may be used to furnish at least part of the required amplification so that very little gain may be needed in the 4.5-mc sound i-f amplifier.

Sound Takeoff: Monochrome Receivers.

In monochrome receivers, the 4.5-mc beat can be taken right from the output of the video detector, but in order to get a stronger signal, it is often taken from the output of the video amplifier. Trap circuits are commonly used as sound take-offs.

Fig. 36 shows some forms of trap take-offs. In the

simplest, a parallel-resonant circuit, L_2-C_2, tuned to the 4.5 mc carrier, is placed in the grid circuit of the sound channel amplifier, V_2, and is fed through coupling capacitor C_1 from the plate of the video amplifier, V_1.

A disadvantage of this arrangement is that it does not reduce the amount of the 4.5-mc carrier in the video signal. The circuit shown in Fig. 36B is more satisfactory in this respect. Here, the coupling capacitor C_1 resonates with coil L_2 to form a series-resonant circuit at 4.5 mc. At resonance, this circuit offers a minimum load for the video amplifier V_1, so the output of V_1 at the 4.5-mc carrier frequency is minimized. On the other hand, since this is a series-resonant circuit, whatever 4.5-mc signal does appear across it will produce a maximum voltage across L_2 for application to the sound amplifier.

The arrangement shown in Fig. 36C also minimizes the amount of beat signal in the picture signal. Here, a parallel-resonant circuit tuned to 4.5 mc is connected in series with the load circuit of V_1. Most of the 4.5-mc beat signal in the output of V_1 is developed across this circuit, so very little is passed on through C_3 with the video signal. The sound carrier is fed to the sound amplifier from the resonant circuit L_2-C_2, which is tuned to 4.5 mc and inductively coupled to L_1-C_1.

Parallel-Resonant Circuit.

A variation of this circuit is shown in Fig. 36D. Here L_1-C_1 forms a parallel-resonant circuit to keep the 4.5-mc signal out of the video. Coupling from the video amplifier V_1 to the sound i-f is through C_2. C_3-L_2 is resonant at 4.5 mc and forms the input-tuned circuit for the sound system. The signal is coupled from

this resonant circuit to the grid of the sound i-f tube, V_2, through the capacitor C_4.

The sound take-off from a transistor receiver is shown in Fig. 36E. Notice that a PNP transistor is used as the video amplifier in an emitter-follower circuit. The sound signal is taken directly from the emitter of the transistor and fed through C_3 to the primary winding at the sound input i-f transformer T_1. The primary of the transformer and the capacitor C_3 form a series-resonant circuit that is resonant at 4.5 mc. Thus a strong sound signal flows through the primary winding of the transformer which will induce a strong sound signal into the secondary. This signal is fed to the base of Q_2, the sound i-f amplifier.

At the same time, the 4.5-mc series-resonant circuit offers a low impedance to 4.5-mc signals so that very little 4.5-mc signal will be developed between the emitter and ground of Q_1. The video signal is taken through L_1 to R_2, which is the contrast control, and fed from the sliding arm on the contrast control to the video-output stage.

Another transistor sound take-off circuit is shown in Fig. 36F. This circuit is essentially the same, except that in this case the video amplifier Q_1 uses an NPN transistor. Again, the emitter-follower circuit is used and the sound signal is fed from the emitter through C_2 to the primary winding of T_1. C_2 and the primary winding of T_1 form a series-resonant circuit at 4.5 mc. The video signal is taken directly from the emitter of Q_1 and fed to the base of the video-output stage. Once again, the series-resonant circuit connected between the emitter of Q_1 and ground keeps the amplitude of the 4.5-mc signal fed to the following video stage at a low value.
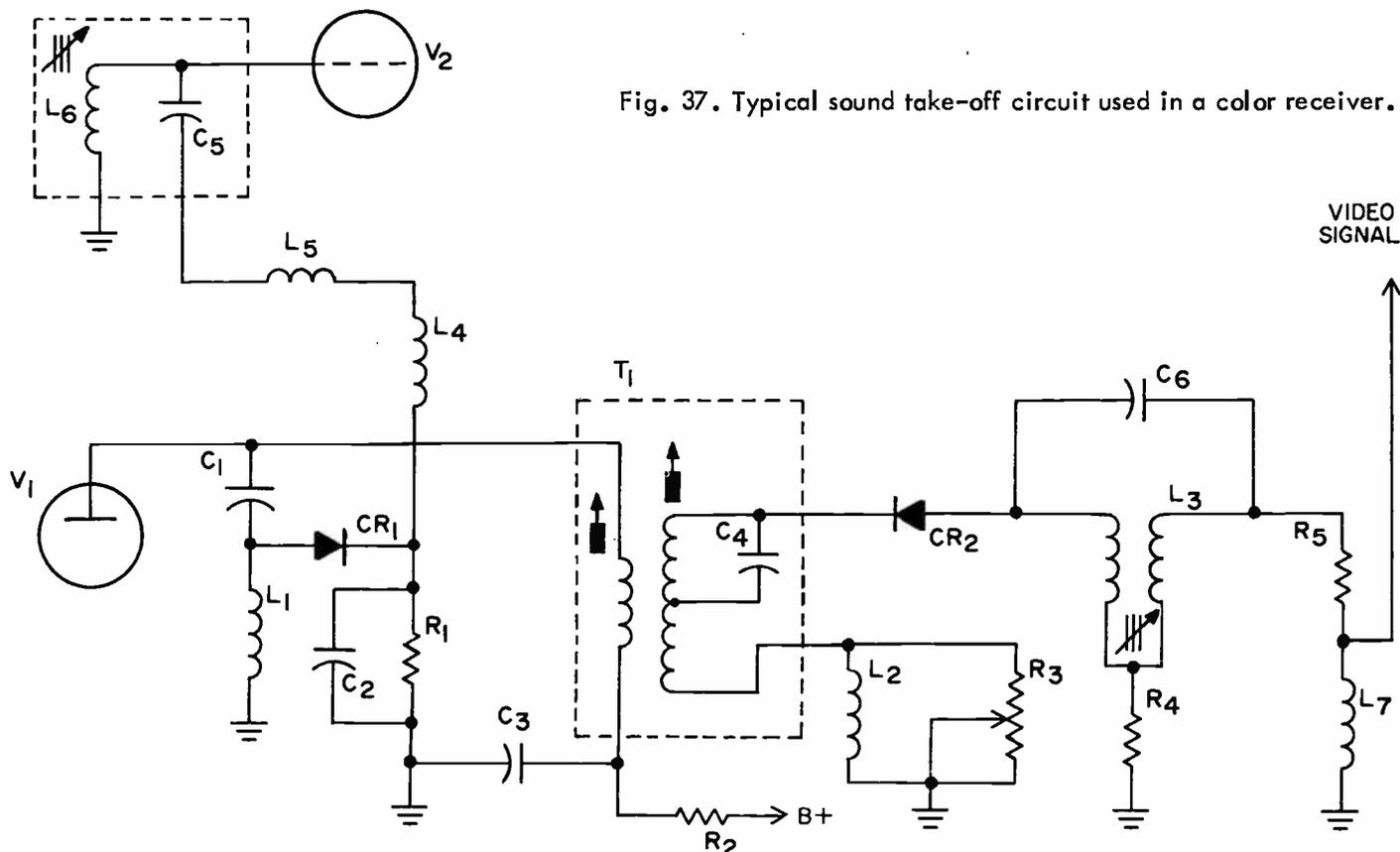
Fig. 37. Typical sound take-off circuit used in a color receiver.
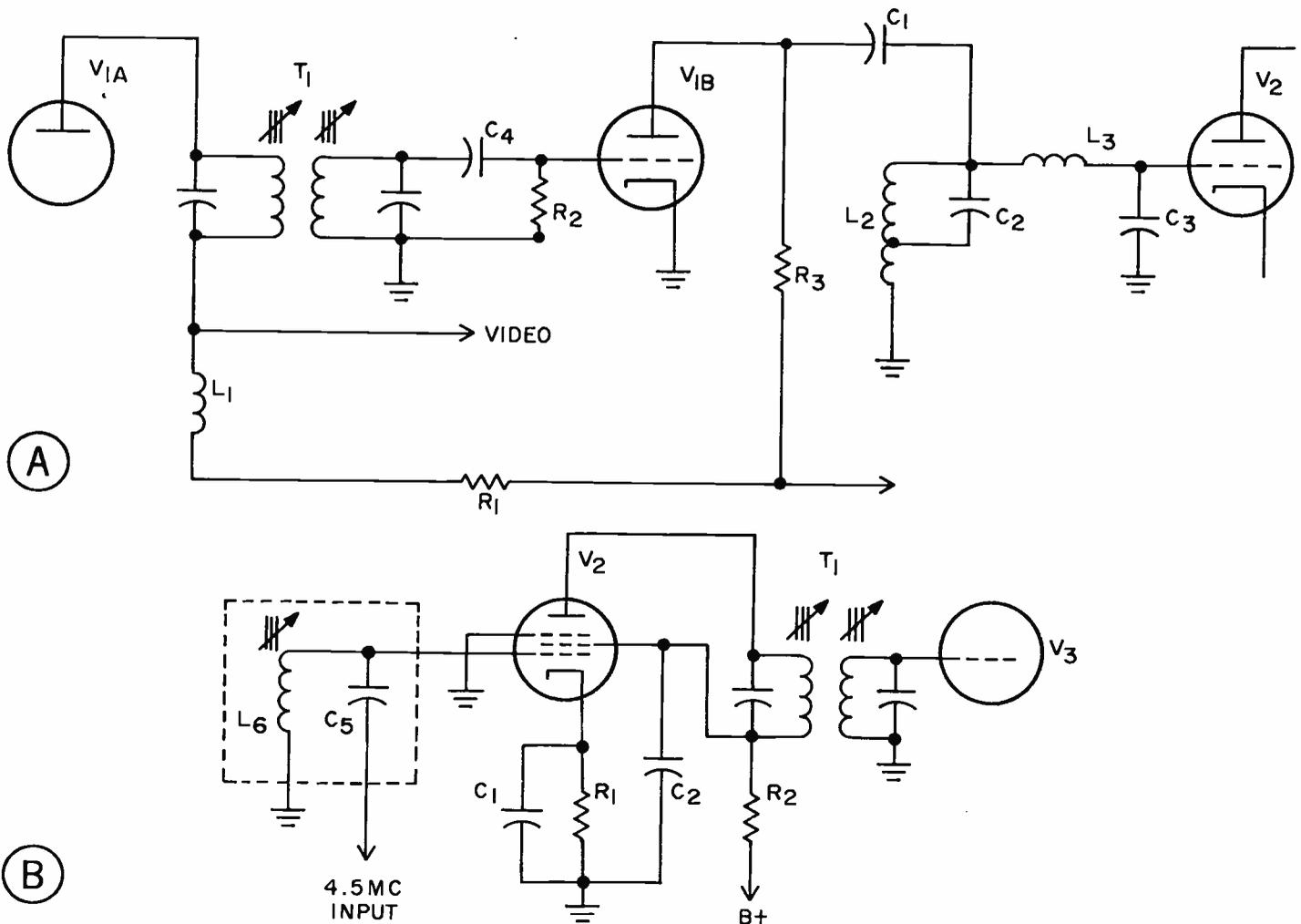
Fig. 38. A typical 4.5 mc sound i-f amplifier.

Sound Takeoff: Color Receivers.

The sound take-off circuit used in a typical color TV receiver is shown in Fig. 37. V_1 is the last video i-f amplifier in the receiver, V_2 is the 4.5-mc sound i-f amplifier. CR_1 is called the sound detector; its purpose in the circuit is to produce a 4.5-mc sound signal at the video i-f output.

In circuits of this type, the 41.25-mc sound i-f signal and the 45.75-mc video i-f signal are taken from the plate circuit of the last video i-f stage through a small capacitor, such as C_1 in Fig. 37. This capacitor will usually have a value of from 1 to 2 pf, so the coupling to the last i-f stage is light and hence does not affect the response of the video detector transformer appreciably.

The 41.25-mc sound i-f signal and the 45.75-mc video signal beat together in CR_1 to produce a 4.5-mc signal across the parallel combination of C_2-R_1. L_1 completes the detector circuit; its inductance is high enough to prevent the 41.25-mc or 45.75-mc signals from flowing through it, but low enough not to affect the 4.5-mc signal. The 4.5-mc signal developed across C_2 and R_1 is fed through L_4, L_5 and C_5 to the grid of V_2, the sound i-f amplifier. L_6, along with the grid-to-cathode capacity, stray-circuit capacity and C_5, from a 4.5-mc resonant circuit.

From the plate circuit of V_1, the video i-f signal

with the color subcarrier superimposed on it and the 41.25-mc sound signal are fed to the video detector transformer T_1. If there is any of the 4.5-mc signal in the plate circuit of V_1, it can't get across the transformer which operates up in the 45-mc region.

The potentiometer R_3 is called a sound rejection control. Along with L_2 and T_1 it keeps the 41.25-mc signal getting through T_1 as low as possible. Any of the 41.25-mc signal that does get through T_1 to the video detector CR_2 will beat with the video i-f signal to produce a 4.5-mc signal. This 4.5-mc signal is then trapped by L_3.

This circuit is typical of what you can expect in color TV receivers. The sound is taken off before the video detector to keep the sound signal from producing interference in the picture and to keep it from beating with the color signal to produce a 920-kc interference pattern.

As we mentioned earlier, the 4.5-mc sound amplifier usually consists of only a single stage (tuned to 4.5 mc but otherwise like a conventional sound i-f stage). In modern black-and-white receivers, where dual and triple section tubes are often used, the sound i-f stage may be a triode as shown in Fig. 38A. In color receivers the sound i-f stage is usually a pentode tube. A typical 4.5-mc sound i-f amplifier from
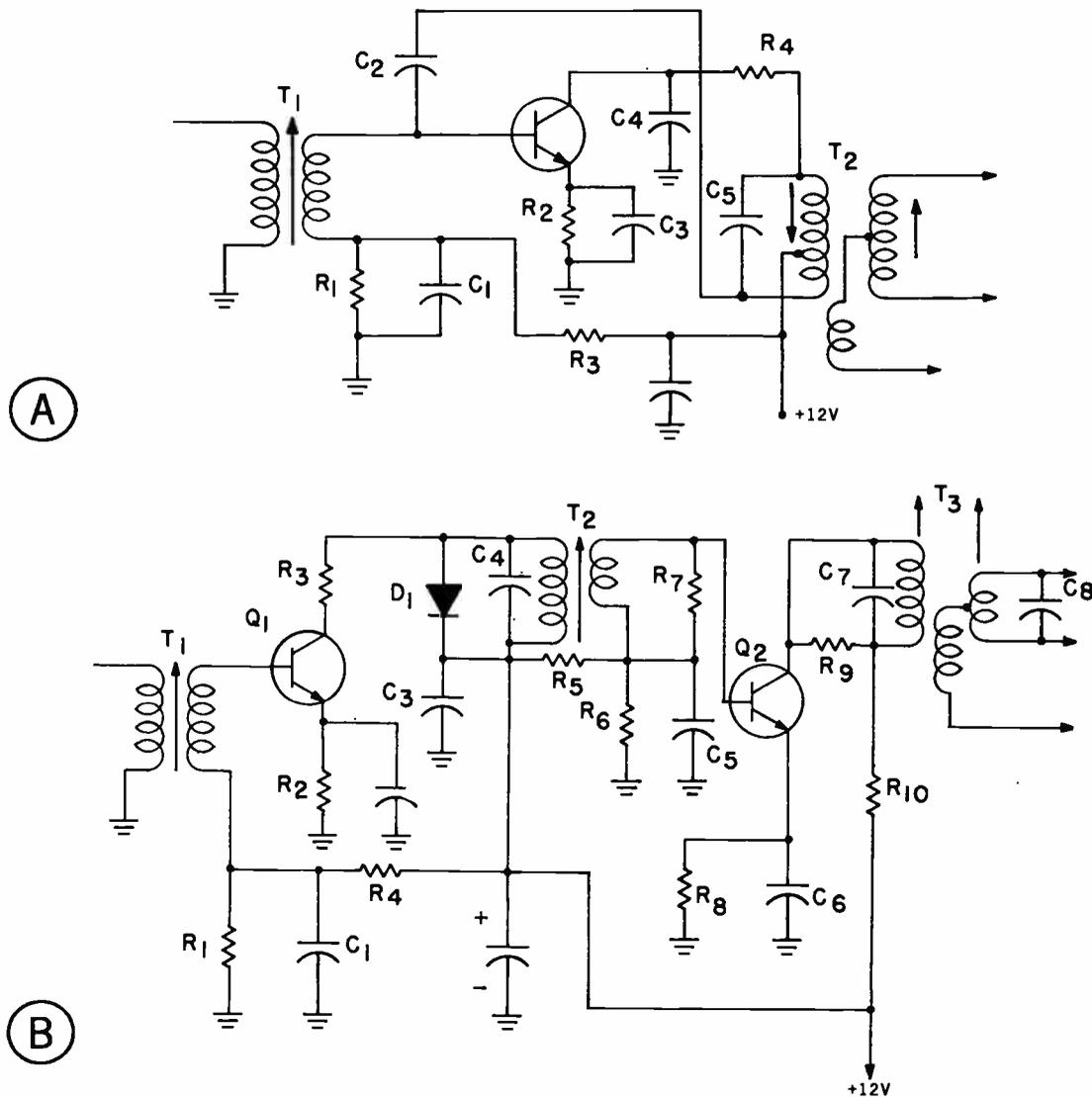
Fig. 39. Transistor sound i-f amplifiers.

a color receiver is shown in Fig. 38B. This is taken from the same receiver as the sound take-off circuit shown in Fig. 37. L_6, C_5 and V_2 are the same in Fig. 37 and Fig. 38B.

In the circuit shown in Fig. 38A, V_{1A} is the video output tube. The parallel-resonant circuit in the plate circuit of V_{1A} keeps the 4.5-mc signal out of the video circuit. The secondary of T_1 is inductively coupled and forms a 4.5-mc series-resonant circuit in the input to V_{1B}. V_{1B} is a triode and is in the same envelope as V_{1A}. This makes a very convenient arrangement, particularly where printed circuits are used.

The schematic diagram of a transistor sound i-f amplifier is shown in Fig. 39A. This is the i-f amplifier that is used with the sound take-off shown in Fig. 36E. The high sound signal current flowing in the primary of T_1 induces a strong 4.5-mc signal in the secondary and this signal is applied to the base of the i-f amplifier transistor, and to the emitter through C_1 and C_3. The NPN transistor is connected in the common-emitter circuit. An amplified signal current flows through R_4 and through the primary winding of T_2 which is tuned to resonance at 4.5 mc. A signal is

taken from the lower end of the primary winding of T_2 and fed through C_2 back to the base of the transistor for neutralization. Forward bias for the base is provided by the resistor network consisting of R_1 and R_3; emitter bias to prevent thermal runaway is provided by the resistor R_2 in the emitter circuit.

TWO-STAGE SOUND I-F AMPLIFIERS

In the circuit in Fig. 39B we have shown a transistor sound i-f amplifier that uses two amplifier stages. This amplifier is used with the sound take-off circuit shown in Fig. 36F.

Both stages use NPN transistors. The primary of T_1 and the primary of T_2 tune to resonance at 4.5 mc. The secondary of T_1 and the secondary of T_2 form a step-down transformer to match the input impedance of the transistors Q_1 and Q_2. Both halves of the output i-f transformer T_3 are tuned. The diode connected across the primary winding of T_2 is an overload diode. Normally, no current will flow through this diode because the cathode and anode will have essentially the same potential. However, in the event that the signal

from Q_1 is extremely strong, the anode will be driven positive with respect to the cathode and the diode will conduct. This will lower the impedance of the primary winding of T_2 and reduce the signal developed across it.

In some transistor receivers you'll find two-stage sound i-f amplifiers. The gain per transistor stage is usually not as high as the gain that can be obtained with modern high-gain tubes; therefore, in transistor receivers it is sometimes necessary to use two-stage amplifiers. However, in a circuit such as that shown in Fig. 39B, you can expect the gain per stage to be less than the gain obtained per stage in the single-stage amplifier in the figure shown in 39A. However, the overall gain of the two-stage amplifier will be higher than the gain of the single-stage amplifier.

In the intercarrier system, the 4.5-mc sound i-f is not produced by the local oscillator in the receiver, but by the oscillators at the TV station. These oscillators generate the video and sound carrier signals and keep them exactly 4.5 mc apart. As a result, drift in the local oscillator in the TV tuner does not present any trouble insofar as changing the frequency of the 4.5-mc sound signal is concerned. The only thing that an oscillator shift can do is change the relative levels of the sound and video i-f carriers to such an extent that the sound signal may have an undesired amount of video signal in it; or, if the shift is very large, the sound beat signal may become somewhat weakened. In general, however, the oscillator could drift far more than it is likely to without causing any sound problems. This advantage, along with its obvious economy, has made the intercarrier system standard in modern receivers.

SOUND DETECTORS

The three principal types of sound detectors that you are apt to find in TV receivers are the limiter-discriminator combination, the ratio detector, and the quadrature grid FM detector. You will most likely find the limiter and discriminator in older sets and in some of the new high-priced receivers featuring complete radio-TV and stereo sound systems. The older receivers using the discriminator or ratio detector will probably use double diode vacuum tubes as the detector, whereas modern sets generally use solid state diodes. Regardless of the type of diode used, the operation is the same.

Most modern TV receivers use the quadrature grid detector. The ratio detector was widely used for a number of years between the time the limiter-discriminator was dropped and the quadrature grid detector came into wide usage.

Limiter-Discriminators.

A typical limiter-discriminator circuit is shown in Fig. 40. Here, the limiter stage, V_1, is much like any other i-f amplifier stage except that the bleeder resistor R_5 and the series resistor R_6 make the screen grid and plate voltage on this stage very low--only about 48 volts. These low operating voltages make the upper knee of the characteristic response of this stage very low and sharp.

The grid circuit contains a grid leak resistor and capacitor combination R_4-C_9. Capacitor C_9 tends to keep charged to the average voltage of the peaks of the input signal, thus maintaining a steady bias on the tube that will keep its output constant even if the input signal undergoes sudden momentary changes in amplitude.
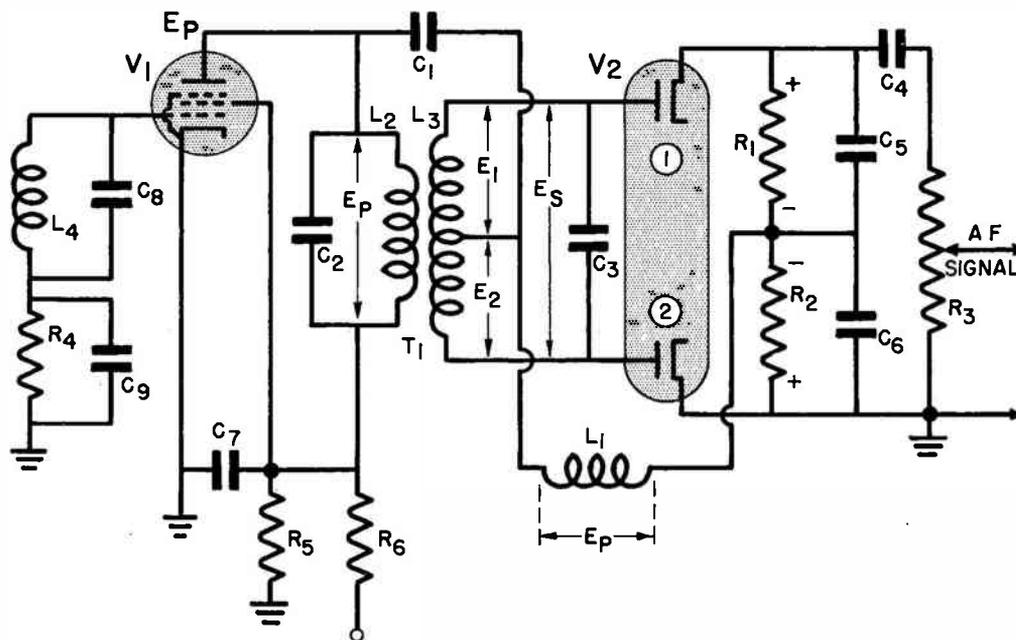
Fig. 40. Schematic diagram of a typical FM limiter-discriminator section.

This capacitor therefore minimizes the effect of noise when the signal is weak.

When the signal is strong, the low voltages applied to the screen and plate effectively wipe out amplitude changes in the input signal. Because these voltages are so low, the output of the stage will not go above a certain limit no matter how strong the input signal becomes. Thus, if the strength of the FM signal is great enough to drive the stage to its full output, any increases in signal strength caused by noise accompanying the FM signal will not affect the output. In other words, the noise will be wiped out by the limiter stage. (In an intercarrier system, this limiting action will also tend to wipe out any portions of the video signal that may accompany the sound carrier.)

The transformer T_1 transfers the signal from the limiter V_1 to the discriminator circuit, in which the double, diode tube V_2 is used. The primary circuit L_2-C_2 is tuned to the incoming signal. This signal is transferred to the tuned secondary circuit L_3-C_3 and is also fed through C_1 so that it appears across L_1.

The voltage induced in L_3 produces the voltages E_1 and E_2 across the two sections of this coil. These voltages are always equal in magnitude and 180° out-of-phase with each other.

The voltage applied to diode 1 of V_2 consists of E_1 plus the signal E_p that exists across L_1. (The path from L_1 to the cathode of this diode is through the bypass capacitor C_5, which is virtually a short at the frequencies involved.) Similarly, the voltage applied to diode 2 of V_2 consists of E_2 plus E_p, the path being completed through bypass capacitor C_6. Therefore, at resonance and with no modulation, equal voltages are applied to the diodes; as a result equal and opposite currents flow through the resistor R_1 and R_2. The voltage between the two cathodes of V_2 is zero under such conditions.

Off resonance (that is, at frequencies other than the resting or no-modulation frequency), however, the shift in phase relationships cause the voltages applied to the two diodes to be unequal. When the applied signal swings below the resting frequency, the voltage applied to diode 1 of V_2 becomes greater than that applied to diode 2; consequently, a greater current flows through R_1 than through R_2. As a result, the voltage drops across the two resistors become unequal, and a net voltage appears across them that has the same polarity as the drop across R_1. Con-

versely, when the applied signal swings above the resting frequency, a net voltage appears across R_1 and R_2 that has the polarity of the drop across R_2.

Thus, swings of the applied signal above and below the resting frequency produce an ac voltage across R_1-R_2. This voltage feeds through C_4 to appear as the output voltage across R_3. At each instant the value of this output voltage is proportional to the deviation of the incoming signal frequency from the resting frequency. Thus, it is an audio signal voltage that corresponds to the one used to modulate the FM transmitter.

Ratio Detectors.

The use of a ratio detector eliminated the need for the limiter stage. Since it cut manufacturing costs, it is natural that for awhile before the development of the quadrature grid detector, it became almost universally used in TV receivers. A schematic diagram of a typical ratio detector circuit is shown in Fig. 41.

At first glance, this circuit is very similar to that of the discriminator you have just studied. However, there are two important differences--one of the diodes, D_2, is reversed, and a charge storage capacitor, C_4, has been added to the circuit.

At the resting frequency, the voltage E_p adds to E_1 and to E_2 to make both diodes conduct equally, just as in the discriminator. Because of the way they are connected, both diodes conduct at the same time, charging the equal capacitors C_2 and C_3 with the polarities shown. At the same time, capacitor C_4 is charged to a voltage that is equal to the sum of the voltages across C_2 and C_3.

The capacity of C_4 is such that the voltage across it cannot change very fast. As a result, the sum of the voltages across C_2 and C_3 will remain relatively constant unless the average strength of the received signal changes.

Now let us suppose that the incoming signal varies in frequency. When it shifts in one direction, one diode will conduct more than the other, so that the instantaneous voltages across C_2 and C_3 will no longer be equal. However, their sum will remain that of the charge across C_4--because the voltage across C_4 cannot change readily. Let us assume that diode D_1 momentarily conducts more current so that the voltage across C_2 goes up, and the voltage across C_3 drops, but the voltage across C_4 remains the same. There will now be a voltage difference between points M and N, because the voltage between the cathode of D_1 and point M has changed, while that between the cathode of D_1 and point N has not.

When the incoming frequency swings in the other direction, the opposite action will occur--the voltage across C_3 will become greater and that across C_2 will become less. As a result, a voltage difference of opposite polarity will be produced between points M and N.

The voltage difference between points M and N will therefore be an ac signal whose amplitude depends on how the amount of incoming signal deviates from the resting frequency and whose frequency depends on the rate at which the deviation occurs. In other words, it will be a reconstruction of the audio signal that was originally used to modulate the FM carrier.
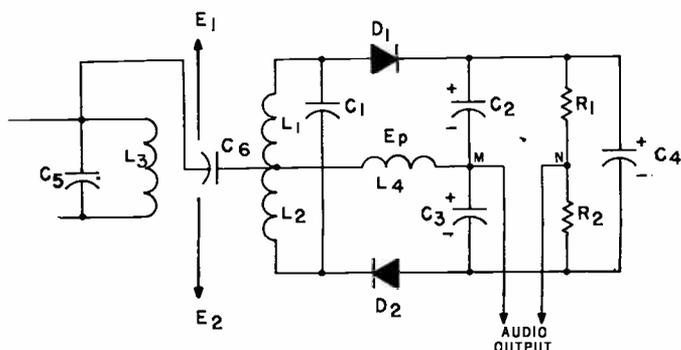
Fig. 41. A ratio detector circuit.
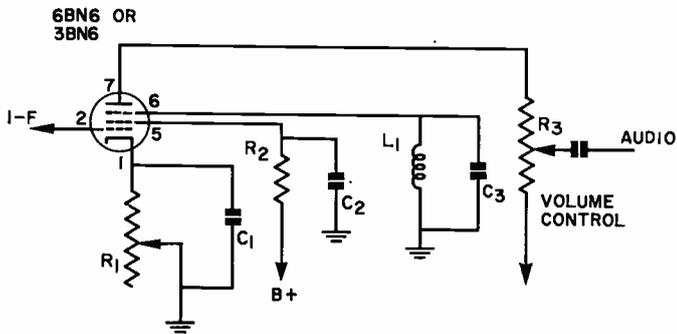
Fig. 42. Schematic of a gated-beam FM detector.

This circuit will not respond to amplitude variations in the input signal, because such changes will merely make both diodes conduct either more or less without making them conduct unevenly. As we have seen, the diodes must conduct different amounts of current to make any voltage difference appear between points M and N, and this difference in their conduction can be produced only by a change in the frequency of the applied signal. Therefore, any amplitude variations caused by noise or a video signal accompanying the FM signal will not appear in the output of the circuit.

As we pointed out earlier, manufacturers using the limiter-discriminator detector or the ratio detector have used germanium or silicon diodes in late model receivers in place of the vacuum-tube diode. The operation of these circuits is the same whether solid state diodes or tubes are used. However, the chances are that if germanium or silicon diodes are used, they are a matched pair. Solid state diodes are not as consistent as vacuum-tube diodes, so where diodes with identical characteristics are needed, they must be selected. If you have to replace one diode in either a discriminator circuit or a ratio detector, it will probably be worthwhile to get a matched pair and replace both diodes.

Quadrature Grid Detectors.

The quadrature grid detector also operates as both limiter and detector. Its principle of operation is somewhat different from that of the discriminator or the ratio detector, and it utilizes a tube of special construction. Either of two tube types can be used, a gated-beam tube such as the 6BN6 or 3BN6, or a dual control pentode such as the 6DT6 or 3DT6. The schematic diagram for a typical gated-beam detector circuit is shown in Fig. 42.

The limiting action of the gated-beam tube is caused by the sharp cut-off and saturation characteristics of the grid-voltage plate-current curve as shown in Fig. 43. From this curve you can see that if the tube is biased at the mid-point of the curve, slightly over -4 volts, it takes a positive grid swing of only slightly over 1 volt to reach saturation and a negative swing of about a volt and a half to reach the cut-off point. Thus, when a normal i-f signal is applied to the grid, the positive half of the i-f cycle will drive the tube to saturation, and the negative half cycle will drive the tube to cut-off, so that any amplitude variations in the signal are effectively eliminated. The current flow

through the tube then looks like a limited square wave.

To understand the detector action of this tube, some explanation of the function of the various grids it contains is necessary. The construction of the tube is such that a beam of electrons is formed at the cathode and attempts to travel from cathode to plate. The grid attached to pin 5 is known as the accelerator, and its function is to speed the beam on its way. The other two grids may be referred to as gates. In order for the electron stream to flow from cathode to plate, both gates must be open. That is, they must have a potential on them that will allow the electron stream to pass. When the tube is acting as both limiter and detector, the first gate is cutting off the peaks of the incoming signal, thus performing the limiting function. The accelerator grid has a positive potential applied and its physical shape is such that it helps form the electron beam at the same time that it accelerates it on its trip toward the plate. The second gate (pin 6) is connected to a resonant circuit consisting of L_1 and C_3. The parallel-resonant circuit is resonant at the center frequency of the incoming i-f signal. This circuit will oscillate, because of the space charge within the tube, but its oscillations will lag behind those of the incoming signal by 90°. Thus, both gates are open together for only a fraction of a complete cycle.

When the incoming i-f signal deviates from the center frequency, the phase relationship between the two signals is changed, and consequently the length of time that both gates are open is changed. If the frequency of the incoming signal increases, the two gates are open together for a shorter time, allowing less average plate current to flow. If the incoming frequency decreases, the two gates are opened together for a longer time, allowing more average plate
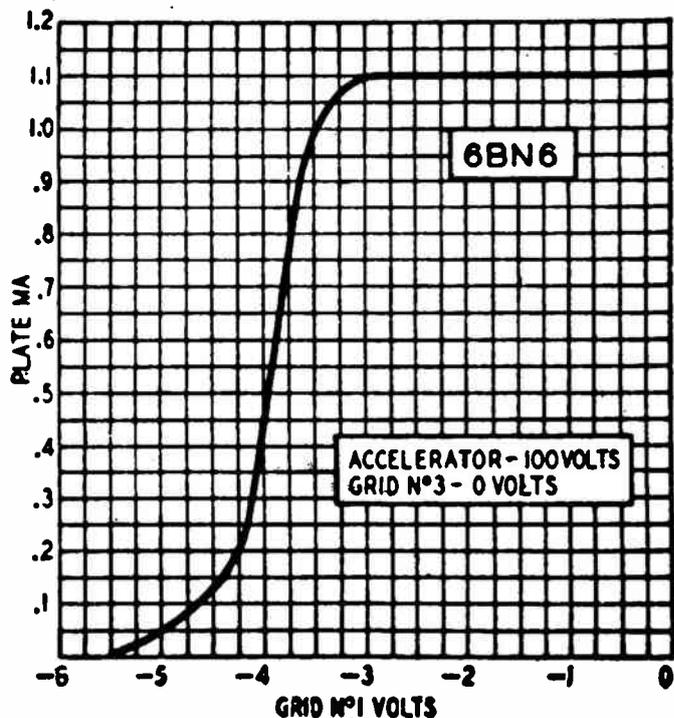
Fig. 43. The grid voltage-plate current curve of a gated-beam tube.
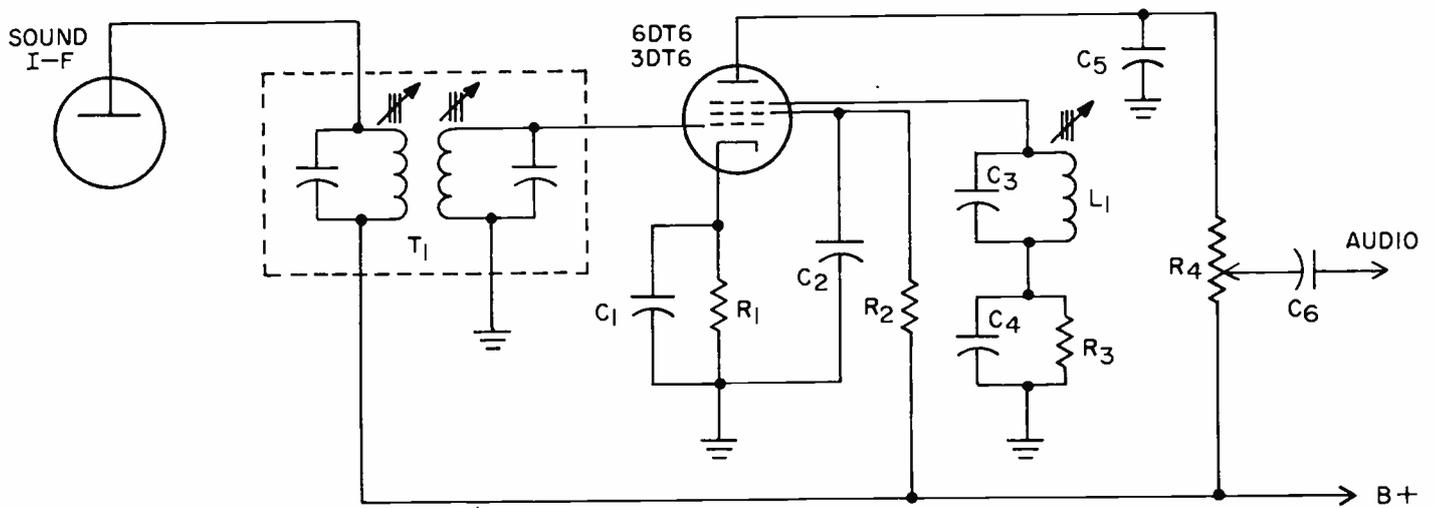
Fig. 44. Quadrature grid detector using a 6DT6 type of tube.

current to flow. Thus, the plate current of the tube varies in amplitude with the frequency of the incoming i-f signal, producing an audio signal.

The potentiometer in the cathode circuit of the 6BN6 tube sets the operating bias on the tube to the correct value for AM limiting. This control is called a buzz control, because there may be some buzz from the amplitude-modulation produced by the sync pulses on the 4.5-mc signal when this control is not set correctly. Careful adjustment of the control will set the tube on the correct point on the curve to provide adequate AM limiting and eliminate any sync pulse buzz.

The circuit shown in Fig. 44 is not too different from the one shown in Fig. 42. The basic operation is the same, but in this circuit, the resistance between grid 3 and ground permits this grid to develop its own bias. The circuit has the advantage in that the buzz control can usually be omitted.

In addition to performing the limiting and detector functions, the quadrature grid detector will supply enough audio amplification to drive a power amplifier tube, so that one stage of audio amplification may be eliminated. Thus, after the quadrature grid detector, there is need for only the power amplifier to drive the speaker, which completes the audio system. Where other types of sound detectors are used, it is usually necessary to have two stages of audio amplification.

INTEGRATED I-F AND DETECTOR CIRCUITS

One of the newer developments that has found its way from computers into TV receivers is the integrated circuit. In an integrated circuit a number of transistors and resistors are all contained within a single unit. A single integrated circuit may be used as a combination i-f amplifier and the sound detector in a television receiver. The schematic diagram of an integrated circuit used in such an application is shown in Fig. 45.

First, notice the symbol used to represent the two stages in the schematic diagram. The first triangle on the left represents the i-f amplifier and the second triangle on the right represents the detector circuit.
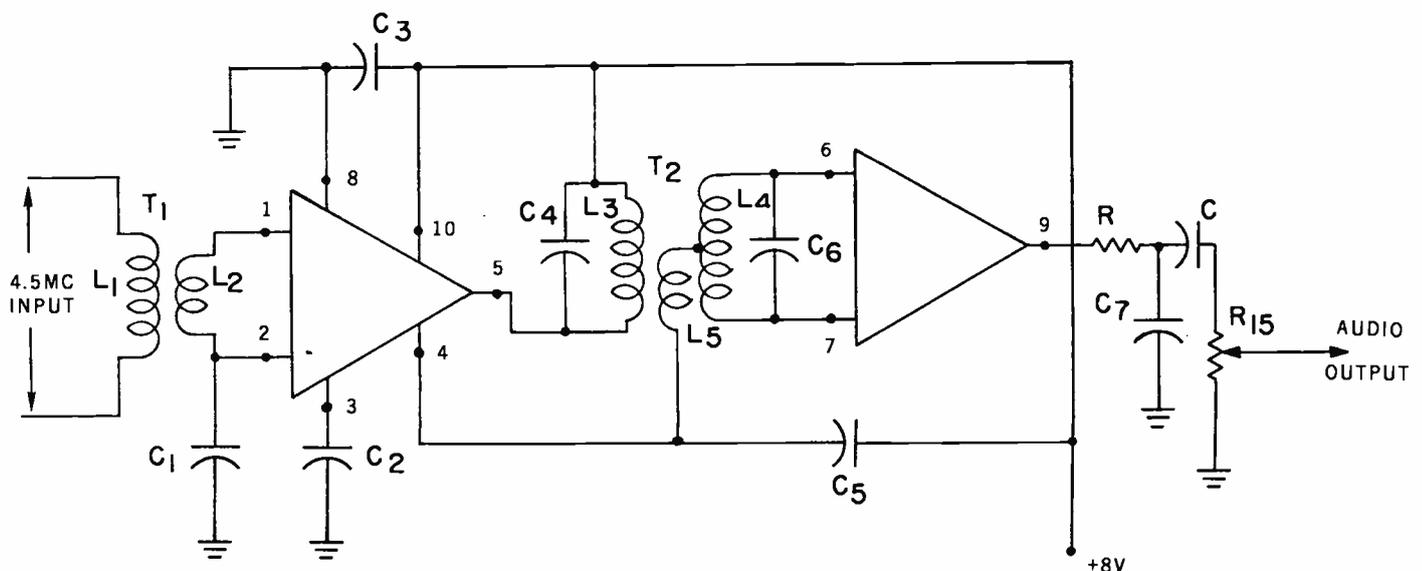
Fig. 45. An integrated circuit sound i-f and detector.
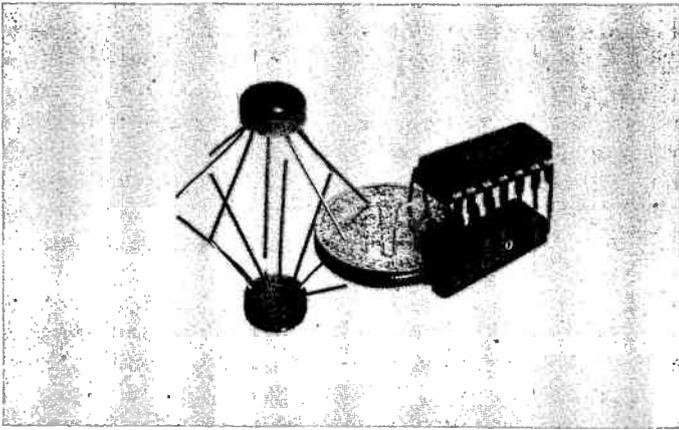
Fig. 46. Photo of an integrated circuit.

To give you an idea of the size of an integrated circuit, Fig. 46 shows a typical integrated circuit beside a dime. Notice that the diameter of the integrated circuit is less than that of the dime.

The schematic diagram of the complete integrated circuit used in Fig. 45 is shown in Fig. 47. Notice that we have omitted the circles usually used around the transistors because manufacturers do this most frequently in drawing schematic diagrams of integrated circuits. We have drawn the diagram deliberately this way so you'll get used to seeing it.

In the circuit in Fig. 47, you'll notice a number of terminals that are numbered. These terminals correspond to the terminals on the integrated circuit shown in the schematic diagram in Fig. 45. Also notice the group of diodes labelled D_1 and D_2. The circuitry to the left of these diodes is primarily the i-f amplifier whereas the circuitry to the right is the detector circuit. At first glance this circuit might appear quite complicated, but if we examine it step by step we'll see that it is not as complex as it seems.

Going back to Fig. 45, notice that the input i-f transformer, T_1, feeds to terminals 1 and 2 of the integrated circuit. Also notice that terminal 2 is grounded through capacitor C_1. Therefore, the actual i-f signal is fed into terminal 1.

Now look at Fig. 47 and note that terminal 1 connects to the base of Q_1. Q_1 and Q_2 make up what is called a differential amplifier. In Fig. 48 we have redrawn the schematic diagram of this amplifier so you can see how it works.

In a differential amplifier we can feed two signals, e_1 and e_2, into the amplifier. Signal e_1 is fed into the base of Q_1 and e_2 is fed into the base of Q_2. Let's suppose these signal voltages are equal and in phase. When e_1 drives the base of Q_1 in a positive direction, the current flow through Q_1 will increase. This will result in an increased voltage drop across R_1. In other words, the emitter of Q_2 will be swung in a posi-
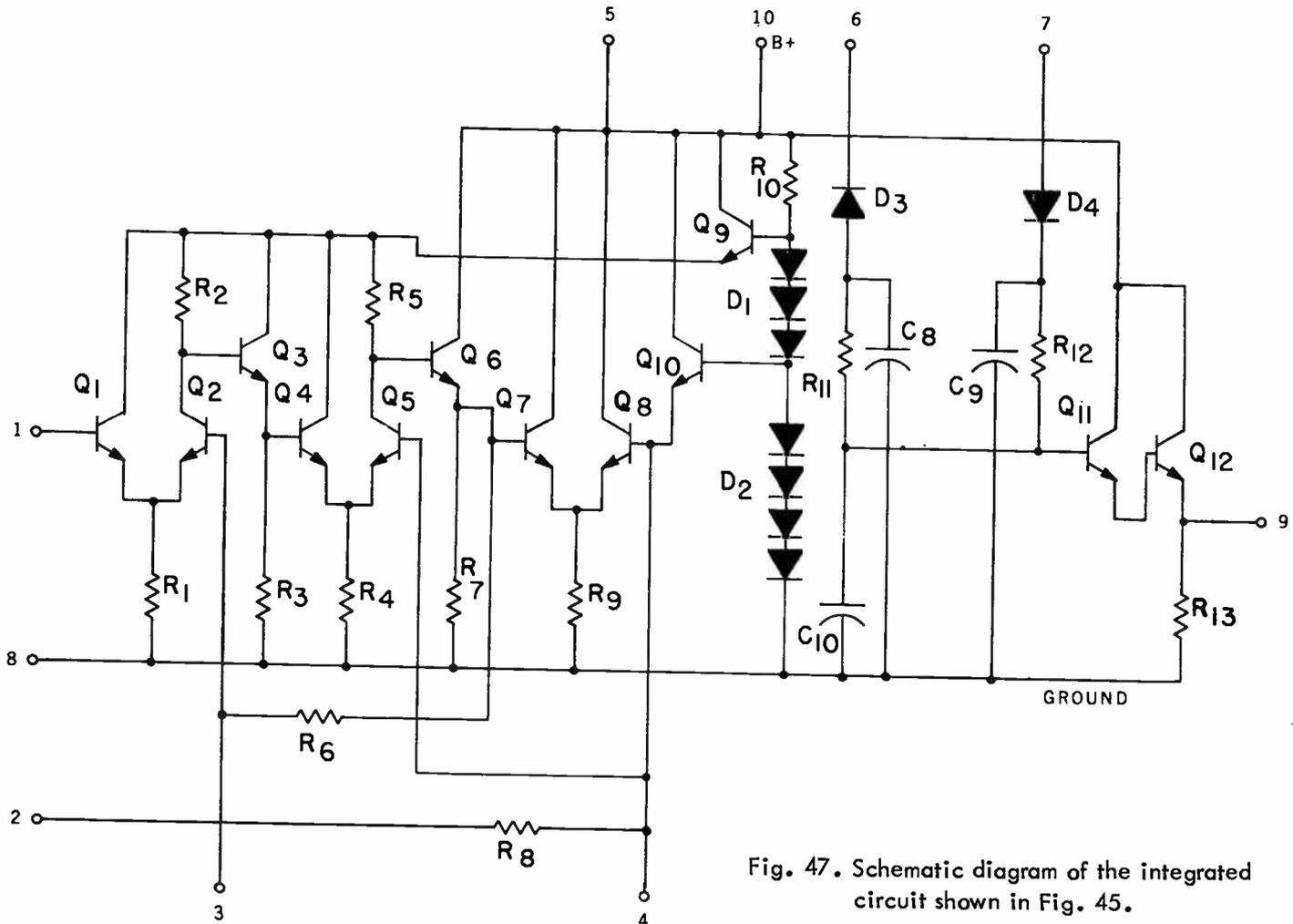
Fig. 47. Schematic diagram of the integrated circuit shown in Fig. 45.
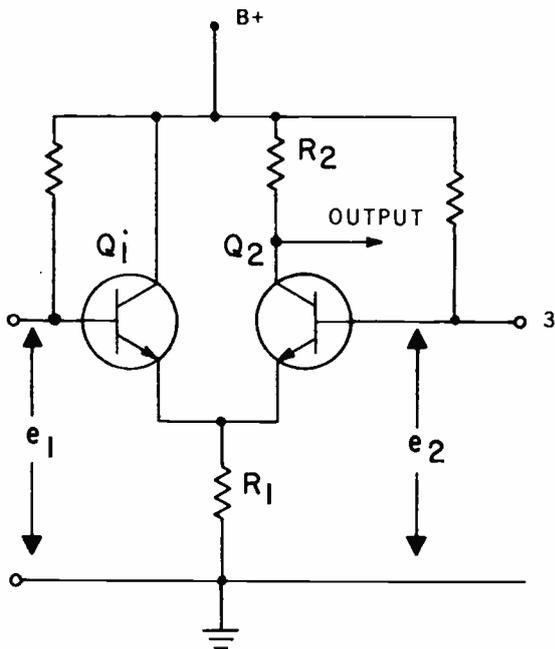
Fig. 48. Schematic diagram of a differential amplifier.

tive direction. The amplitude of the voltage across R_1 will be almost equal to the input voltage e_1. Now if the voltage e_2 swings the base of the transistor Q_2 in the positive direction, the net change in voltage between the base and emitter of Q_2 is practically zero. There will be some slight increase, and this might produce an output from Q_2 if it were not for the fact that the net collector-to-emitter voltage across Q_2 will go down because the emitter has moved in a positive direction. Therefore, if an equal in-phase voltage is fed to the two bases, the net output from the differential amplifier is effectively zero.

If instead of feeding the signal into the base of Q_2, we ground Q_2, then when e_1 swings the base of Q_1 in a positive direction, the emitter voltage will swing in a positive direction. This will cause the forward bias across the emitter-base junction of Q_2 to go down and therefore the current flow through Q_2 will go down. When this happens, the voltage drop across R_2 will decrease; in other words, the voltage at the collector of Q_2 will swing in a positive direction.

Similarly, if the voltage e_1 swings in a negative direction, current flow through Q_1 will decrease; this means that the voltage across R_1 will swing in a negative direction. As a result, the emitter-base forward bias across Q_2 increases, causing the current flow through Q_2 to increase. This increases the voltage drop across R_2 so that the collector of Q_2 will swing in a negative direction. Thus by grounding the base of e_2 and feeding an input signal into the base of Q_1 we can get an amplified signal at the collector of Q_2.

Now, looking back at the integrated circuit shown in Fig. 47, notice that the base of Q_2 connects to terminal 3. If we refer back to Fig. 45 we see that terminal 3 is connected to ground through C_2. Therefore, as far as the signal is concerned the base of Q_2 is at ground potential. The signal fed into the base of Q_1 will produce an amplified signal voltage at the collector of Q_2. This voltage is fed to the base of Q_3, which

is connected as an emitter-follower. The signal between the emitter and ground of Q_3 is fed to the base of Q_4.

The combination of Q_4 and Q_5 forms another differential amplifier. This differential amplifier amplifies the signal fed to the base of Q_4 and an amplified signal output appears at the collector of Q_5. Once again, this signal is fed to the base of Q_6, which is also connected as an emitter-follower, and the signal between the emitter and ground of Q_6 is fed to the base of Q_7. Q_7 and Q_8 form another differential amplifier. The collector of Q_8 is fed to terminal 5 of the integrated circuit and this in turn connects to the primary of T_2. The parallel-resonant circuit making up the primary winding of the output i-f transformer T_2 forms the load for this differential amplifier. This winding is inductively coupled to L_4 and L_5, so voltages are induced in these windings.

The diodes D_1 and D_2 are all connected so that they are forward-biased. There is a small voltage drop across each forward-biased diode. The voltage drop will remain essentially constant. Therefore, these diodes are used for voltage regulation. The voltage drop across D_2 holds the voltage at the base
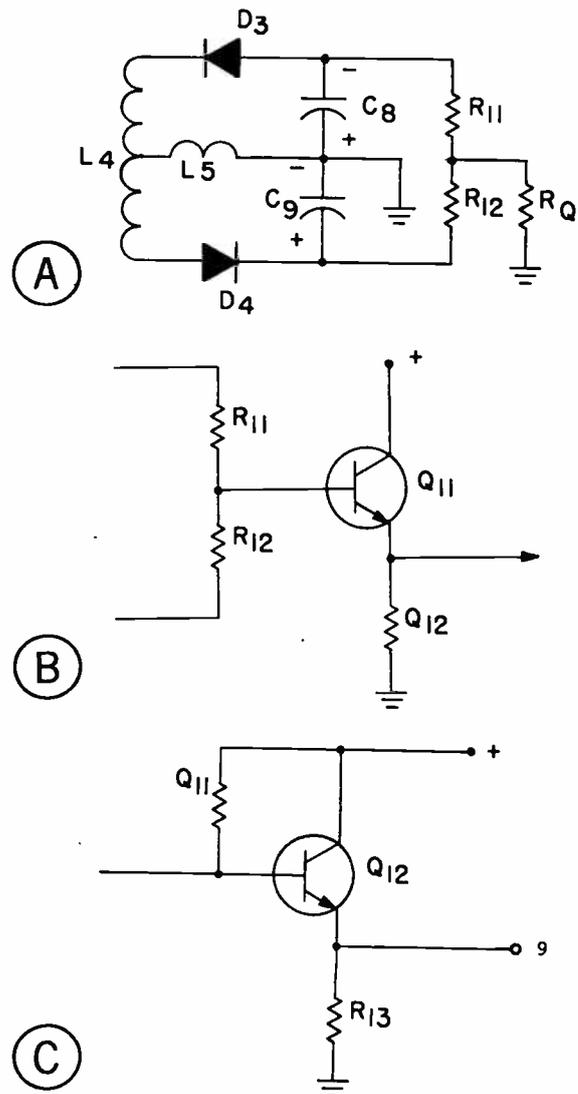
Fig. 49. Equivalent circuit of detector and amplifier.

of Q_{10} constant and the voltage drop across D_1 in series with D_2 holds the voltage at the base of Q_9 constant. The transistors Q_9 and Q_{10} act as regulators in conjunction with the diodes D_1 and D_2.

The diodes D_3 and D_4 form a ratio-detector circuit. We've redrawn the schmatic of these diodes in Fig. 49A. Notice that this circuit is essentially the same as the ratio-detector circuit you studied earlier. As long as the frequency of the signal is 4.5 mc, the voltage developed across the two halves of L_4 will be equal and opposite in polarity and $90°$ out-of-phase with the voltage across L_5. Therefore, the voltage across the upper half of L_4 plus the voltage across L_5 will be equal to the voltage across the lower half of L_4 plus the voltage across L_5. This means that equal voltages will be developed across C_8 and C_9 and across R_{11} and R_{12}. Therefore the net difference in potential between the junction of C_8 and C_9 and the junction of R_{11} and R_{12} will be zero.

When the frequency of the sound signal swings above or below 4.5 mc, then the voltage at the junction of R_{11} and R_{12} will vary above and below the voltage at the junction of C_8 and C_9. Since this junction is grounded, we can say the voltage varies with respect to ground. This audio voltage is fed on to the next transistor which we have shown simply as R_Q. The varying voltage at the junction of R_{11} and R_{12} will be the audio-output voltage from the ratio detector.

In addition to the diode-detector circuit, we also have two transistors, Q_{11} and Q_{12}, that act as two audio stages. We've redrawn the circuit of Q_{11} in Fig. 49B so you can see how it is used. The base of the transistor is connected to the junction of R_{11} and R_{12}. Thus any varying voltage developed at the junction of these two resistors is applied directly to the base. The load resistor between the emitter and ground of Q_{11} is the transistor Q_{12} which we have represented by the resistor in Fig. 49B. The collector of the transistor is connected directly to B+ so that Q_{11}

operates as an emitter-follower circuit.

In Fig. 49C we have shown how Q_{12} is connected. Notice that Q_{11} is connected between B+ and the base of Q_{12}. Therefore, the voltage developed by Q_{11} is fed directly to the base of Q_{12}. The resistor R_{13} represents an actual resistor in the integrated circuit that is connected between the emitter of the transistor and ground. The amplified signal is developed across R_{13} and fed to the output terminal, 9. Thus not only do we have detector action occurring within the detector part of the integrated circuit, but also we have two stages of audio amplification.

It is likely that you will run into all kinds of integrated circuits in TV receivers. Their low cost and high reliability make them attractive to TV manufacturers. The chances are that as time goes on more and more of them will appear in television receivers.

AUDIO AMPLIFIERS

The audio section of the modern TV receiver that uses vacuum tubes usually consists of only one stage, the audio-output stage. Many receivers use some form of quadrature detector and develop sufficient output voltage in the detector stage to drive the output stage directly. In an older model TV receiver that uses a ratio-detector or a limiter-discriminator, a voltage amplifier is needed between the detector output and the power output stage, because the output from the detector is not high enough to drive the output stage. Therefore, in the older receiver, you will find two audio stages.

In a transistor receiver you will usually find two audio stages because diodes are used, usually in the ratio-detector circuit, as the sound detector. Since the output from this type of detector is comparatively low, two sound stages are required.

Fig. 50 is a schematic diagram of the audio section of a transistor receiver. Notice that the output tran-
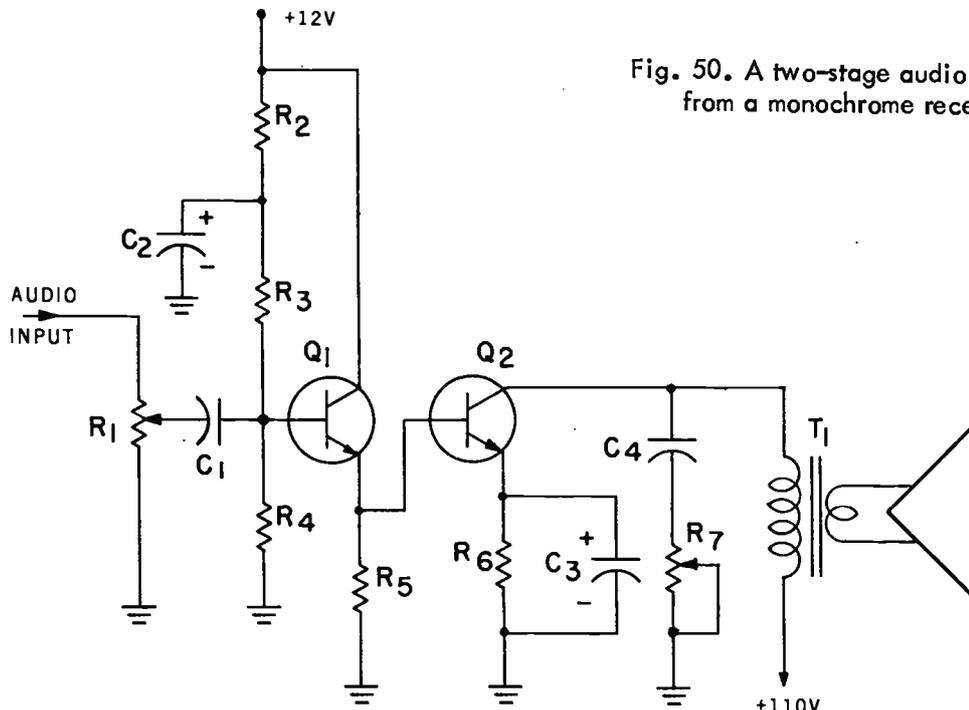
Fig. 50. A two-stage audio amplifier from a monochrome receiver.
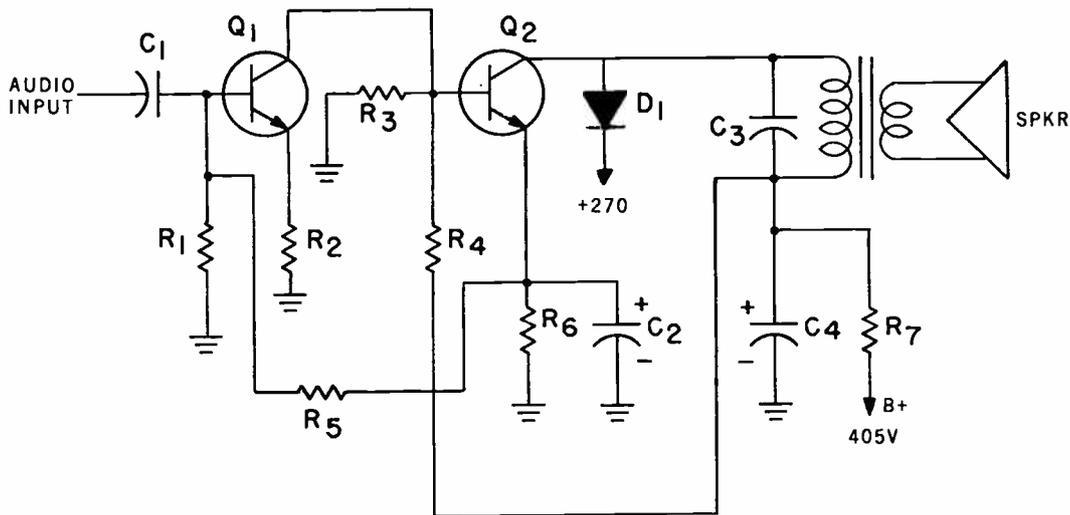
Fig. 51. A two-stage audio amplifier from a color TV receiver.

sistor is a high-voltage transistor; it is designed to operate with a collector voltage in excess of 100 volts.

In this circuit the audio from the detector stage is fed to the volume control R_1. A portion of the signal is selected across R_1 and fed through C_1 to the base of the first audio stage Q_1. The forward bias across the emitter-base junction is produced by the network consisting of R_2, R_3 and R_4 that is connected from B+ to ground. The base is connected at the junction of R_3 and R_4 and therefore will be positive with respect to ground.

The transistor Q_1 is used in an emitter-follower circuit. The load resistor, R_5, is in the emitter circuit. The emitter is connected directly to the base of Q_2 and the positive voltage on the emitter of Q_1 is fed directly to the base of Q_2. The positive voltage will be higher than the voltage drop across R_6 so that the transistor will have a forward bias across the emitter-base junction. R_6 is used in the emitter circuit to prevent thermal runaway. If the transistor current tends to increase as the temperature increases, the voltage drop across R_6 will increase; this reduces the forward bias across the emitter-base junction of Q_2 and hence reduces the current through the transistor. The electrolytic capacitor C_3 bypasses R_6 to prevent degeneration.

The network consisting of C_4 and R_7 is a tone-control circuit. C_4 is a comparatively large capacitor and as the resistance of R_7 is decreased by bypassing, the effect of C_4 on the higher frequency signal increases. This has a tendency to cut down on the high-frequency signals fed to the primary of the transformer. It gives an apparent increase in base response.

We have shown another transistor amplifier in Fig. 51. This is the audio section of the TV receiver in which the integrated circuit we discussed previously is used.

The audio signal from the integrated circuit is fed to a volume control, from the volume control to C_1, and from there to the base of Q_1. Q_1 is connected in a common-emitter circuit. The positive voltage developed across the emitter resistor, R_6, is used with the voltage-divider network consisting of R_1 and R_5

to provide the forward bias for Q_1. R_4 is the collector load resistor for Q_1 and it is used with R_3 to place the required forward bias on the base of Q_2.

The transistor Q_2 is operated from the high-voltage B supply and a voltage of 405 volts is applied to the collector through R_7. The transistor, however, cannot stand such a high voltage and the diode D_1 is connected from the collector to the 270-volt B supply. As long as the voltage drop across R_7 is sufficient to lower the voltage (so that the collector voltage Q_2 remains below 270 volts) the diode D_1 cannot conduct. However, if the signal drives the collector current to a very low value the collector voltage on Q_2 may begin to become excessive; in this case, D_1 will conduct and prevent the voltage from reaching such a high value that Q_2 will be damaged.

You might wonder why the collector voltage is taken from such a high-voltage point if the transistor cannot withstand the high voltage. The answer is that this point in the power supply is adequately filtered and therefore the B-supply voltage is taken from this point because the hum level is low. The 270-volt part of the power supply does not receive as much filtering as the 405-volt terminal. Therefore, if we tried to operate the transistor from the 270-volt point on the supply we might run into excessive hum problems.

Basically, both of these amplifiers are straightforward and represent the type of transistor-amplifier you are likely to encounter both in monochrome and color television receivers.

SELF-TEST QUESTIONS

(z) Why is the frequency relationship between the sound and picture signals reversed in the tuner?

(aa) Where is the 4.5-mc sound i-f signal produced in a monochrome receiver?

(ab) Where is the 4.5-mc sound i-f signal produced in a color TV receiver?

(ac) How is the 920-kc interference signal produced in a color TV receiver?

(ad) Is the amplitude of the 4.5-mc sound system going to depend on the amplitude of the strong

video signal or on the amplitude of the weak sound signal?

(ae) What should the strength of the sound i-f signal fed to the video detector be?

(af) What is the disadvantage of the sound take-off circuit shown in Fig. 36A?

(ag) What purpose does C_1-L_1 serve in the circuit shown in Fig. 36D?

(ah) What is CR_1 in Fig. 37?

(ai) What is CR_2 in Fig. 37?

(aj) What is the purpose of L_3 in Fig. 37?

(ak) If the local oscillator in a TV receiver drifts up .1 mc, what effect will it have on the frequency of the 4.5-mc sound system?

(al) What three types of sound detectors are used in

TV receivers?

(am) What does the limiter stage, V_1, do in the circuit shown in Fig. 40?

(an) What is the advantage of the ratio detector over the limiter-discriminator method of FM detection?

(ao) Why is it a good idea to replace both diodes in a ratio detector or discriminator using germanium diodes, if one proves to be defective?

(ap) What two types of tubes are used in quadrature grid detectors?

(aq) What is the potentiometer in the cathode circuit of the 6BN6 in Fig. 42 called?

(ar) What is the advantage of the quadrature grid detector?

Remote Control Tuning Units

Many television receivers are equipped with remote-control tuning units. These units consist of a transmitter and a receiver. The receiver is mounted inside the TV receiver cabinet and is used to control various tuning adjustments in the receiver. The transmitter can be located some distance from the receiver so that the receiver can be controlled remotely. The transmitters vary from rather elaborate electronic units to small hand-held units that are far more mechanical than electrical.

Communications between the transmitter and the receiver are by means of ultrasonic waves. These sound waves are usually waves with a frequency of about 40 kc. They are far above the range that we can hear so the receiver can be controlled without any objectionable sound signals.

In this section of this lesson we are going to study both transmitters and receivers. We'll study two transmitter types, one electronic and the other mechanical. We'll study the receivers that go with these two units.

A THREE-CHANNEL TRANSMITTER AND RECEIVER

In Fig. 52 we've shown a drawing of a three-channel Motorola remote-control transmitter. The button on the left generates a 38.5 kc signal when it is pressed. The button in the center generates a 40 kc signal when it is pressed and the button on the right generates a 41.5 kc signal when it is pressed.

The operation of this transmitter is strictly mechanical. The transmitter contains three rods that

FUNCTIONS CHANNEL BUTTON
1 - CHANGE CHANNEL FROM LOW TO HIGH CHANNELS
2 - (HUE TO RED IF MUTE PRESSED ONCE)

FUNCTIONS MUTE BUTTON
SELECTOR FOR CHANNEL & VOL-ON-OFF BUTTONS
1 - MUTES SOUND & SETS UP HUE FUNCTIONS
2 - RESTORES SOUND & SETS UP CHANNEL & VOL-ON-OFF FUNCTIONS

FUNCTIONS VOL-ON-OFF BUTTON
1 - TURN SET ON (VOLUME NORMAL)
2 - VOLUME MEDIUM
3 - VOLUME LOW
4 - TURN SET OFF
HUE TO GREEN IF MUTE PRESSED ONCE

40.0KC

PUSH MUTE BEFORE ADJUSTING HUE
CHANNEL   VOL-ON-OFF
HUE   MUTE   HUE

38.5KC

41.5KC

MOTOROLA

Courtesy Motorola

Fig. 52. A Motorola Hand-Hold Transmitter.

are of slightly different lengths. When you press the button a hammer arrangement strikes the rod on the end and causes the rod to vibrate. The vibrating rod sets up an ultrasonic signal. The frequency of the ultrasonic signal depends upon the length of the rod. In the transmitter shown in Fig. 52, the rod that is actuated by the button on the left is the longest rod and produces the lowest frequency signal. The rod that is actuated by the button on the right is the shortest rod and produces the highest frequency signal. If you were to examine the three rods, you might not be able to detect any difference at all in their length since they are set to vibrate at frequencies that are comparatively close together.

The various functions of the buttons on the transmitter are shown in Fig. 52. To change the receiver from a low channel to a high channel you press the button on the left. The receiver can be set up so that it automatically goes to the next (higher) channel or it can be set so that it goes to the next (higher) channel in use in your area – in other words, it can be set up to skip over unused channels. We'll go into this operation when we study the receiver.

The button on the extreme right is used to control the receiver volume and turn the set on and off. When you press the button once, the receiver will be turned on and the volume will be at a maximum setting. If you press the button a second time, the volume will be reduced to a medium setting. Pressing the button a third time turns the volume to its lowest setting and pressing the button a fourth time will turn the receiver off. If after you have turned the receiver off you press the button again, the cycle repeats, and the set is turned on with maximum volume.

The button in the center is called the mute button. When you press this button you mute the sound; in other words, you turn the sound off. At the same time you set up the right and left buttons so they can be used to control the hue of the picture. If you press the button on the left the hue becomes redder and if you press the button on the right it turns in a green direction. After the hue has been adjusted, you press the mute button again. This restores the sound and sets up the buttons on the left and right so that they will once again control the channel-changing function and the volume level.

THE RECEIVER

A schematic diagram of the receiver used with the remote transmitter just described is shown in Fig. 53. As you can see, the entire receiver is transistorized.

The ultrasonic signal generated by the transmitter is picked up by a microphone. A condenser-type microphone that is particularly good at picking up high-frequency signals is usually used in this type of application.

The signal picked up by the microphone is fed through a three-stage amplifier consisting of Q_1, Q_2, and Q_3. These amplifiers are simply broadband amplifiers that are capable of amplifying the ultrasonic signal picked up by the microphone. Each transistor is connected in a common-emitter circuit similar to common-emitter circuits you studied previously. The range control that is connected in the collector circuit of Q_3 controls the range by varying the operating potential on Q_3. When the control is adjusted so that the sliding arm is in the ground end of the control we have maximum forward bias and maximum collector voltage applied to Q_3 and the unit operates with maximum gain. With the control adjusted at the other extreme, then the junction of R_{11}, R_{12} and R_{13} is grounded so that there will be no voltage applied to the collector of Q_3 and no forward bias across the emitter-base junction, so that the unit will in effect be cut off.

Range Control Adjustment.

The correct adjustment for the range control is somewhere between these two extremes. If the control is turned up too high, there is the danger of the unit being triggered by noise. Therefore, the range control should be turned up high enough to enable the unit to work with the transmitter at a normal maximum distance from the receiver. However, turning the range control for extrasensitivity beyond this point can only result in problems.

The output from Q_3 is fed to three parallel-resonant circuits. It is fed to a parallel-resonant circuit that is resonant at 41.5 kc through the coupling capacitor C_7. It is also fed through C_8 to a parallel-resonant circuit that is resonant at 40 kc and to a third parallel-resonant circuit that is resonant at 38.5 kc through the capacitor C_9. When a signal is picked up from the transmitter by the microphone, and fed through the amplifier, a much higher voltage will be developed across the resonant circuit that is resonant at the frequency of the receiver signal. Some signal will also be picked up by the other coils; however, the amplitude will be much lower than the amplitude of the signal in the resonant circuit.

For the sake of explanation, let's say that a 41.5 kc signal is transmitted. This signal is picked up by the microphone, amplified by the three-stage amplifier, and then a maximum signal will be developed across the 41.5 kc parallel-resonant circuit. This signal will be fed to Q_4. Notice that the base of Q_4 is returned directly to ground and that the emitter goes to ground through the 47-ohm resistor R_{16}. Therefore, there is no forward bias applied to the transistor. However, when the signal is picked up, during the positive half-cycle it will place a forward bias across the emitter-base junction and cause the transistor to conduct.

Meanwhile, the emitter current flowing through R_{16} will develop a voltage across it having a polarity such that the end of the resistor connected to the emitter of the three transistors is positive. This voltage will be high enough to place the reverse bias across the emitter-base junctions of Q_5 and Q_6 so that any weak 41.5 kc signal fed through the 40-kc resonant circuit or the 38.5-kc resonant circuit will not be sufficient to cause Q_5 or Q_6 to conduct.

When Q_4 conducts, it energizes the relay E_1. This closes the relay contacts. Signals at the other frequencies do essentially the same thing. The signal at the frequency of the resonant circuit develops maximum voltage in that circuit, causing the transistor con-
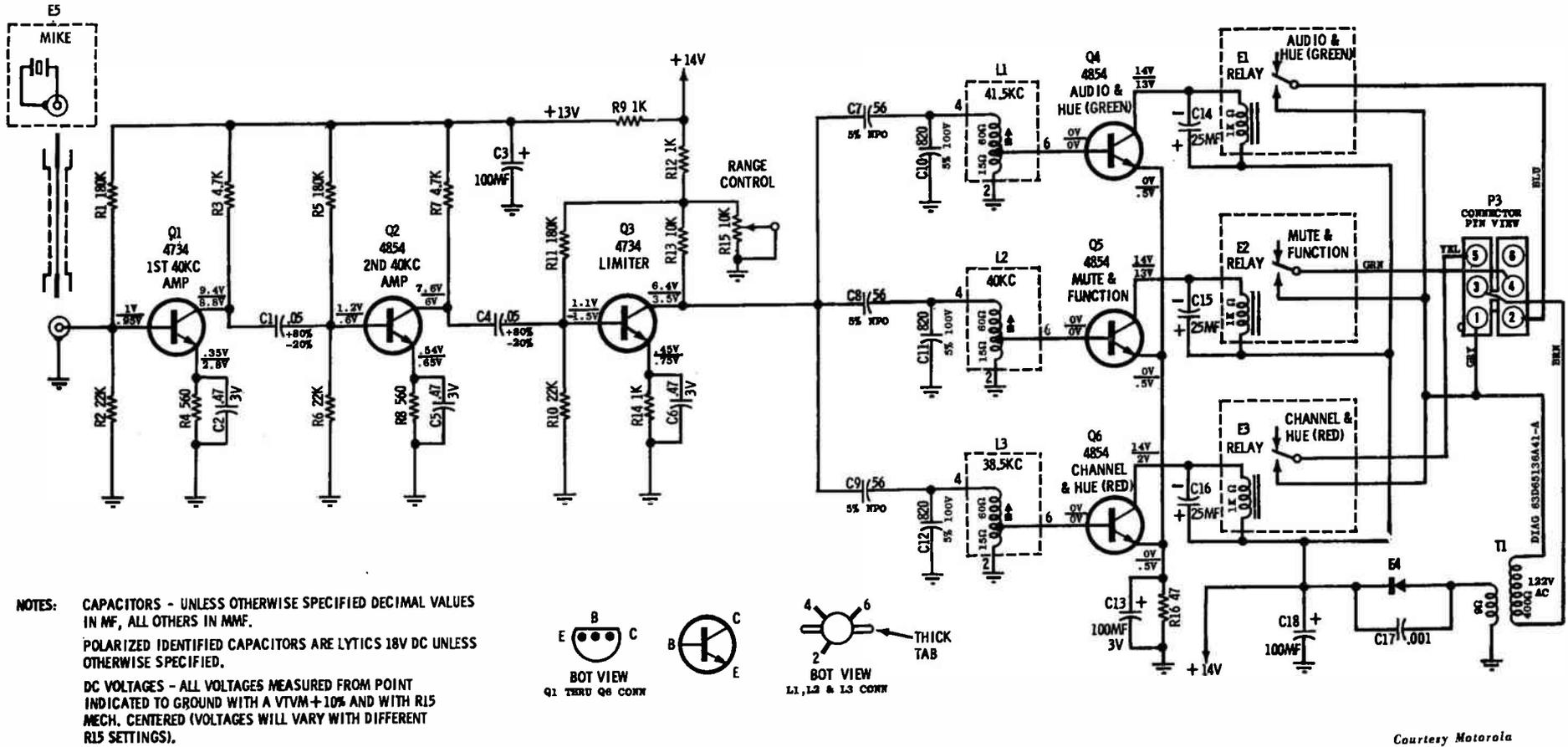
Fig. 53. A Motorola remote-control receiver.
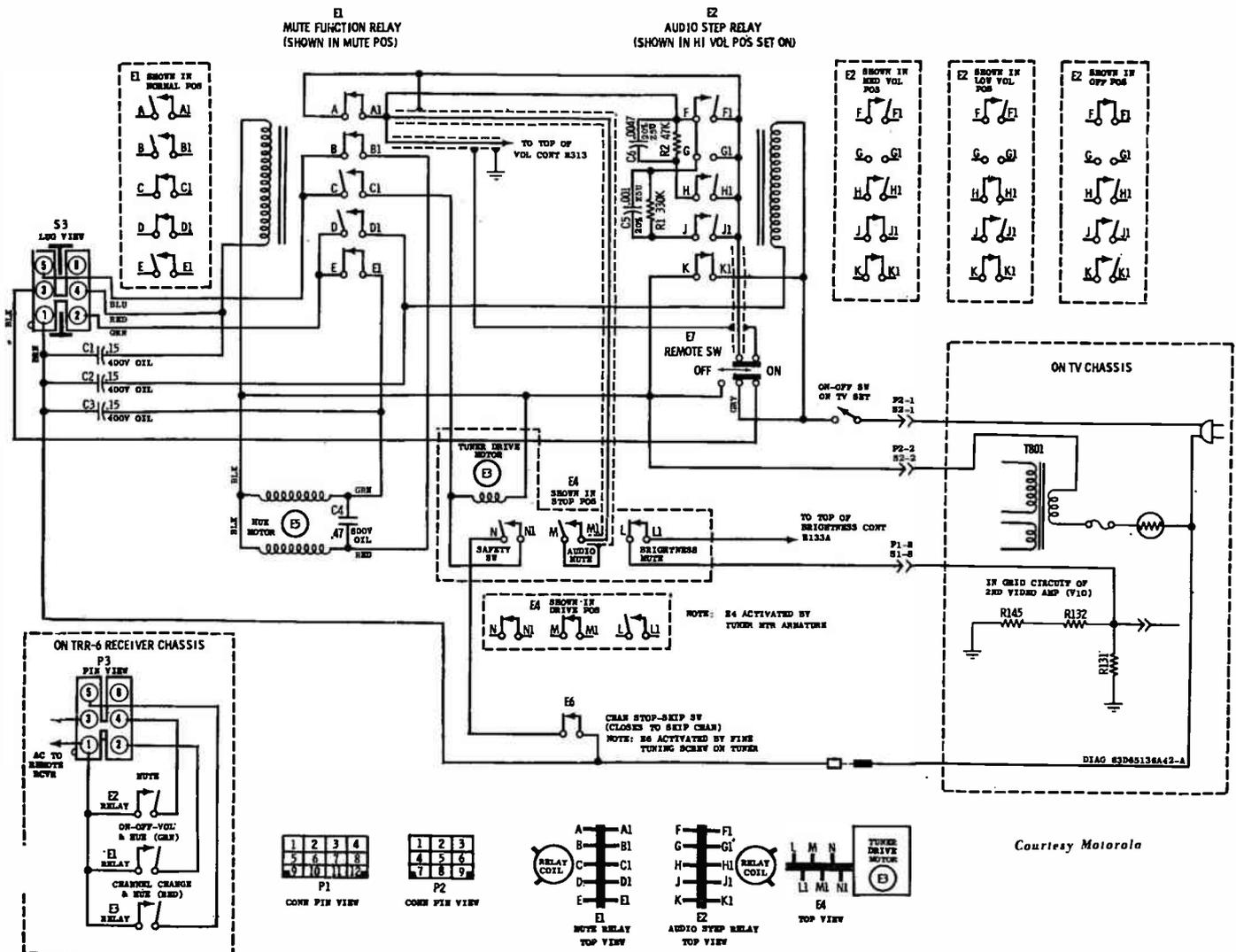
Fig. 54. Remote-control unit wiring diagram.

nected to that circuit to conduct; this, in turn, develops sufficient voltage across the 47-ohm resistor R_{16} to prevent the other transistors from conducting. Thus only one of the relays, E_1, E_2, or E_3 closes at any given time.

The receiver shown in Fig. 53 is connected to the control unit shown in Fig. 54. The connector S_3 shown in Fig. 54 is joined to the connector P_3 shown in Fig. 53. The connector on the receiver chassis and the various relay circuits are shown on the lower left of the remote-control unit wiring diagram so that you can trace out the various functions without having to refer back to Fig. 53.

The first step in operating a receiver remotely is to turn it on. When you do this you press the button on the right of the transmitter-control unit and this energizes relay E_1. When the relay E_1 closes it steps one position so that we have in effect a switch that is moved one position. The various contacts are labelled E_2 Audio Step Relay in Fig. 54. The switch is shown in the high volume position with the set turned on.

If we want to change a channel, after we have the receiver turned on we press the button on the left of the transmitter unit. This closes the relay E_3. This

will take ac from the power line and apply it to terminal 5 of the receiver chassis connector. The power is applied from terminal 5 on S_3 in Fig. 54 over to the mute function relay. This relay is shown in the mute position – in order for the tuner to operate the switch must be in the opposite position. When this happens we'll have the circuit from terminal 5 on S_3 over to terminal C. The relay will be closed between C and C_1 so the power line will be applied through C_1 to the tuner drive motor. The circuit is then traced through the motor to terminal K on the audio-step relay, through the relay to K_1, and through the on/off switch in the receiver, which must be in the "on" position at all times in order for the remote control unit to work, and back to the other side of the power line.

Thus when the "channel" button is pressed, the tuner drive motor is energized. The motor is connected to a series of gears which drop into position and rotate the tuner from one channel to the next channel.

Fig. 55A is a simplified diagram of the channel change function. Notice that there is a safety switch on the motor; as soon as the motor starts to turn, this switch closes. The stop-skip switch is on the tuner. This switch is activated by taking the fine tuning con-

A CHANNEL BUTTON (CHAN CHANGE FUNCTION)

TRR-6 CHAN RELAY — MOMENT. CLOSED
MUTE RELAY (NOT MUTED) — C C1
SAFETY CLOSES WHEN MTR RUNS
STOP-SKIP CLOSES TO SKIP
TUNER MTR
TV PRI
AC
REMOTE ON-OFF SW
MANUAL ON-OFF SW
VOL STEP RELAY — K1 K

B AUDIO BUTTON (ON-OFF-VOL FUNCTION)

TRR-6 AUDIO RELAY — MOMENT. CLOSED
MUTE RELAY (NOT MUTED) — D D1
TV PRI
AC
REMOTE ON-OFF SW
HUE & TUNER MTR FUNCTIONS
VOL STEP RELAY
K1 K — OPENS IN "OFF" POS.
MANUAL ON-OFF SW
VOL CONT — .0047 47K 330K .001 — LO MED HI OFF

C CHANNEL BUTTON (RED FUNCTION)

TRR-6 CHAN. RELAY — MOMENT. CLOSED
MUTE RELAY (MUTE POSITION) — B B1
GRN RED — HUE MTR — BLK
TV PRI.
AC
REMOTE ON-OFF SW
MANUAL ON-OFF SW
VOL STEP RELAY — K1 K

D AUDIO BUTTON (GREEN FUNCTION)

TRR-6 AUDIO RELAY — MOMENT. CLOSED
MUTE RELAY (MUTE POSITION) — E E1
GRN RED — HUE MTR — BLK
TV PRI
AC
REMOTE ON-OFF SW
MANUAL ON-OFF SW
VOL STEP RELAY — K1 K

Courtesy Motorola

Fig. 55. Simplified schematic of various remote-control functions.

trol and turning it ten times in a clockwise direction for any channel you want to skip. When the motor is engaged and rotates the channel switch, it turns it to a certain point. Then, the detent in the switch takes hold and rotates the channel selector to the next position.

Meanwhile, the motor is still rotating, so the safety switch is closed. If the fine tuning has been set so the unit is to skip the next channel, when the detent drops the channel selector into position the step-skip switch will close, energizing the motor again, and the motor will go on to the next channel. It will keep doing this until it comes to a desired channel, at which time the fine tuning will be set to tune the station correctly and the slug in the coil will not be out far enough to close the stop-skip switch. The tuner will then stop in this channel position.

The volume and on/off function is shown in simplified form in Fig. 55B. As we mentioned previously, when the audio button is pressed the first time, the volume-step relay is energized and this turns the set

on. The set remains in the on position in the high, medium and low volume positions. As the button is pressed, the volume control moves from the high position to the medium position so that the 330K-ohm resistor and the .001 mfd capacitor are shunted across the volume control to reduce the volume.

If you press the button again, the switch moves to place the 47K-ohm resistor and the .0047 mfd capacitor across the volume control to reduce the volume still further. In the next position, the circuit is open, the volume control is completely shorted out, and the switch between terminals K and K_1 opens, thus opening the power to the primary of the power transformer.

Mute Functions.

The two mute functions are shown in Fig. 55C and Fig. 55D. When the mute button is pressed, the switch is closed between terminals B and B_1 when the red function button is pressed. This energizes the hue motor as shown so that the motor turns in one direction. As the green hue button is pressed the switch is closed between terminals E and E_1 as shown in Fig.
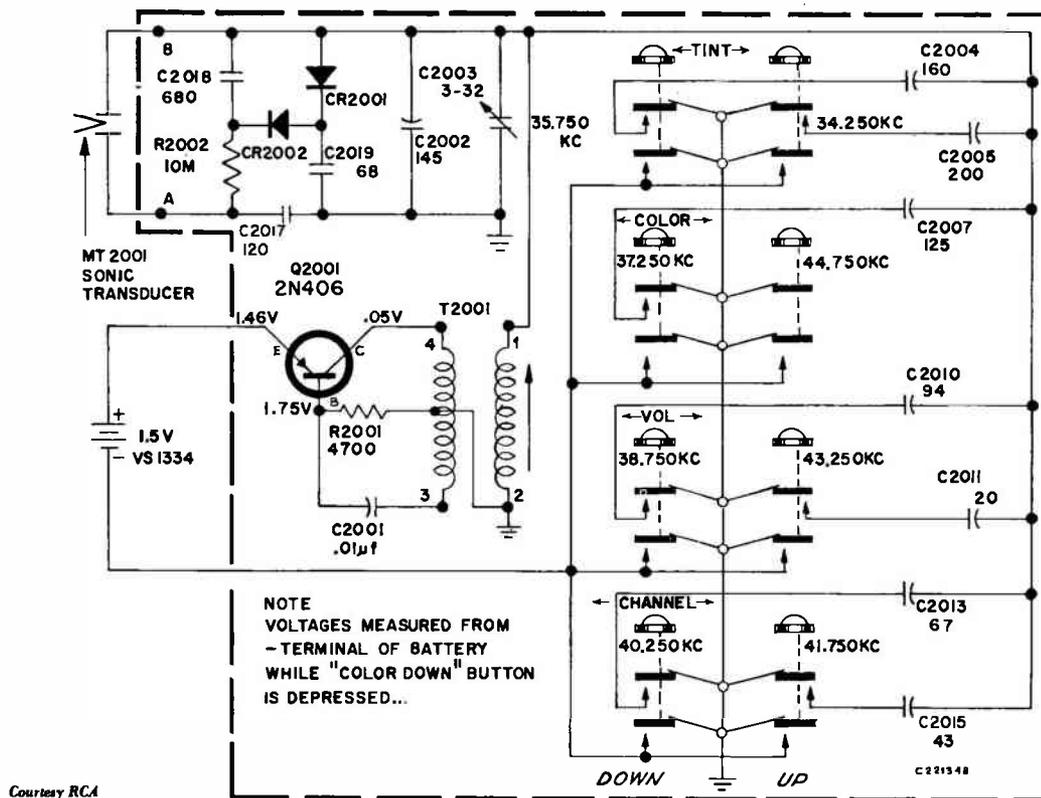
Fig. 56. An eight-channel remote-control transmitter.

55D and the motor is energized as shown so that it rotates in the opposite direction.

In this receiver the hue control is simply a potentiometer which is mounted so that the shaft sticks out on one end and can be controlled by the knob attached to this end. A slow-speed motor is connected at the other end that turns at a speed of about 6 rpm. This is the hue motor. Pressing the hue-control button actuates this motor, causing it to rotate in one direction or the other.

AN 8-CHANNEL REMOTE TRANSMITTER

An electronic remote transmitter that operates on eight channels is shown in Fig. 56. Notice that instead of using a mechanical system to set up the ultrasonic signals, this transmitter actually uses an electronic system. The 2N406 transistor is used in a Hartley-type oscillator. Pressing one of the buttons on the transmitter connects the negative side of the 1.5-volt battery to ground and completes the battery circuit and at the same time connects one of the capacitors from terminal 1 to terminal 2 of the oscillator transformer T2001. The frequency at which the oscillator will operate depends upon the capacitor connected across the coil.

In this transmitter two controls are provided for the tint. Pressing one tint control button energizes a 35.75 kc oscillator; this causes the motor connected to the tint control to rotate in such a way as to turn the tint control in a counterclockwise direction or towards red. Pressing the other tint-control button causes the oscillator to operate at 34.25 kc; this causes the motor to operate the tint control in a clock-

wise direction or in other words turn the tint toward the green region.

There are two remote color control functions; pressing one button causes the oscillator to operate at 37.25 kc and turns the color control in a counterclockwise direction so as to reduce the amount of color in the picture. Pressing the other button causes the oscillator to operate at 44.75 kc; the motor will turn the color control in a clockwise direction in order to put more color into the picture.

There are also two controls on the receiver volume. Pressing one button causes the oscillator to operate at 38.75 kc, which turns the motor in such a way as to reduce the volume. Pressing the other button causes the oscillator to operate at 43.25 kc; this turns the volume up.

Channel Selector Controls.

Two channel selector controls are used. They both turn a channel drive motor in the same direction. The button on the left causes the 40.25 mc oscillator signal to be generated and this sets the vhf tuner motor into operation. Pressing the 41.75 kc button closes the relay circuit that sets the uhf tuner motor into operation. Both the vhf and uhf tuners rotate in the one direction at all times. Therefore, if you should have the receiver tuned to channel 4 and want to go to channel 2, you will have to go from 4 all the way through 13 and back to channel 2.

The sonic transducer used with this unit is, in effect, a condenser-type microphone that is used as a transmitter instead of a pickup device. The ultrasonic signal fed to it causes the transducer to set up ultrasonic sound waves which travel through the air to the receiver.
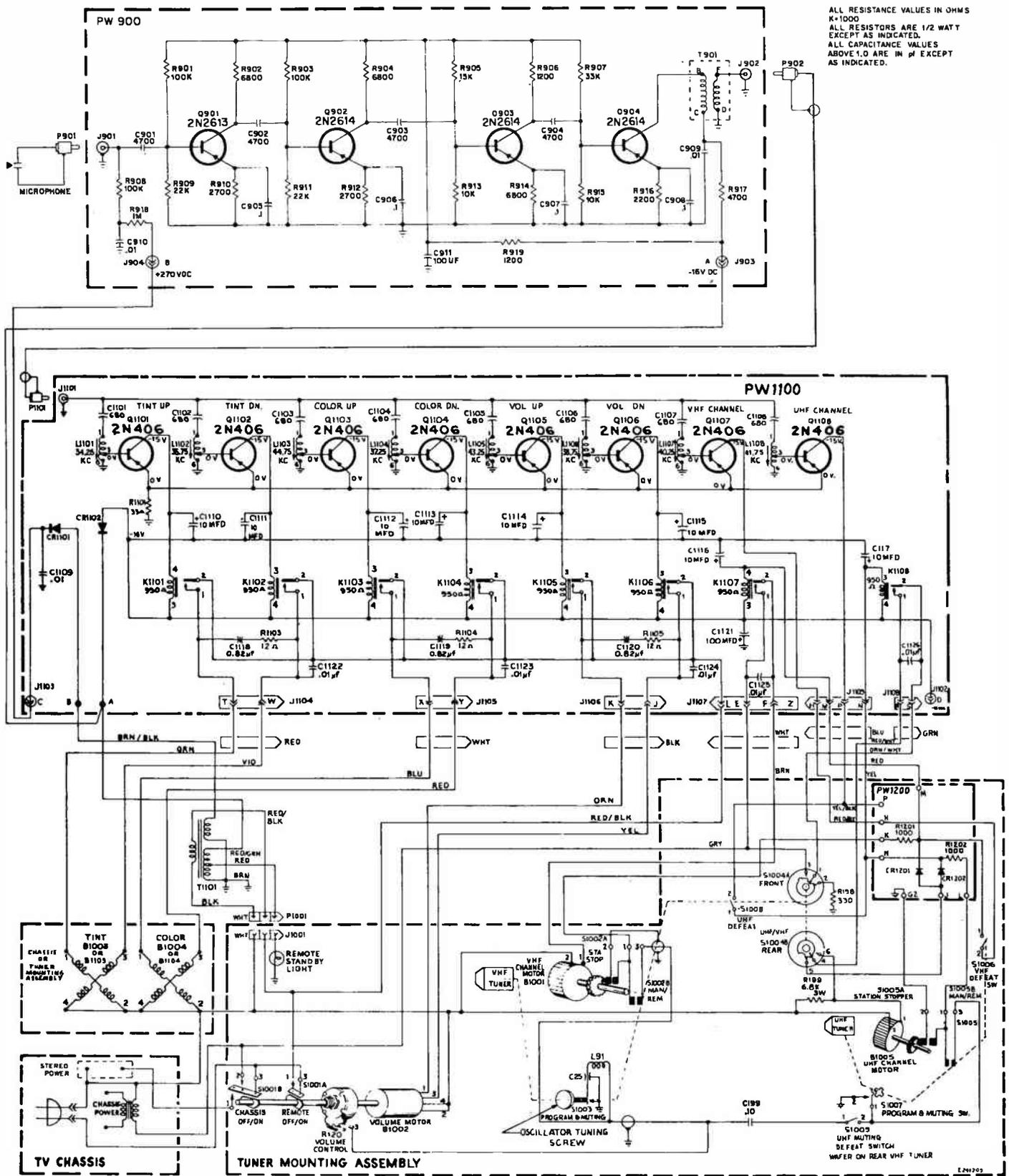
Fig. 57. An eight-channel remote-control receiver.

Courtesy RCA

AN 8-CHANNEL REMOTE RECEIVER

An eight-channel remote receiver (to be used with the eight-channel transmitter previously described) is shown in Fig. 57. The pickup device is a microphone, usually a capacitor-type microphone. The signal from the microphone is fed to a four-stage broadband transistor amplifier which amplifies the signal and then feeds the signal to eight series-resonant circuits. Maximum signal current will flow through the circuit that is resonant at the frequency being received. This causes the transistor connected in that circuit to con-

duct and draw current through the 33-ohm emitter resistor R101. The negative voltage developed across this resistor will bias the PNP transistors to cutoff so that the only transistor that passes current is the one in the series-resonant circuit.

The emitter current flowing through the one transistor will energize one of the relays. This in turn will cause the motor controlled by the relay circuit to operate.

As we mentioned previously, the tint, color, and volume control motors can be rotated in either direction. Actually, the motors used on these three controls are essentially the same. This particular unit has an advantage in that the motor provides a continuous drive so that the volume can be raised or lowered smoothly, rather than in steps as in the transmitter-receiver discussed previously. With the volume control turned in the up or clockwise direction, the first thing it does is turn the receiver on; thus the on-off function is related to the volume control.

Notice that two different motors are provided for the tuners: one controls the vhf tuner; the other, the uhf tuner. When either of the tuner motors is placed in operation, the sound is muted so that there is not a great deal of objectionable noise heard as you tune from channel to channel.

The receiver used here is basically similar to the simpler receiver we discussed previously -- there are simply extra channels, extra relays and extra relay circuits.

Servicing the electronic part of the remote receiver is not particularly difficult. The transistorized unit operates on comparatively low voltages and currents and seldom causes electronic trouble.

Mechanical Difficulties.

The majority of the trouble encountered in the unit is mechanical due to coupling problems between the motor and controls and between the motor and the tuner. There is no magic formula that you can use to determine exactly what is causing the trouble when you run into mechanical difficulties of this type. The only thing you can do is study the mechanism carefully to see what has to happen in order to make the unit work. Then you should look for a damaged or bent part or some part that is slipping so that the unit does not function as it should. Sometimes a simple adjustment will correct the difficulty; at other times, replacement parts are needed. Whenever you have to replace a part in a mechanical assembly, it is best to get an exact duplicate replacement from the distributor handling the particular brand of receiver that you are servicing.

SELF-TEST QUESTIONS

(as) What type of signal is transmitted by a TV remote-control transmitter?

(at) How many positions does the volume control relay in Fig. 54 have?

(au) What is the advantage of the volume control arrangement in the 8-channel control unit?

(av) If in the receiver in Fig. 53, a 40-kc signal induces some voltage in L_1 and L_3, why do Q_4 and Q_6 fail to conduct?

(aw) What type of resonant circuits are used to select the signal in Fig. 53?

(ax) What type of resonant circuits are used to select the signal in the receiver in Fig. 57?

Answers to Self-Test Questions

(a) If one tube burns out, the rectifier will continue to function as a full-wave rectifier.

(b) 335 volts.

(c) (1) They have no heater and hence save on power. (2) They generate less heat inside the cabinet. (3) They generally last longer than tubes.

(d) (1) Smaller size. (2) Lower forward voltage drop. (3) Higher reverse resistance. (4) Last indefinitely unless overloaded. (5) Lower cost.

(e) There are 120 pulses in the output from the rectifiers, one from each half-cycle, and therefore the rectifier circuit is a full-wave rectifier.

(f) A full-wave voltage doubler.

(g) To keep the cathode-to-heater voltage on the tricolor tube as low as possible. The cathodes of the tube are direct-coupled to the plate of the video output tube and hence have a positive voltage applied to them. A positive voltage is applied to the heater through R_2.

(h) A half-wave rectifier.

(i) Three.

(j) A zener diode.

(k) The resistors are special resistors that have a high resistance to limit the current when they are cold. As the resistors heat along with the tubes, the resistance goes down, permitting the tubes to draw their rated current.

(l) A tube that has a heater that operates on a current of 600 milliamperes (.6 amps) is called a 600-mil tube.

(m) A tube that has a controlled warm-up time of 11 seconds. Tubes of this type are designed for use in heater strings where it is important that all tubes heat at the same rate.

(n) There is a 25% reduction in the heater power required, and there is less heat dissipated inside the receiver cabinet.

(o) The circuit in Fig. 16 is a half-wave doubler because there are only 60 pulses per second in the power supply output, one pulse every second half-cycle. The other half-cycle pulses are used to keep C_1 charged.

(p) The voltage would be zero. Since V_1 and V_2 are in series, if R_5 opens the path to B+ is open and therefore the plate voltage on both tubes would drop to zero.

(q) The voltage across C_3 will be approximately twice the voltage across C_4.

(r) Silicon rectifiers have such a low forward resistance that the surge current that flows when the receiver is first turned on may be high enough to destroy the rectifier. The resistor will limit the current to a safe value.

(s) The pulse rate is equal to the horizontal sweep rate of over 15 kc.

(t) If the horizontal sweep fails there will be no high voltage generated. If the high voltage is applied to the tube with no sweep, it will burn the phosphor on the face of the tube.

(u) To avoid convergence and purity problems.

(v) The focus electrode of the color set requires approximately 5000 volts. This is too high to be obtained from the low-voltage supply.

(w) By adjusting the 500K-ohm voltage adjust potentiometer in the grid circuit of V_5, the loading on the high-voltage power supply can be varied to give the correct output voltage of 24 kv.

(x) In Fig. 33, the high voltage is regulated by controlling the current through the horizontal output tube.

(y) High voltage regulation can be accomplished by controlling the picture tube beam current.

(z) The frequency relationship between the sound and picture signals is reversed in the mixer because the local oscillator is operated at a frequency above the frequency of the incoming signals. Since the sound signal is higher in frequency than the video signal, it will be closer in frequency to the oscillator than the video signal. Therefore the difference between the sound and oscillator signals will be less than the difference between the video and oscillator signals and the sound i-f will be lower in frequency than the video i-f.

(aa) In the video detector.

(ab) In a separate sound detector placed after the last video i-f, but before the video detector.

(ac) It is produced by the 4.5-mc sound signal beating with the 3.58-mc color subcarrier. It can also be produced by the 41.25 mc sound i-f beating with the 42.17 mc color i-f signal.

(ad) The amplitude of the signal will depend on the amplitude of the weak sound signal.

(ae) The amplitude of the sound i-f signal fed to the video detector should be 5% to 10% of the amplitude of the video i-f carrier.

(af) There are no traps to reduce the amplitude of the 4.5-mc signal getting into the video circuits. This will result in a 4.5-mc gain pattern appearing on the face of the picture tube.

(ag) They form a parallel-resonant circuit at 4.5 mc and keep the 4.5-mc signal out of the video circuits.

(ah) CR_1 is the sound detector in which the 45.75-mc video i-f signal is beat with the 41.25-mc sound i-f signal to produce the 4.5-mc sound signal.

(ai) CR_2 is the video detector. It develops the video signal from the video i-f and also the 3.58-mc color subcarrier. Any 4.5-mc sound that is developed is undesirable.

(aj) L_3 is a 4.5-mc trap. It is used to keep any 4.5-

mc signal developed in CR_2 from getting further on into the video circuits.

(ak) None. The 4.5-mc signal is the result of the difference between the sound and video carrier frequencies. Changes in the frequency of the local oscillator in the TV receiver have no effect.

(al) Limiter discriminator, ratio detector and quadrature detector.

(am) It limits the amplitude of the signal fed to the detector V_2, so that the signal fed to the detector is a constant amplitude and does not vary with changes in amplitude due to noise.

(an) It eliminates the need for a limiter stage and hence is a more economical detector.

(ao) The characteristics of germanium diodes are not as consistent as those of diode tubes. Thus, to get balanced operation in a ratio detector or discriminator, manufacturers select the diodes to match their characteristics. Therefore, if you replace one diode, you should get a matched pair and replace both diodes.

(ap) A gated beam tube or a dual control pentode.

(aq) A buzz control.

(ar) It has a very high output and permits driving the output tube directly from the detector output, thus eliminating the need for an audio voltage amplifier stage.

(as) An ultrasonic signal.

(at) Four positions: high, medium, low and off.

(au) The setting of the volume control is continuously variable.

(av) The 40-kc signal will induce a much higher voltage in L_2. Therefore, Q_5 will conduct heavily and develop a voltage across R_{16} that will reverse-bias the emitter-base junctions of Q_4 and Q_6.

(aw) Parallel-resonant.

(ax) Series-resonant.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. List the two voltages that the low-voltage power supply must furnish in a TV receiver that uses tubes.

2. What is the advantage of a quadrature grid detector?

3. What is a controlled warm-up tube?

4. Why is a focus rectifier used in a color TV receiver?

5. Why is voltage regulation used in the high-voltage power supply of a color TV receiver?

6. If the oscillator in the tuner of a modern TV receiver drifts up 500 kc, which way will the 4.5-mc sound drift?

7. Is the power transformer in a transistorized TV receiver likely to be (a) a step-up transformer or (b) a step-down transformer?

8. Name three advantages of the silicon rectifier over the tube rectifier.

9. What function does Y_1 in Fig. 30 perform?

10. What two signals can cause a 920-kc interference signal in color TV receivers?

WASTED TIME

A minute seems such a little thing—something most of us thoughtlessly throw away. But, just as pennies make dollars, so do minutes make hours. Few people realize that ten minutes wasted daily make over sixty hours—more than a work-week—in a year's time.

Study the habits of most successful men and you will find that they made use of odd moments, reading or writing, or thinking. Those precious minutes gave them the extra weeks, months, and years of time necessary to prepare and to advance themselves.

Now, time spent in healthful recreation is not being wasted. But, how much of your time is spent in idle amusements instead? How much time do you waste "stalling" before starting a task—doing unnecessary or useless things—or doing nothing at all?

Study your actions during the day. Make a list of the things you do. You'll be surprised at the number of five-or-ten-minute intervals you can put to better use, in studying or planning for the future. Be ready for your opportunity when it comes!

J. M. Smith
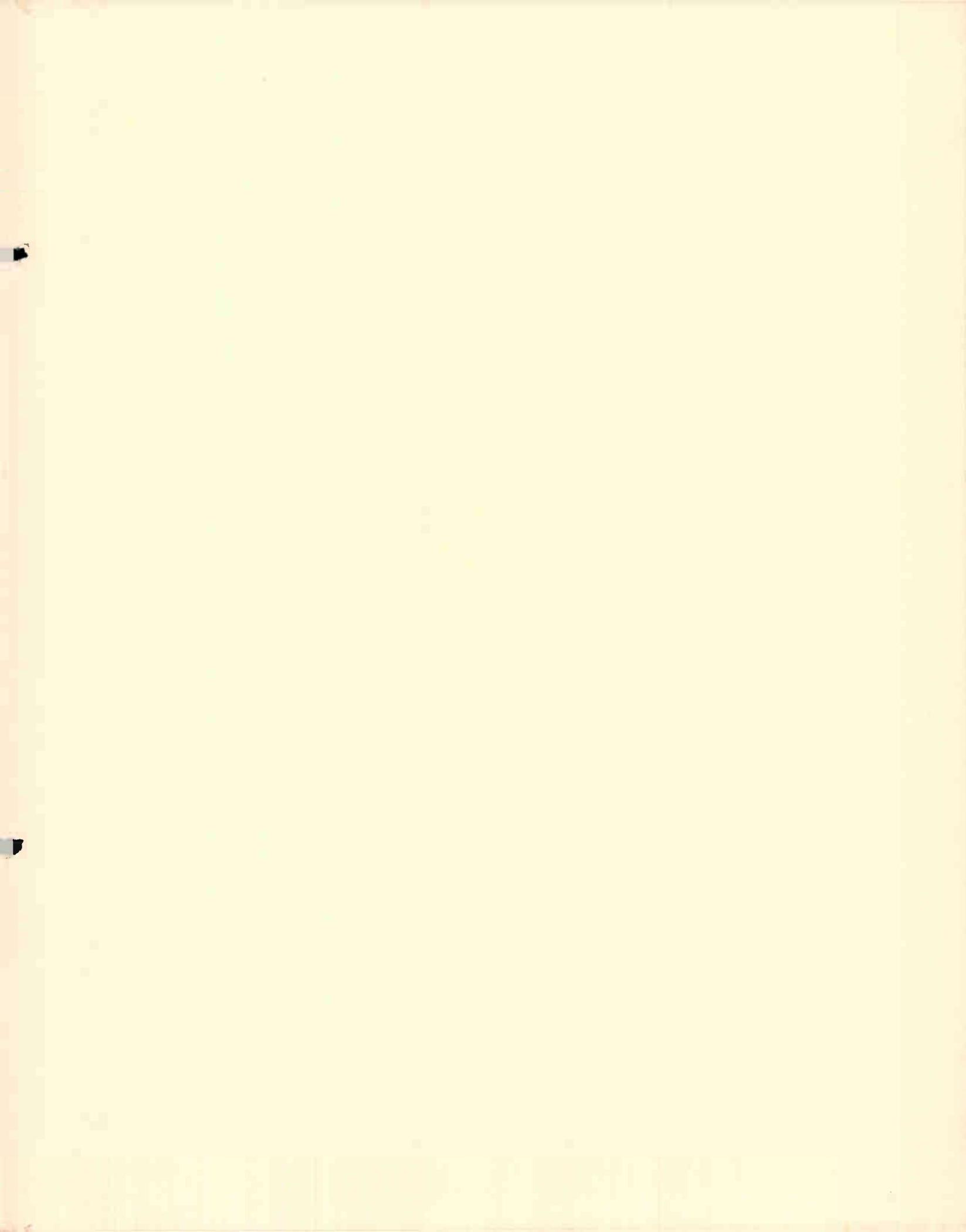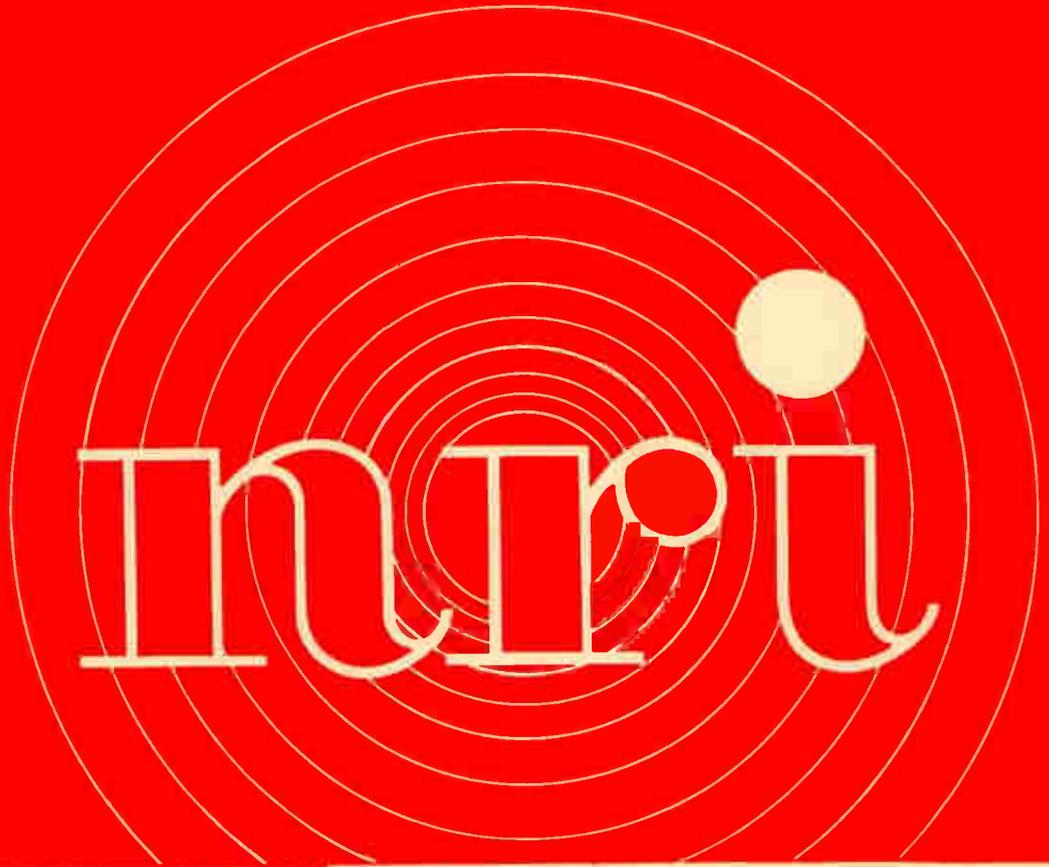
COLOR I-F AMPLIFIERS AND DEMODULATORS

B513

COLOR DEMODULATORS AND AMPLIFIERS

B514

TV ANTENNAS

B515

COLOR I-F AMPLIFIERS AND OSCILLATORS

●

STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

☐ **1. Introduction. . . . . Pages 1-3**
You review the color section of a TV receiver by tracing through a block diagram.

☐ **2. Bandpass Amplifiers. . . . . Pages 4-13**
You study color i-f amplifiers (bandpass amplifiers) and associated circuits including automatic color control, color killer and blanker circuits.

☐ **3. Burst Amplifiers. . . . . Pages 14-20**
You study a number of typical burst amplifier circuits.

☐ **4. Reinserting the Color Subcarrier. . . . . Pages 21-25**
In this section you learn how the 3.58-mc signal is generated in the receiver.

☐ **5. Automatic Frequency and Phase Control Systems. . . . . Pages 26-32**
You study a complete system for locking the locally generated 3.58-mc signal in phase for correct demodulation of the color information.

☐ **6. Answer the Lesson Questions.**

☐ **7. Start Studying the Next Lesson.**

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COLOR I-F AMPLIFIERS AND OSCILLATORS
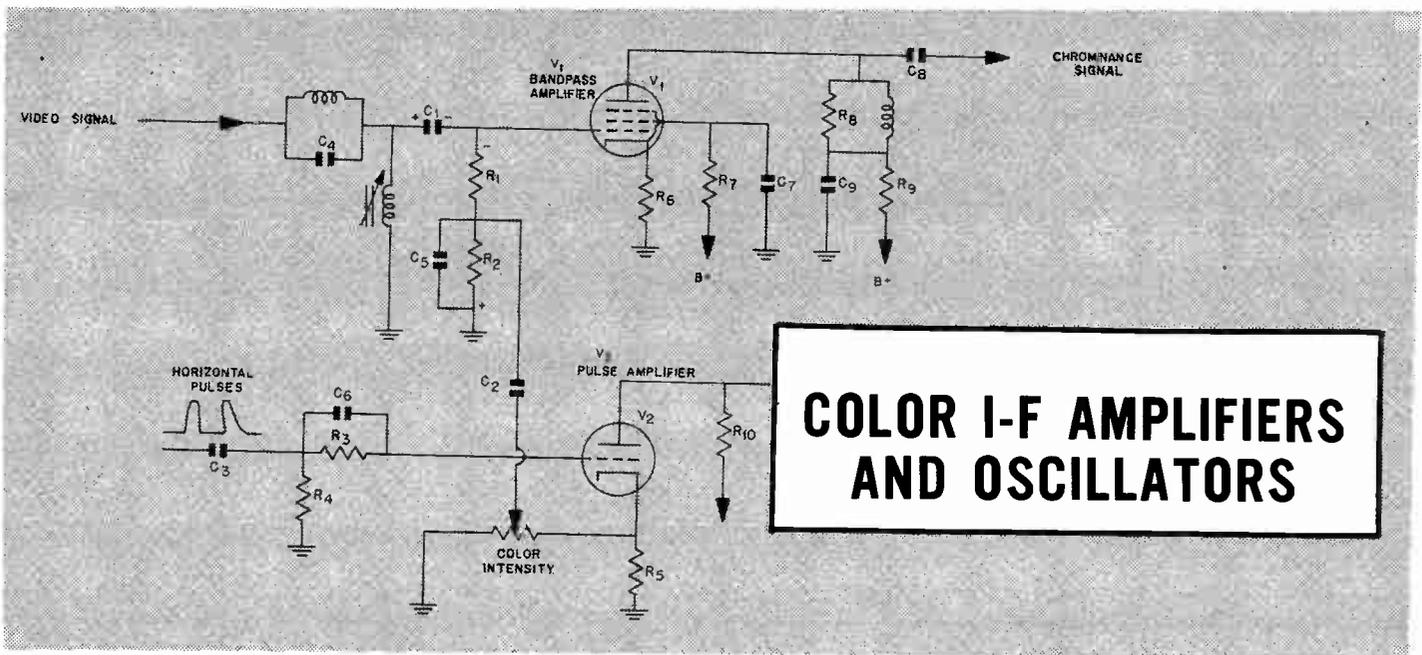
In this lesson we make a detailed study of the color i-f amplifiers and oscillators used in color TV receivers. A thorough understanding of this section of the color receiver is important for rapid troubleshooting of color defects. You will find many circuit variations for performing the functions of these circuits. For this reason it is important that you know what the circuits must do in handling the color signal.

Then when you come across a circuit variation with which you are not familiar, you can easily figure it out.

Fig. 1 shows a block diagram of the color section of a receiver with shaded blocks of those circuits covered in this lesson. Let's follow the signals through the block diagram as a review of how the color circuitry functions.
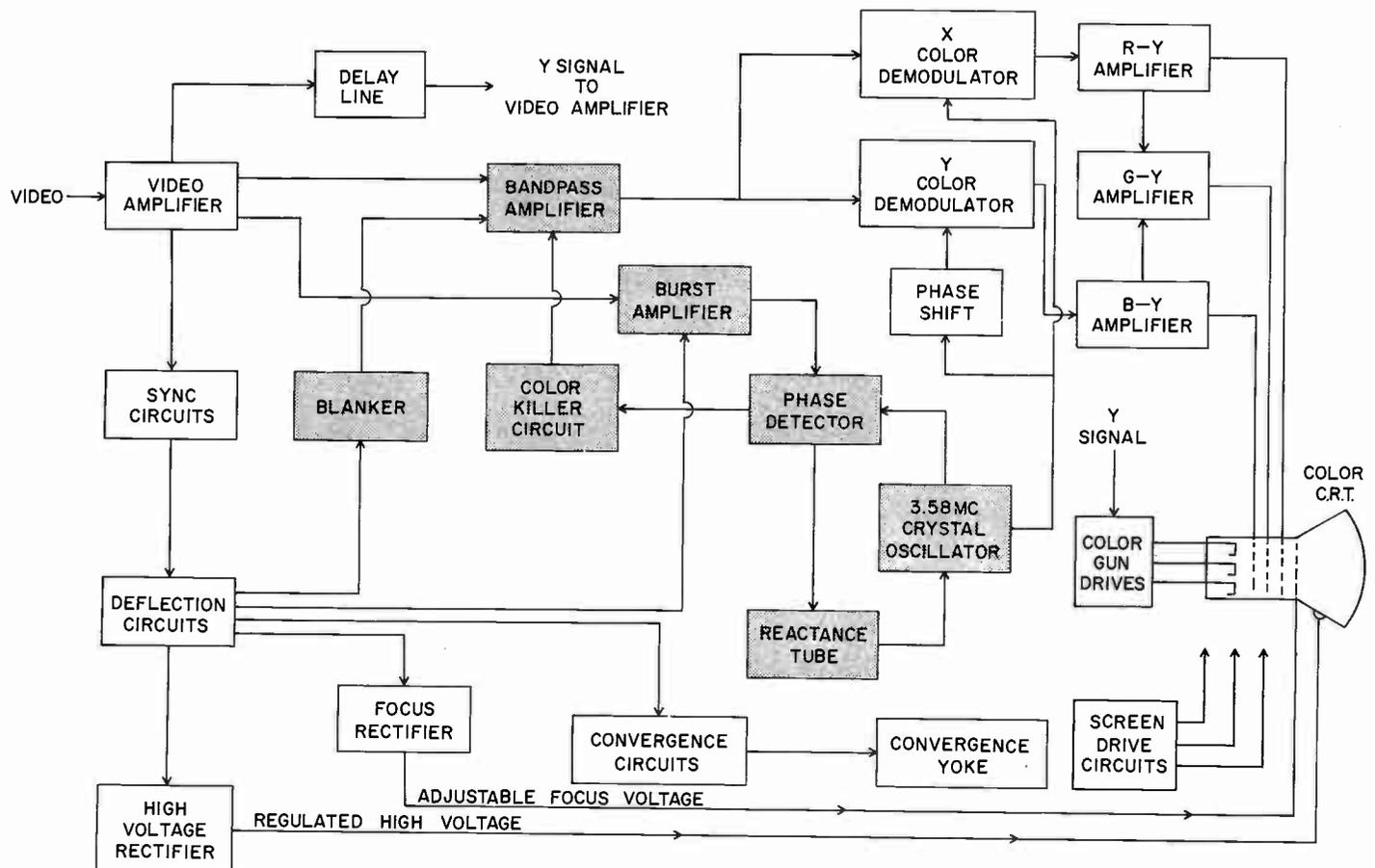
Fig. 1. Block diagram of the color section of a receiver. The shaded blocks are covered in this lesson.

The video signals are fed from the video amplifier to four different stages. A video signal is fed through the delay line to become the delayed Y signal or luminance signal. After further amplification, the Y signal is applied through the drive circuits to the cathode of each of the three guns of the color tube in most receivers. You'll see an exception to this in a circuit you will study later. The delay line is a necessary part of the color receiver. As you recall the Y signal must be delayed to compensate for the inherent delay in the narrow bandpass chrominance amplifiers.

Thus the color information and the corresponding luminance information arrive at the picture tube at the same time. This results in a picture that is "in register" meaning that the colored areas fall in their proper places in relation to black-and-white picture detail.

Bandpass Amplifier.

Another video signal from the video amplifier is fed to the bandpass amplifier. This amplifier is designed to accept and amplify only a narrow band of frequencies around the 3.58 mc color subcarrier frequency. Essentially, the bandpass amplifier selects the chrominance signal and rejects the remaining signals of the composite video signal. A blanker circuit biases the bandpass amplifier beyond cutoff during the horizontal retrace time, to prevent sync signals from passing through the amplifier and affecting other parts of the color circuitry. When color signals are not being received, the bandpass amplifier is cut off by a color killer circuit to prevent spurious signals from passing through the color circuit and introducing specks of color in the black-and-white picture.

The color control, for setting the desired saturation of the color picture, is usually associated with the bandpass amplifier. This control adjusts the amplitude of the chrominance signal that is fed to the color demodulators. At this point, the chrominance signal consists of a sine wave having a frequency of approximately 3.58 mc.

At any instant the amplitude of the sine wave represents the color saturation being transmitted and the phase of the sine wave represents the hue being transmitted. This instantaneous sine wave can be represented as a vector. The phase of the vector in relation to the color burst signal represents the hue, and the length of the vector represents the saturation of the color being transmitted at that instant.

Color Demodulators.

The color demodulators resolve the chrominance signal into separate color signals. This is the reverse of the process at the transmitter, where the I and Q signals were combined in doubly balanced modulators to produce a single chrominance signal. You will remember that the modulation process removed the 3.58-mc carrier, leaving only the sidebands. The 3.58-mc carrier is reinserted at the receiver as one step in the demodulation process.

It is practical to demodulate the signal on any two of several axes. In the receiver represented by the block diagram in Fig. 1, demodulation is performed on the "X" and "Z" axis. Each demodulator compares the instantaneous phase and amplitude of the chrominance signal with the reinserted 3.58-mc subcarrier frequency. The exact phase of the subcarrier applied to each demodulator determines the axis of demodulation.

The filtered output from the demodulators are fed to the R - Y and B - Y amplifiers. The outputs from these two difference amplifiers are combined to produce the G - Y signal. The three color difference signals are applied to the grids of the three-gun picture tube. Since the Y signal is present on the cathodes, the picture tube effectively matrixes the color difference signals with the Y signal. Thus the resultant grid-to-cathode signals on the different guns are the color signals, R, G, and B.

Applying the Y signal to the cathodes of the tri-color tube and the color difference signals to the grids is not the only way of matrixing the Y and color difference signals. The signals can be matrixed before they are fed to the picture tube. For example, in one color TV circuit which you will study later, the Y signal is fed to the color demodulator. The receiver uses three separate color demodulators and the signal at the output of each demodulator is the Y signal matrixed with the color difference signals so that we have a true color signal at the output of each detector. The color signals are amplified by color amplifiers and fed to the cathodes of the tri-color tube. The three grids of the picture tube are simply tied together.

Another possible arrangement would be to matrix the color difference signals with the Y signals in the detector circuit and then feed the amplified signal to the grids of the tri-color tube. The only difference between feeding the signal to the grid or the cathode is in the polarity required. For example, if you are televising a bright red scene and are feeding the signal to the grid of the tube you would want the red gun driven in a positive direction. On the other hand, if you are feeding the signal to the cathode of the red gun, you would want the signal to swing in a negative direction. Inverting the signal phase can be accomplished simply by using an extra amplifier stage.

While at the present time most TV manufacturers make use of the picture tube to matrix the brightness signal with the color difference signals, there is no reason to think that this practice will continue indefinitely. More efficient and more economical methods of matrixing the signals may be discovered and manufacturers will probably adopt them.

Color Sync.

The burst signal is used to synchronize the operation of the color circuits in the receiver. The burst signal consists of eight cycles of the 3.58-mc color subcarrier frequency. It appears on the back porch of the horizontal sync signal when a color program is transmitted. The video signal from the video amplifier is applied to the burst amplifier to recover the sample burst of the 3.58-mc subcarrier frequency.

The burst amplifier is also called the burst keyer stage because the amplifier is keyed on only during the horizontal retrace time when the burst is received. In this way the burst signal is separated from the rest of the composite video signal. An amplified burst sig-

nal is applied to the color killer circuit. Absence of the color burst allows the color killer to cut off the bandpass amplifier. This occurs only when a black-and-white signal is being received.

The burst signal is used to synchronize the frequency and phase of the 3.58-mc crystal oscillator. The demodulators require a continuous 3.58-mc reference signal which maintains a constant phase relation to the 3.58-mc subcarrier frequency at the transmitter. To meet this requirement, a phase detector compares the output of the 3.58-mc crystal oscillator with the color burst signal. The phase detector detects any difference in the phase of the two signals and produces an error voltage proportional to this phase difference. This dc error voltage from the phase detector is applied to the reactance control stage as a dc correction voltage. The reactance stage acts on the 3.58-mc oscillator to correct the phase of the output signal and hold it in step with the phase of the burst signal.

The hue control, sometimes called the tint control, is associated with the color sync circuitry. It functions to change the phase of the 3.58-mc oscillator signal in relation to the phase of the burst signal. Since this changes the demodulation axis of the demodulators, it will change the exact hues displayed on the picture tube. The hue control can be used to compensate for slight changes in circuit characteristics. The customer uses the hue control to adjust the colors in the picture to his liking.

The hue control may be located in any part of the crystal oscillator control circuit loop. In some receivers it shifts the phase of the burst signal; in others it shifts the phase of the output of the 3.58-mc oscillator; and in others it controls the action of the reactance stage.

Picture Tube Circuits.

The color picture tube requires other circuitry in addition to that required for black-and-white picture tubes. Also the operating voltages for the color tube must be carefully controlled. The sync circuits for synchronizing the horizontal and vertical sweep circuits are handled in the same way as in black-and-white receivers. As shown in Fig. 1, a video signal is fed to the sync circuits where the horizontal and vertical sync signals are separated from the composite video signal.

The synchronized deflection circuits in a color receiver produce signals used in the chrominance section of the receiver. A horizontal pulse during flyback time drives the blanker stage, and another pulse keys the burst amplifier. An adjustable focus voltage for the color crt is produced in the horizontal deflection circuit by a focus rectifier. The high voltage for the ultor anode of the color crt is adjustable and regulated. This is necessary to prevent blooming, which gives the appearance of misconvergence. Voltage waveforms for the deflection circuits are fed to the convergence circuits where adjustable static and dynamic signals are made up for driving the convergence yoke of the color crt. This arrangement provides adjustments to converge the three electron beams onto the correct color dots, and to keep them on the correct dots as the three beams are swept over the face of the color tube.

The block labeled "screen drive circuits" in Fig. 1 provides a means of adjusting the beam intensity of each electron gun in the color crt. These circuits are necessary to balance the output from the three electron guns.

Now that we have reviewed the overall operation of the color section of the receiver, let's examine in detail the circuitry in the shaded blocks in Fig. 1. If you have forgotten how the Y signal and the color signals are formed, or if you do not remember how the 3.58-mc color subcarrier was modulated, you should review the earlier color lessons before going ahead with this lesson.

Bandpass Amplifiers

The first place in the color receiver where the color signal appears separately is at the output of the bandpass amplifier. These circuits are often called color i-f amplifiers. The circuit separates the color signal from the rest of the video signal and amplifies it to the level needed by the color demodulators. Color receivers may have one, two, or even three stages of color i-f amplification. Tuned circuits in these stages provide the desired bandpass response and thus separate the color signal from the rest of the composite video signal.

Fig. 2 shows a simplified diagram of a single stage bandpass amplifier. The composite video signal from the video amplifier is applied to the chroma takeoff coil, L_1. The combination of L_1 and C_1 forms a series-resonant circuit. A tap on the coil feeds the signal to the control grid of the amplifier tube. R_1 is a small value resistor which is in series with L_1 and C_1 to broaden the response of the resonant circuit. When no color signal is being received, a negative voltage from the color killer is applied to the junction of R_1 and R_2. This negative voltage is applied to the grid of the tube through R_1 and L_1 and cuts the tube off. This prevents any extraneous signal from passing through the amplifier during black-and-white reception. A positive horizontal pulse from the blanker stage is applied to the cathode of the bandpass amplifier to blank the stage during the horizontal retrace period.

The amplified chroma signal current from the plate of the tube (Fig. 2) flows through the primary winding of the tuned bandpass transformer, T_1. The primary winding along with the plate-to-cathode capacity of the tube and stray wiring capacity form a parallel-resonant circuit. The signal from the primary of T_1 is coupled to the secondary winding and applied to potentiometer, P_1. The setting of the color control, P_1, selects the amplitude of the color signal applied to the demodulators, and thereby controls the saturation of the colors displayed on the picture tube.

A two-stage transistor color bandpass amplifier is shown in Fig. 3. The circuit is essentially the same as any transistor i-f amplifier, but there are a few unusual features.

The composite video signal which contains the color information is fed through C_1 to the primary of the 3.58-mc color i-f transformer T_1. From the primary the signal is inductively coupled to the secondary and then fed through C_3 to the base of the first color bandpass amplifier stage, Q_1. Q_1 is connected in a common-emitter circuit.

Notice that the bias applied to the base of the transistor is fed through R_2 from the lead labeled ACC. This lead comes from an automatic color control circuit. This circuit, which you will study later in this lesson, develops a variable bias for the transistor. If the amplitude of the color signal is high, the forward bias applied to Q_1 is reduced and as a result the gain of the stage goes down. In the event that the color signal amplitude is comparatively low, then maximum forward bias is applied to Q_1 so the stage operates at maximum gain.

The diode, D_1, which is connected across the primary of the color i-f transformer T_2, is an overload diode. Normally the potential applied to the anode and cathode of the diode will be essentially the same so that the diode will not conduct. However, in the event that the amplitude of the signal becomes excessively high, then the voltage developed across the primary of T_2 will be sufficient to permit the anode of the diode to become positive with respect to the cathode. When this happens the diode conducts and reduces the load impedance in the collector of Q_1. This will reduce the amount of signal voltage developed across the primary of T_2 and hence the signal fed on to the second i-f amplifier stage.

Q_2 is the second color i-f stage. Notice that this stage is neutralized by means of a signal fed from the primary of T_3 through C_8 back to the base of the
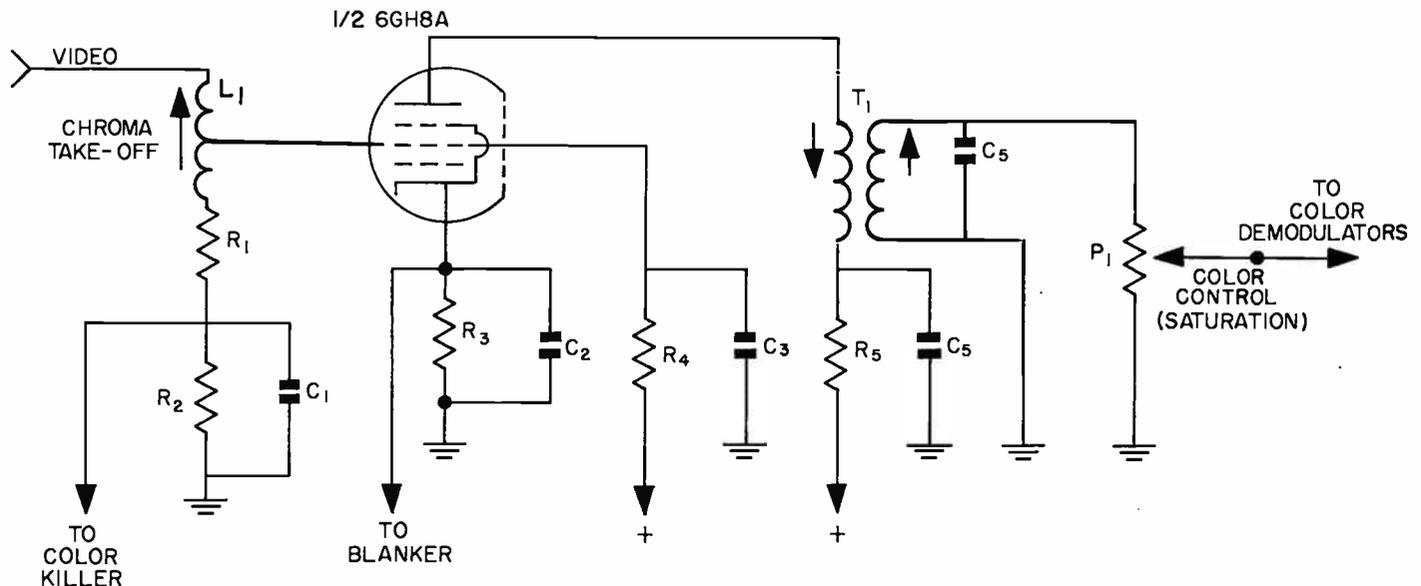
Fig. 2. Single stage bandpass amplifier.
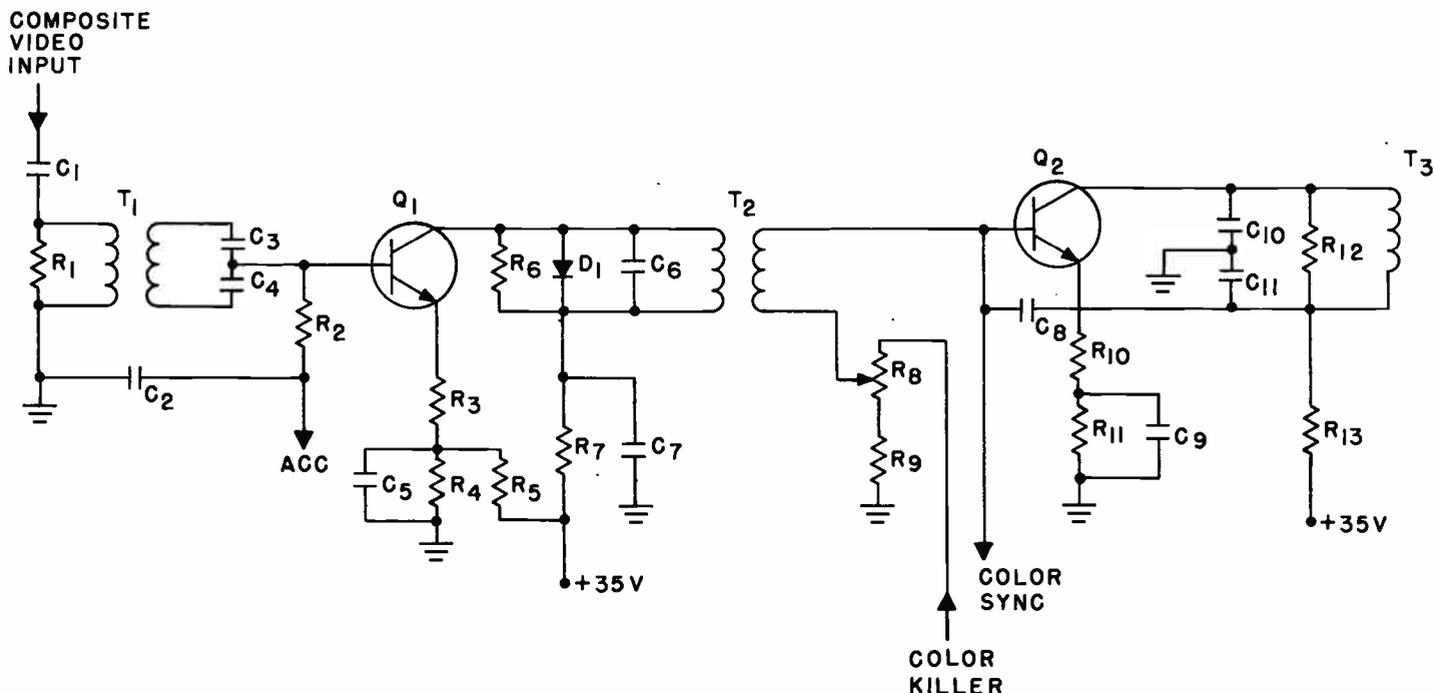
Fig. 3. A two-stage transistor color i-f amplifier.

transistor. We have only shown the primary winding of the transformer, T_3; the secondary feeds to the diode demodulators.

The color-killer signal is fed through R_8 and the secondary of T_2 to the base of Q_2. When there is no color signal being transmitted a high negative voltage is developed by the color-killer circuit and fed to the base of Q_2 and cuts off the transistor. During a color broadcast the base of the transistor will be driven positive so there is a forward bias across the emitter-base junction and the transistor will conduct.

The control, R_8, is a threshold control. It is adjusted to control the gain of the transistor and to provide the required color intensity of the picture. Once it is set, the automatic color control voltage applied to Q_1 should regulate the gain of that stage so that the overall gain of the two-stage amplifier will be sufficient to give the desired color intensity regardless of the amplitude of the signal fed into the amplifier.

Notice that the color sync signal is taken off from the secondary of T_2. This provides a color sync signal which has been amplified by the first bandpass amplifier Q_1. The color killer will have no effect on the color sync signal because it controls Q_2. In other words, if you are watching a black-and-white program, the color killer will feed a negative signal to the base of Q_2 and cut off this transistor. If the next program is transmitted in color, the signal will automatically be amplified by Q_1 and then fed to the color sync takeoff. The color sync takeoff, is fed to another amplifier and then is used to control the color oscillator. You'll see later that the color sync signal must get to the oscillator in order to cause the color killer to remove the bias from Q_2.

We will study this entire circuit later in this lesson to see how the various control voltages are tied in with these two stages. The important thing for you to study now is the bandpass amplifier itself. It is essentially a conventional two-stage transistor i-f amplifier tuned to 3.58 mc.

AMPLIFIER RESPONSE

The bandpass amplifier is designed to amplify a band of frequencies above and below the 3.58-mc subcarrier frequency. This band of frequencies consists of the upper and lower sidebands that are the chrominance signal. As you recall, the Q color signal sidebands extend .5 mc above and below the 3.58-mc subcarrier frequency. The I color signal sidebands extend 1.5 mc below and .5 mc above the subcarrier.

To simplify receiver circuitry, most bandpass amplifiers have a response that extends about .6 mc above and .6 mc below the subcarrier frequency. This cuts off part of the lower sidebands of the I signal and causes some color distortion in the fine detail areas of the color picture. However, the resulting color distortion is hardly perceptible at normal viewing distances.

All frequencies in the chrominance signal must receive equal amplification in order to reproduce the transmitted colors accurately. Some early color receivers had bandpass amplifiers with a flat response. These receivers had four or five i-f stages, and were able to produce a flat i-f response curve that gave equal amplification to the upper and lower sidebands of the color subcarrier in the i-f amplifier. Most modern color receivers have two or three video i-f stages and the color subcarrier is positioned on one slope of the i-f response curve. This produces unequal amplification of the subcarrier sidebands in the video i-f amplifier. As a result, the color modulation compo-
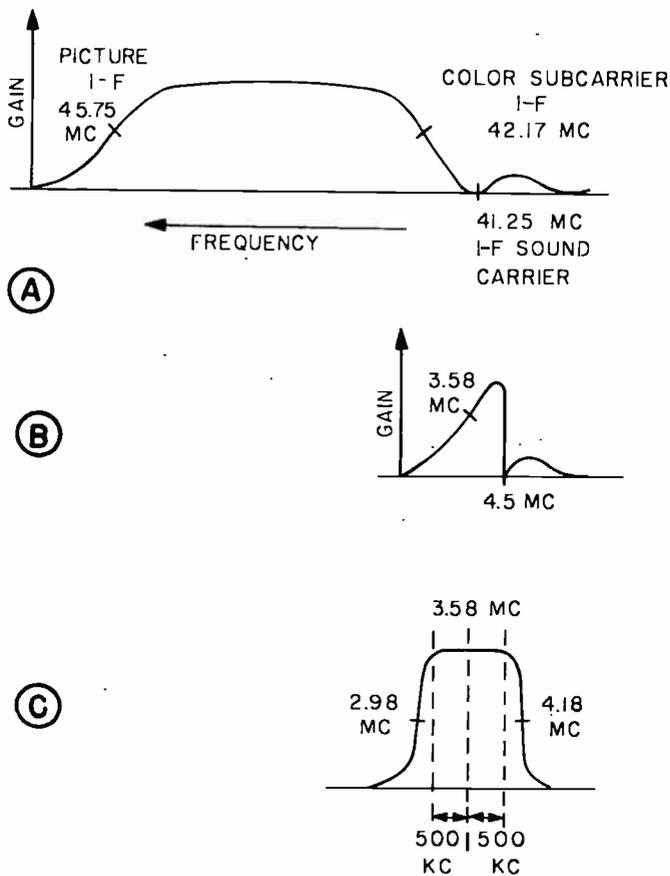
Fig. 4. Unequal amplification of the color subcarrier sidebands in the i-f response (A) is converted by shaping the bandpass amplifier (B) to give the overall response (C).

nents of the 3.58-mc subcarrier are distorted at the video detector output. The response curve of the bandpass amplifier is shaped to compensate for this distortion.

Fig. 4A shows the response curve of a typical three-stage video i-f amplifier with the 42.17-mc i-f color subcarrier positioned at the 50 percent point on the slope of the curve. The sideband frequencies above and below the subcarrier frequency receive unequal amplification. Fig. 4B shows the response curve of the bandpass amplifier. The rising slope of the bandpass amplifier response curve is designed to exactly compensate for this falling response curve of the i-f amplifier. The resultant response curve shown in Fig. 4C gives an essentially flat response, 500 kc (.5 mc) above and below the 3.58-mc subcarrier.

The desired bandpass amplifier response is attained by adjusting the circuits associated with the bandpass amplifier. In Fig. 2 this includes L_1 and the primary and secondary windings of T_1. Color control P_1 in this circuit is a low resistance potentiometer that loads the transformer secondary to lower the Q of the tuned circuit and broaden its response.

COLOR CONTROL

The color saturation control, sometimes called the "chroma" control or "color intensity" or simply the "color" control, adjusts the amplitude of the color signal. This corresponds to the contrast control for the luminance signals. Color controls usually work in one of two ways. In some sets the color control varies the bias on the bandpass amplifier. This changes the gain of the stage and adjusts the amplitude of the color signals delivered to the demodulators. In other sets, the color control is a potentiometer that selects a portion of the signal from the bandpass amplifier.

Where the set uses two bandpass amplifier stages, the potentiometer may be located between the stages or at the output of the second stage. Fig. 2 is an example of a color control located at the output of the bandpass amplifier. It selects a portion of the signal from the output of the amplifier. Fig. 3 is an example of a two-stage amplifier where the control is in the second stage and varies the bias on the stage.

Fig. 5 is an example of a single stage color amplifier where the color control adjusts the gain of the amplifier by varying the grid bias. The color control, labeled "color intensity", is located in the cathode circuit of a pulse amplifier stage, V_2. Positive horizontal pulses are fed to the grid of V_2. The stage operates as a cathode follower, producing horizontal pulses across the color intensity control.

The setting of the control selects the size of the horizontal pulses coupled through C_2 and R_1 to the grid of V_1. The positive pulses drive the grid of V_1 positive causing the tube to draw current and charge C_1 with the polarity shown. C_1 discharges between pulses through R_1 and R_2, placing a negative bias on the grid of V_1 as shown. Large pulses produce a large grid current which in turn places a large charge on C_1 and therefore a large negative grid leak bias on V_1. The amount of negative bias on V_1 determines the gain of this stage. Thus the amplitude of the chrominance signal out of the bandpass amplifier is adjusted by the setting of the color intensity control.

ACC.

Automatic color control (acc) is a feature found in many color receivers. These circuits attempt to hold the color saturation constant even if the color signal varies in strength. The circuit operates much like an automatic volume control for a radio or like an automatic gain control for a TV receiver.

Fig. 6 shows a two-stage color i-f with acc (automatic color control) applied to the grid of the first color i-f amplifier. The acc voltage is a negative dc voltage that originates in the color phase detector. Its amplitude varies with the amplitude of the color burst signal. A large color burst signal produces a large negative acc voltage that limits the gain of the first color i-f amplifier. Any change in the strength of the color burst signal will change the gain of the amplifier and tend to deliver a constant amplitude color signal out of the first color i-f amplifier. Notice that in this circuit the color intensity control is a potentiometer that adjusts the size of the color signal fed to the second color i-f amplifier.

COLOR KILLER

The color killer circuit detects the presence of a
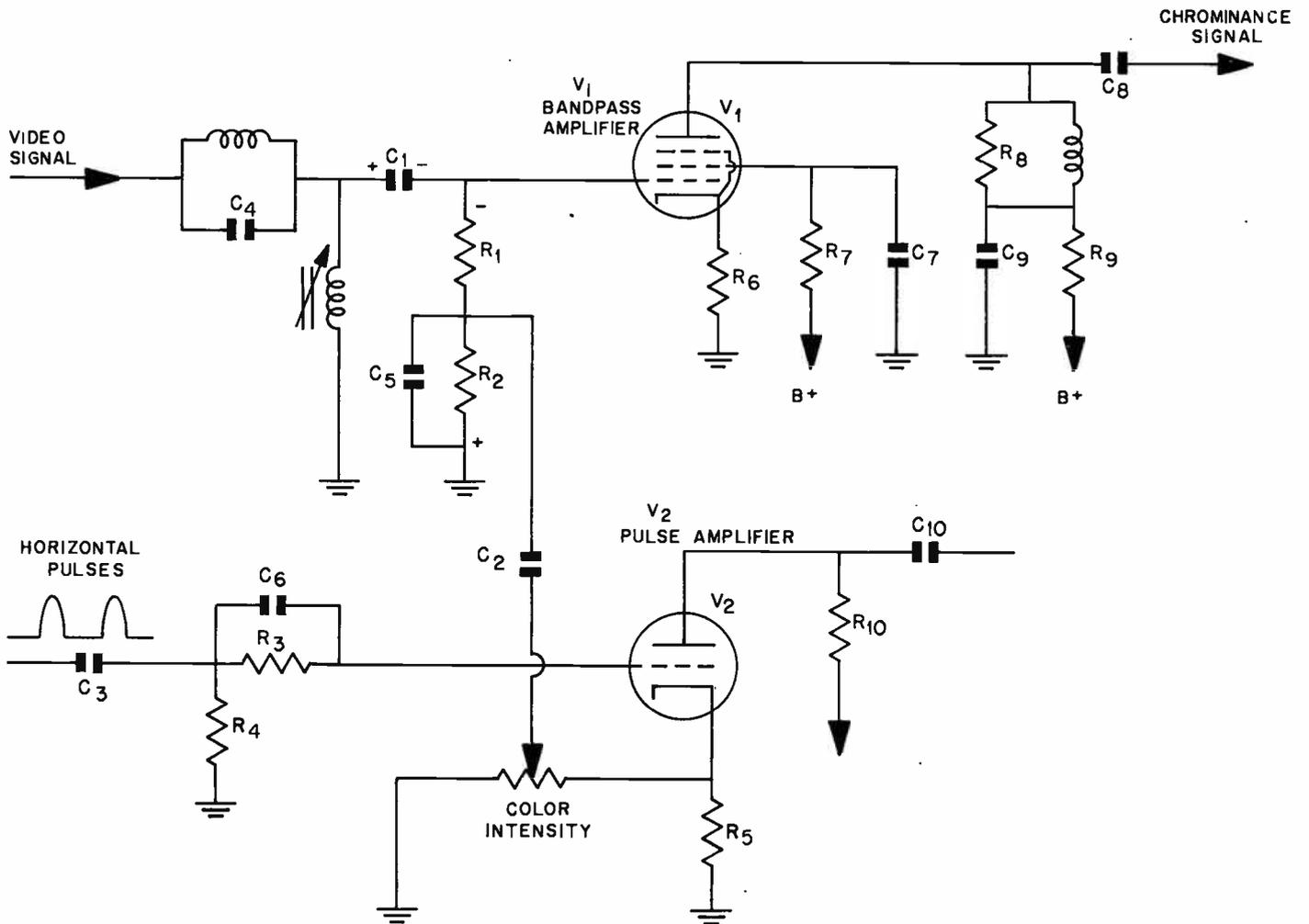
Fig. 5. The amplitude of the chrominance signal is controlled by adjusting the bias on the bandpass amplifier.

color burst signal and cuts off the color i-f amplifier when a burst signal is not present in the received TV signal. This prevents high frequency components of the black-and-white video signal from triggering the color demodulator circuits and putting streaks of color in the black-and-white picture.
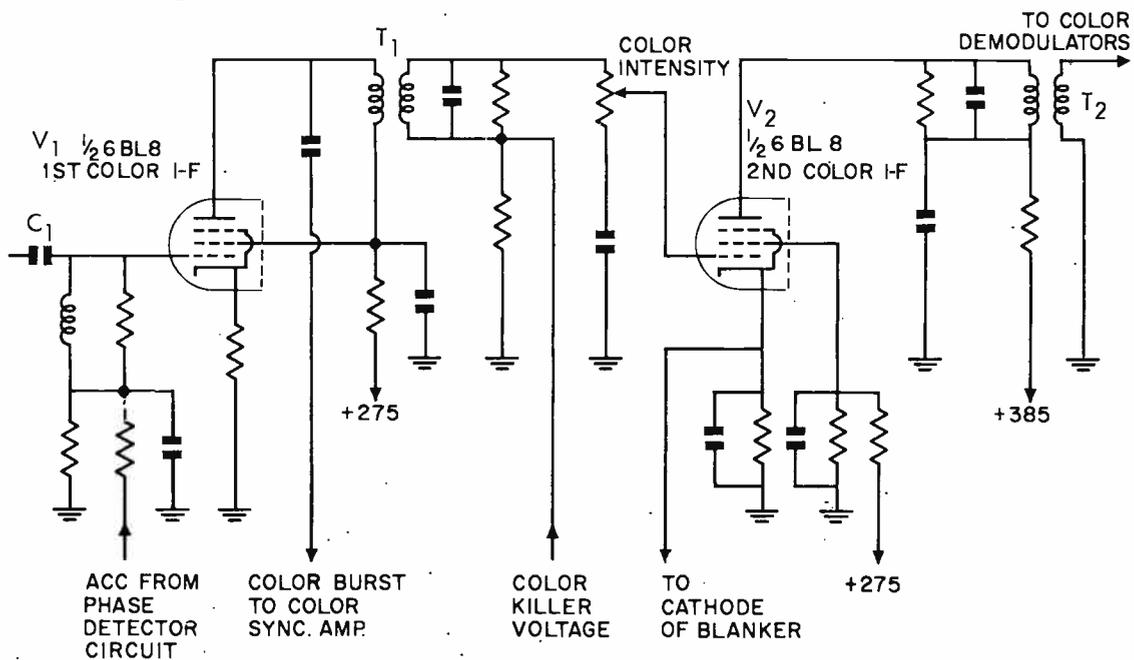
Fig. 6. Two-stage color i-f amplifier.

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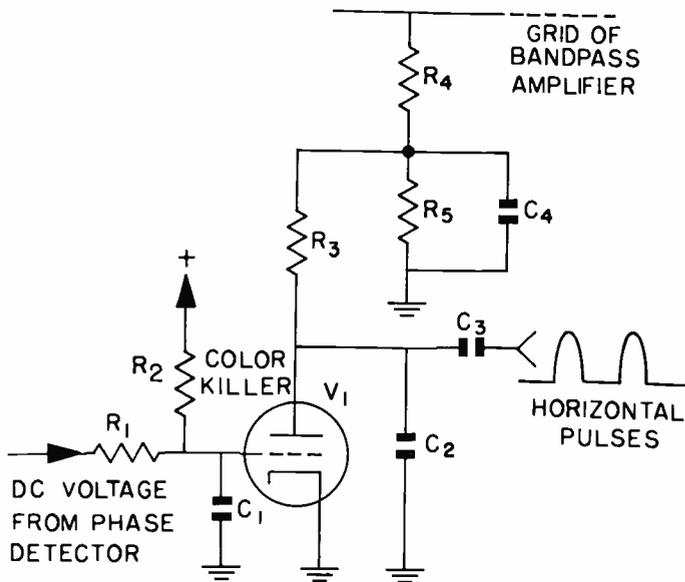
Fig. 7. Simple color killer circuit.

A simple color killer circuit is shown in Fig. 7. Triode V_1 operates like a keyed agc circuit. The positive horizontal pulses from the horizontal sweep output are applied to the plate of V_1 through capacitor C_3. The tube conducts heavily during each horizontal pulse because the grid is at approximately zero potential. When the tube conducts, plate current flows through R_3 and R_5 to ground, producing a negative voltage at the junction of R_4 and R_5. The current pulses are filtered by C_2, R_3, and C_4. The negative voltage is applied through R_4 to the grid of the bandpass amplifier, cutting off the tube. This is the condition that exists when a black-and-white picture is being received.

When a color telecast is received, the phase detector (which compares the phase of the color burst with the phase of the signal produced by the 3.58-mc oscillator) produces a negative voltage that is fed through R_1 (Fig. 7) to the control grid of the color killer tube. This negative voltage cuts off V_1 and prevents the horizontal pulses applied from causing the tube to conduct. This allows the bias on the bandpass amplifier to return to normal, and the stage amplifies the color signals.

Another simple color killer circuit is shown in Fig. 8. In this circuit, the bandpass amplifier is cut off by grid leak bias when a black-and-white signal is being received. Negative horizontal pulses are coupled through C_1 to the grid of the color killer, V_1. When no color signal is being received, V_1 amplifies and inverts the horizontal pulses. These positive horizontal pulses are coupled through C_2 and R_3 to the grid of the bandpass amplifier, V_2. The tube draws grid current on the peaks of each horizontal pulse, charging C_3 as shown. During the interval between pulses, C_3 discharges through R_3 and R_4 and develops a negative bias that holds the bandpass amplifier stage cutoff.

When a color burst signal is present in the received signal, the phase detector supplies a negative dc voltage to the junction of R_1 and R_2, in the grid circuit of V_1. This negative voltage holds V_1 cutoff so the stage cannot amplify the horizontal pulses. With no pulses applied to the grid of the bandpass amplifier, the stage operates with normal bias and the color signals are amplified.

Color killer circuits, like those shown in Figs. 7 and 8, have been used with minor variations in many color sets. These circuits have a serious disadvantage when operating with weak signals. The phase detector circuit tends to mistake noise pulses for color burst signals. Large noise pulses may cause the phase detector to produce a high enough negative voltage to bias the killer circuit to cutoff and let noise pass through the color circuits of the receiver. Other color killer circuits that are able to discriminate between noise and burst signals have been developed. These circuits usually have a separate killer detector stage, called a burst detector, in addition to the killer stage.

Burst Detectors.

Fig. 9 shows a color killer circuit with a killer detector stage. The plate and grid of V_1 are tied together so that the tube operates as a diode.

A positive voltage is applied to the cathode of V_1. At the same time, a 3.58-mc signal from the color oscillator in the receiver is applied to the plate of V_1 through C_1, C_2, and R_1. When the 3.58-mc signal drives the plate in a positive direction, the plate of the tube will become slightly positive with respect to the cathode. This will cause V_1 to conduct slightly.

The plate current from V_1 flows through R_3 and R_5 to the tap on the killer threshold control. This will cause voltage drops across R_3 and R_5 as shown. Whether the junction of R_3 and R_5 is actually positive or negative with respect to ground will depend on the setting of the threshold control. With no signal applied to the antenna of the TV receiver, the threshold control is adjusted until all traces of color disappear from the face of the picture tube.
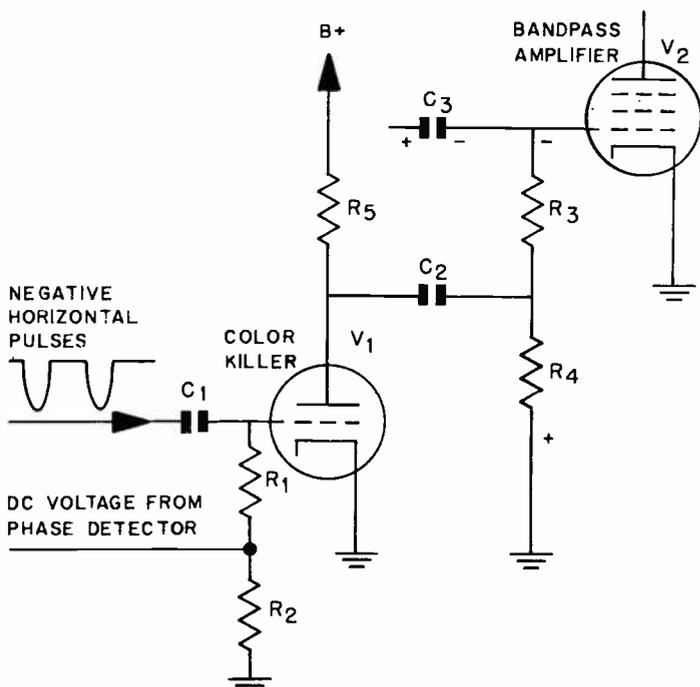
Fig. 8. Color killer circuit using amplified horizontal pulses to produce cutoff grid leak bias.

Fig. 9. Color killer circuit with triode killer detector and killer threshold adjustment.

A 3.58-mc signal from the color burst amplifier is fed to the cathode of the killer detector. This signal is 180° out-of-phase with the 3.58-mc signal applied to the plate. When the 3.58-mc signal applied to the plate drives the grid positive, the 3.58-mc signal applied to the cathode drives the cathode negative. This produces a high potential difference between the plate and cathode and causes the tube to conduct heavily. This high plate current places a high negative charge on C_4 as shown. C_4 then discharges through R_5 and cuts off V_2.

Positive pulses from the horizontal sweep output are fed to V_2. When V_2 is conducting, a negative voltage is developed in the plate circuit and fed to the grid of the bandpass amplifier. When V_2 is cut off, the negative bias is removed from the bandpass amplifier and the tube amplifies the color signal.

Fig. 10 shows a color killer circuit that uses a crystal diode for a burst detector. The operation of this circuit is not too different from the preceding color killer detector.

Signals from the 3.58-mc color oscillator are fed

Fig. 10. Color killer circuit using crystal diode to detect color burst.

Fig. 11. Color killer circuit with a separate phase discriminator for detecting the color burst (A). Vector relationship of burst signal and oscillator signal (B).

to the plate of V_{1A} and the cathode of V_{1B} through C_3, and to the anode of the diode through C_4 and R_8. The color oscillator operates at all times, whether the set is receiving a color or a black-and-white program.

When the receiver is receiving a black-and-white program, the signal applied to the plate of V_{1A} causes the tube to conduct when the signal swings positive. When this happens, current flows through R_1, producing a voltage drop across the resistor as shown. This tends to charge C_1 and C_2 as shown.

During the next half-cycle, when the cathode of V_{1B} is driven negative, this tube conducts and current flows through the tube to the plate and through R_4, producing a voltage drop across it as shown. This also charges C_1 and C_2 as shown. With both halves of V_1 conducting equally, the junction of R_2 and R_3, and the ends of C_1 and C_2 that connect to the burst transformer, will be at ground potential. This means that the cathode of V_{1A} will be maintained at a positive potential.

The cathode of V_{1A} is connected to the cathode of the diode, D_1. This will bias the diode so it will not conduct (often called back-bias). The signal from the 3.58-mc oscillator is attenuated by R_8, so it cannot drive the anode of the diode far enough in a positive direction to make it conduct.

While this is happening, high amplitude positive pulses are fed from the horizontal sweep output to V_2, the color killer. V_2 conducts and charges C_6 with the polarity shown. R_{13} and C_7 filter the negative pulses and apply a negative voltage to the grid of the second color i-f stage and cut off the tube.

When a color program is received, a color burst is fed from the burst transformer, through C_1 to the cathode of the diode, D_1. This burst is 180° out-of-

phase with the signal from the 3.58-mc oscillator. As a result, while the oscillator drives the diode anode in a positive direction, the burst signal is driving the cathode in a negative direction. This overcomes the bias on the diode, causing it to conduct heavily; this charges C_5 with the polarity shown and cuts off V_2.

In the interval between color bursts, C_5 discharges through R_{10}, setting up a voltage drop across it and keeping the color killer tube cut off. When the tube is cut off, there is no negative bias developed to keep the 2nd color i-f stage cut off so that it amplifies the color signals fed to it.

Phase Discriminator.

Another type of color killer system, shown in Fig. 11A, uses a separate phase discriminator as a killer detector. When no burst signal is present, the junction of R_2 and R_3 is approximately at zero volts dc. The 3.58-mc oscillator signal causes V_{1A} and V_{1B} to conduct on alternate half-cycles. When the cathode of V_{1A} is driven negative, current flows through the tube to the plate, and into one side of C_1, and tries to charge C_1. However, C_1 is large enough so that very little charge is built up on it.

During the next half-cycle when the plate of V_{1B} is positive, electrons flow out of C_1, through R_3 and through V_{1B} to the plate. Since R_2 and R_3 are of equal value and both tubes conduct the same amount, there will be no charge built up on C_1 and the junction of R_2 and R_3 remains at zero volts. This means that the grid of the color killer stage, V_2, has no bias on it, so the tube conducts.

The killer control potentiometer has a positive voltage applied to one end and a negative voltage applied to the other end. Thus the pot arm can pick off voltages above or below zero to adjust the threshold operating voltage for the grid of V_2.

When a color burst signal is received, the junction of R_2-R_3 becomes highly negative, so the color killer (V_2) is cut off. Let's see how this happens.

The burst signal applied to the plate of V_{1A} is 180° out-of-phase with the burst signal applied to the cathode of V_{1B}, because the signals are taken from opposite ends of the secondary winding of the burst transformer. The phase relation of the 3.58-mc oscillator signal compared to the burst signal is shown in Fig. 11B.

For V_{1A}, the signals are 180° out-of-phase. That is, when the plate of V_{1A} is positive, the cathode is negative, and the diode conducts heavily. For V_{1B}, the signals are in phase. Therefore, when the plate of V_{1B} is positive, the cathode of V_{1B} is also positive and the diode does not conduct.

So when V_{1A} conducts heavily, electrons flow through the tube, through R_2 and into C_1, charging it as shown. During the next half-cycle, since V_{1B} does not conduct, C_1 cannot get rid of the surplus electrons except through R_1. R_1 is a very large resistor, so the capacitor discharges very little. Thus the negative charge on C_1 keeps the color killer, V_2, cut off. With V_2 cut off, the bias on the bandpass amplifier returns to normal and amplifies the color signal.

This circuit works very well on weak signals, because the killer stage is not cut off until sufficiently large burst signals are present to lock the 3.58-mc oscillator into sync. In this way, color information is not displayed unless the received signal is strong enough to produce a synchronized color picture.

AUTOMATIC COLOR CONTROL AND COLOR KILLER CIRCUIT

An interesting circuit that functions as an automatic color control and as a color killer is shown in Fig. 12. This transistorized circuit is used in conjunction with the two-stage bandpass amplifier shown in Fig. 3.

In the receiver in which this is used, the 3.58-mc crystal operates only when a color burst is being transmitted. Thus during a color program when the burst is transmitted, the crystal generates a 3.58-mc signal. This is fed to the input of the acc circuit through capacitor, C_1.

The 3.58-mc sine wave has its negative half-cycles eliminated by the diode, D_1. When the signal swings in a negative direction the diode conducts and hence acts as a low impedance between the base of Q_1 and ground. However, during the positive half-cycle, the 3.58-mc signal drives the base of Q_1 in a positive direction placing a forward bias across the emitter-base junction of the transistor. This causes current to flow through the transistor.

When current flows through the transistor, Q_1, there will be a voltage drop across R_5. The amount of voltage across R_5 will depend on the amplitude of the current and this in turn will depend on the strength of the 3.58-mc signal fed to the base of the transistor. The voltage drop across R_5 will cause the positive potential at the collector of Q_1 to drop. Thus, the cathode of D_2 becomes negative and the anode positive and the diode conducts. The actual drop in voltage that will occur will depend upon how high the current through Q_1 is and this in turn will depend upon the strength of the signal fed to the base of Q_1. The output from the oscillator will depend upon the strength of the burst being received and this in turn depends upon the strength of the color signal.

The automatic color control voltage which is taken off at the junction of D_2 and R_6 is fed to the base of the first color i-f amplifier in the circuit shown in Fig. 3. The higher the amplitude of the color burst signal, the more the voltage drops at the junction of D_2 and R_6. This drops the forward bias applied to the base of Q_1 and hence reduces the gain of this stage. Therefore, the transistor, Q_1, in the circuit shown in Fig. 12 acts as an automatic gain control and controls the gain of the first color i-f stage depending upon the strength of the signal received.

The diode D_2 is used to delay the automatic color control voltage. A small weak 3.58-mc signal reaching the base of Q_1 will not cause any appreciable current through the transistor. Hence there is not a great voltage drop across R_5. This means that the forward bias applied to the base of the first color i-f amplifier will be at a maximum value. The strength of the received color signal must reach a certain amplitude before D_2 begins conducting. Thus we have a delayed automatic color control situation.

Transistors, Q_2 and Q_3, act as a switch and are used as the color killer. In the circuit shown in Fig.
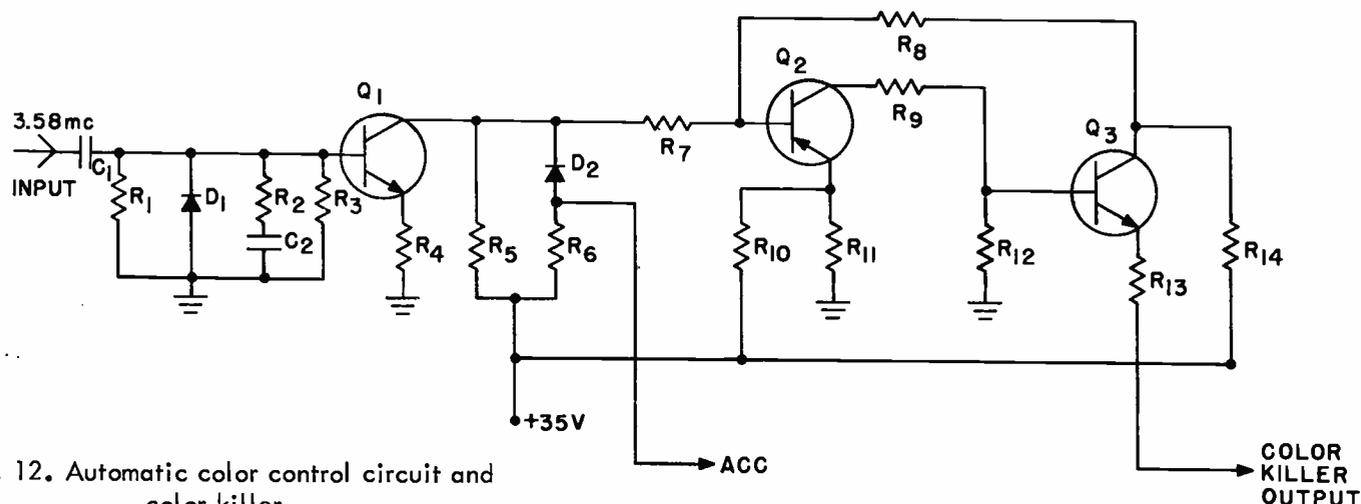
Fig. 12. Automatic color control circuit and color killer.

3, you'll notice that the potentiometer, R_8, feeds back to the color killer output. During monochrome reception, when no color burst is transmitted, the transistor, Q_3, in the circuit shown in Fig. 12 will not be conducting. When this happens there will be no forward bias across the emitter-base junction of the second color i-f amplifier in Fig. 3. As a result the transistor will be cut off. When a 3.58-mc signal is fed to Q_1 and causes the collector voltage on this transistor to drop, this will place a forward bias across the PNP transistor, Q_2. The forward bias that is across the emitter-base junction of this transistor will cause the transistor to conduct and develop a positive voltage on the base of Q_3. This will cause Q_3 to conduct and the current will flow through the resistor, R_9, and the color potentiometer, R_8, in Fig. 3, and then through R_{13} in Fig. 12 to the emitter of Q_3. This current will place a positive voltage on the base of Q_2, the second color i-f amplifier in Fig. 3, and hence turn this stage on.

The feedback resistor, R_8, connected between the collector of Q_3 and the base of Q_2 in Fig. 12 is used to make the action of the color killer positive. Once Q_2 begins to conduct and causes Q_3 to conduct the drop in collector voltage on Q_3 is fed back to the base of Q_2 through R_8. This feedback causes the base voltage of Q_2 to swing highly negative, which is the condition we want for the switch to close fully when the color signal is received. When Q_2 is turned all the way on, it will develop maximum forward bias at the base of Q_3 and turn this part of the switch on fully and hence develop maximum forward bias for the second color i-f amplifier in the two-stage amplifier shown in Fig. 3. The potentiometer, R_8, in Fig. 3 is adjusted to give you the required gain in this stage which will give you the degree of color saturation desired.

BLANKER

In some color receivers, the color i-f amplifier is disabled (blanked) during the horizontal retrace period to prevent the burst signals from reaching the color demodulators. If the burst signals reach the color demodulators, color signals will be produced during retrace time. These signals can be large enough to overcome the retrace blanking and produce color on the screen during retrace. Another reason for blanking the color i-f is to prevent the burst signal from upsetting any keyed dc restorer circuits. The presence of the burst signals can cause keyed restorer circuits to establish an incorrect saturation level.

A blanker stage, also called a horizontal blanking amplifier, is included in many color TV receivers to prevent undue loading of the horizontal circuits. A horizontal pulse is used to blank the color i-f amplifier during retrace. If this pulse is taken from a winding on the flyback, it tends to load the circuit because of the sizeable amount of power needed to blank the color i-f amplifier. The blanker stage operates as an impedance-matching power amplifier. The high impedance grid circuit accepts the pulse from the transformer and produces a low impedance pulse in the cathode circuit. This positive pulse is applied to the cathode of the color i-f tube to cut off the stage.

Fig. 13 shows a typical blanker stage (horizontal blanking amplifier). Positive horizontal pulses from the flyback transformer circuit are coupled through C_1 and R_1 to the grid of the blanker stage, V_1. These large pulses draw grid current, charging C_1 and C_2 to a high negative potential as shown. In the circuit shown, the average dc grid voltage is -45 volts. This negative voltage holds V_1 cutoff except for the duration of the horizontal pulse. Resistor R_5 is the common cathode resistor for V_1 and the bandpass amplifier, V_2. When V_1 conducts, the large positive pulse in the cathode circuit biases V_2 to cutoff and effectively blanks the bandpass amplifier for the duration of the horizontal retrace period.
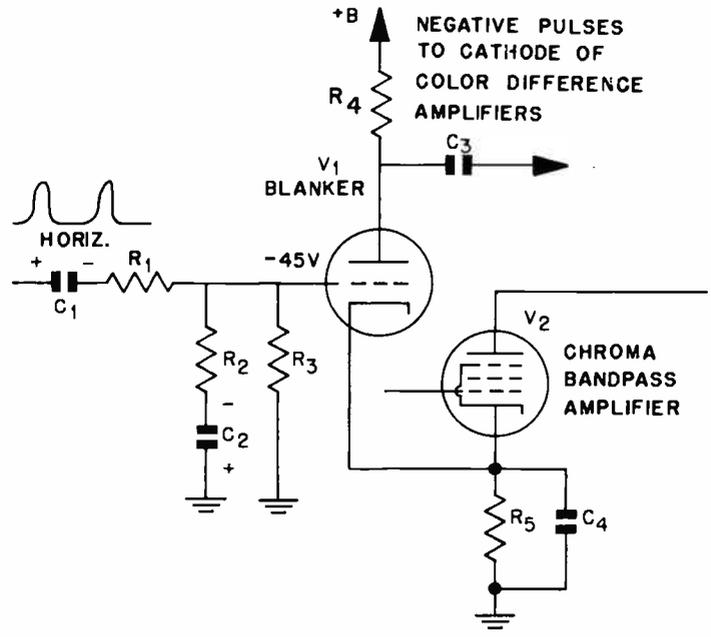
Fig. 13. A horizontal blanking amplifier.

A negative horizontal pulse is available in the plate circuit of the blanker stage. In the circuit shown in Fig. 13, the negative horizontal pulses are coupled through C_3 to the cathodes of the color difference amplifiers. The pulses provide keyed dc restoration for the color signals.

TYPICAL BANDPASS AMPLIFIER

You have studied several one and two stage bandpass amplifiers in this section. These circuits are examples taken from modern color TV receivers. You will find many variations of these circuits in color receivers. Let's examine one more typical two-stage bandpass amplifier shown in Fig. 14. The bandpass amplifier stages, V_1 and V_2, are labeled first and second color i-f amplifier. Notice that the killer voltage is applied through R_6 and R_5 to the grid of V_2, so V_1 is always operating, whether a color signal is present or not.

In Fig. 14 the video signal is taken directly from the video detector and coupled through C_1 to the grid of V_1. The inductance, L_1, peaks the grid circuit in the 3.58-mc frequency range. An automatic color control voltage (acc) is applied through R_3 and R_1 to the grid of V_1. This voltage holds the color signal rela-
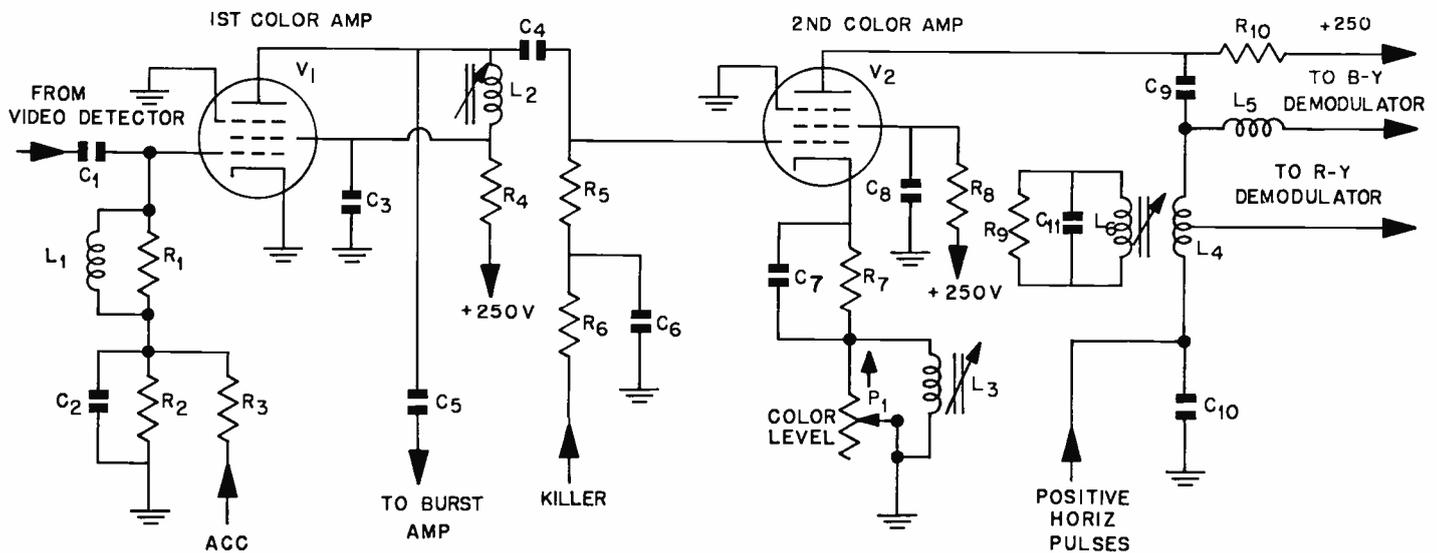
Fig. 14. Two-stage bandpass amplifier.

tively constant at the plate of V_1 even if the level of the received color signal varies. This in turn will keep the color saturation in the picture constant even though the signal strength may vary. The V_1 plate load impedance, L_2, is tuned to shape the amplifier response to the color signal. The amplified color signals are coupled through C_5 to the burst amplifier and through C_4 to the control grid of V_2.

The second color amplifier, V_2, has a saturation control in the cathode circuit. The control, P_1, is labeled "Color Level" in Fig. 14. Notice that cathode bias is produced for V_2 by the drop across resistor, R_7. This resistor is bypassed by C_7, so no signal appears across it. The inductance, L_3, is tuned to resonance at 3.58 mc. It, along with its distributed capacity and circuit capacities, forms a parallel resonant circuit at this frequency so it offers maximum impedance to the color signals. With P_1 turned fully clockwise, the slider of P_1 is at the top of P_1, and L_3 is effectively shorted. This reduces the signal across $P_1 - L_3$ to a minimum and the stage operates with maximum gain. As P_1 is rotated counterclockwise, more of the resistance of P_1 is placed across L_3, reducing the loading on the resonant circuit. This allows the impedance of the circuit to increase and a larger signal develops across P_1-L_3. Since this signal is in the grid to cathode circuit of V_2, the signal causes degeneration of the stage, reducing the output signal. In this way, the color level control adjusts the gain of the stage and determines the saturation of the color signal.

The color signal at the plate of V_2 is coupled through C_9 to a shaping network. Inductance, L_4, is tuned to shape the response curve of the bandpass amplifier. L_6, C_{11}, and R_9 form an absorption trap that helps to shape the response curve. The color signal is taken off through L_5 to the B - Y demodulator, and a tap on L_4 provides the color signal to the R - Y demodulator. Inductance, L_5, provides isolation between the grids of the B - Y and R - Y demodulators. Positive horizontal pulses are coupled into the circuit at the junction of L_4 and C_{10}. These horizontal pulses are applied

to the grids of the demodulator tubes to produce the dc restoration of the color signal.

SELF-TEST QUESTIONS

(a) Where is the first place in the signal path of the color receiver that the color signal appears separately?

(b) What is used in the bandpass amplifiers to separate the color signals from the rest of the video signal?

(c) Would the color burst signal be amplified by the bandpass amplifier?

(d) How does the potentiometer, P_1, in Fig. 2 affect the bandpass of the amplifier?

(e) How does the color intensity control in Fig. 5 change the amplitude of the color signals?

(f) What is the correct setting for a color killer threshold control?

(g) What is the disadvantage of the simple color killer circuits shown in Figs. 7 and 8?

(h) In a discriminator type of killer detector, what conditions must exist before the killer circuit will remove the cutoff bias from the bandpass amplifier?

(i) What determines the size of the negative acc voltage applied to the grid of the bandpass amplifier?

(j) What is the result of unequal amplification of the color signal sidebands?

(k) Under what signal conditions does the color killer voltage hold the bandpass amplifier cutoff?

(l) Where does the back bias for diode, D_1, (Fig. 10) originate under a no-color burst signal?

(m) Why is a pulse amplifier stage (blanker stage) used to blank the bandpass amplifier instead of using a flyback pulse directly?

(n) What could happen in a color receiver if the bandpass amplifier was not blanked during the horizontal retrace period?

(o) What purpose does D_2 in Fig. 12 serve?

(p) What is the advantage of having automatic color control?

Burst Amplifiers

The color burst signal is separated from the composite video signal and amplified before it is used to synchronized the 3.58-mc reference oscillator. These functions are performed in a burst amplifier stage. In some receivers, you will find the stage labeled burst keyer or color sync amplifier. Most receivers use a single stage, but a few receivers have two stages that process the burst signal. The input to the burst amplifier may come directly from the video amplifier or it may come from the first color i-f stage.

The burst signal is separated from the rest of the input signal by keying on the burst amplifier during horizontal retrace time. A horizontal pulse from the flyback circuit is used to bias the stage into conduction only during the time the burst signal is present. The stage is then cut off for the duration of the line. In this way only the amplified burst signal appears in the output of the burst amplifier.

The color burst signal is used to lock the 3.58-mc reference oscillator in phase with the 3.58-mc subcarrier at the transmitter. You recall that the 3.58-mc subcarrier was suppressed during the modulation process at the transmitter. In the receiver, the subcarrier must be reinserted so that the color information can be recovered from the 3.58-mc sidebands that make up the received color signal.

Since only a sample of the subcarrier signal is received, an oscillator is used to produce the continuous wave signal. The oscillator is synchronized to the burst signal so that the output of the oscillator becomes the equivalent of the transmitter subcarrier. Therefore this oscillator output can be used for subcarrier reinsertion in the demodulators of the receiver.

SUBCARRIER REINSERTION

The color signal applied to the demodulators in the receiver consists of a 3.58-mc signal. As you recall, this signal carries both phase modulation and amplitude modulation. The amplitude of this signal conveys the saturation information of the color being transmitted, while the phase conveys the exact hue being transmitted. The color information can be recovered from the signal by comparing it with the subcarrier signal.

You will also recall that the color information was in the form of the I and Q signals, and these two signals were used to modulate the subcarrier. At the receiver, the color information can be recovered along any desired axis by reinserting a subcarrier of the proper phase.

The color vector diagram is reproduced in Fig. 15 so that you can see the phase relation of the various color signal axes in relation to the reference subcarrier and in relation to each other. The receiver demodulates the signal on the selected axes to recover two or three color signals. Where only two color signals are recovered, they are matrixed to obtain the third color signal. Most receivers demodulate on the X and Z axis or on the R – Y and B – Y
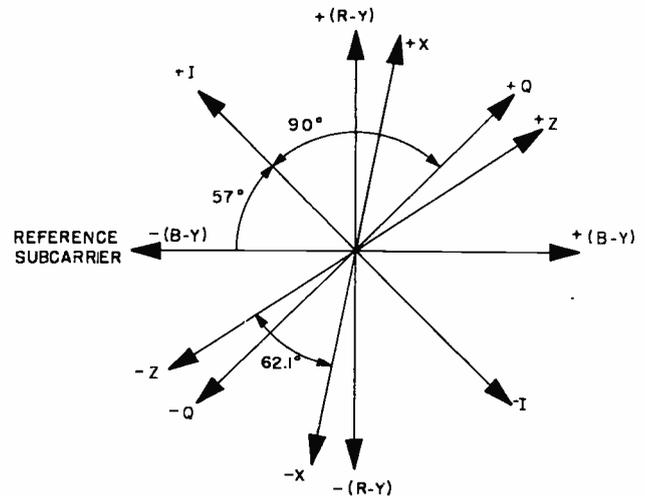
Fig. 15. The color vector diagram is reproduced for reference.

axis and recover only two color signals from the transmitted information. These two signals are then used to develop the third color signal. You will study these different types of demodulators later. The important thing to remember here is that they work on different axes and it is necessary therefore to reinsert the 3.58-mc carrier on the different axis.

To demodulate on the R – Y axis, a phase difference of 90° must exist between the color reference subcarrier and the reinserted 3.58-mc signal at the demodulator. The block diagram in Fig. 16 shows the arrangement for the R – Y demodulator. The burst signal from the burst amplifier stage controls the phase of the 3.58-mc oscillator.

Numerous phase shifts can occur in the circuit between the burst amplifier stage and the output of the oscillator. In practice these phase shifts are made to total 90°, so that the oscillator signal supplied to the R – Y demodulator lags the reference by exactly 90°. The operation of the circuit is such that it maintains this fixed phase relationship between the burst signal and the oscillator signal.

An adjustable phase shift circuit is used as a hue control. It may be placed anywhere between the burst amplifier stage and the output of the oscillator. Its effect will be to shift the phase relationship and determine the axis of demodulation. This will of course change the exact hue of the color recovered from the demodulator and displayed on the picture tube.

Fig. 17 shows an example of how the R – Y demodulator recovers the color information from the chrominance signal. The phase of the reinserted 3.58-mc signal is such that it lies on the R – Y axis. The length of the vector representing the chrominance signal is proportional to the amplitude of the instantaneous color signal being received.

In the example shown (Fig. 17A), the phase of the instantaneous chrominance signal is such that it lags the reference burst by 120° which means that it lags the R – Y axis by 30°. A projection of the chrominance
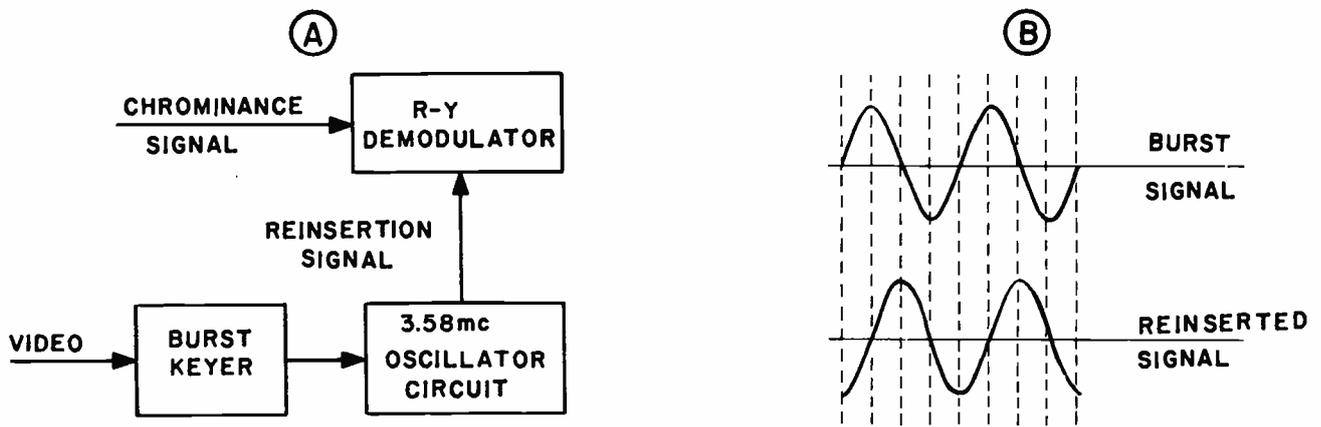
Fig. 16. Subcarrier reinsertion at the B-Y demodulator.

signal vector on the R - Y axis shows the component of the signal that the demodulator must recover in this example.

Fig. 17B is a graphic presentation of the demodulator operation for the example shown in Fig. 17A. The single cycle of the reinserted 3.58-mc signal corresponds to the R - Y axis. In one type of demodulator, shown partially in Fig. 17C, this signal is applied to grid No. 3 of a pentagrid tube. The single cycle of the chrominance signal is drawn with the 30-degree phase relation represented on the vector diagram. This signal is applied to the control grid of the demodulator tube in Fig. 17C.

The resultant plate current for the example given is plotted below the two color-control voltage sine waves. The amount of plate current corresponds to the component of the chrominance signal in the R - Y axis. The amount of plate current is affected by both signals to the grids of the tube. If the chrominance signal were more nearly in phase with the oscillator, more plate current would be produced. This of course

would correspond to a larger R - Y color component. Likewise, chrominance signals with different phase angles would produce different amounts of plate current. In the plate circuit, the variation of plate currents produces an R - Y voltage signal.

The B - Y demodulator works the same as the R - Y demodulator, except the reinserted subcarrier is shifted an additional 90°. As shown in Fig. 15, the B - Y axis is displaced 90° from the R - Y axis. The inserted carrier must lie on the B - Y axis. This is accomplished by inserting a 90° phase shift network between the oscillator output and the B - Y demodulator. The demodulators can be made to work on any desired axis. The desired axis is selected by providing the proper phase shift between the color bursts and the reinserted subcarrier.

We do not expect you to understand how the color demodulator works from the brief information given in this section. The important thing that we want you to see is that the color signal can be demodulated on different axes, but in order to get the desired results
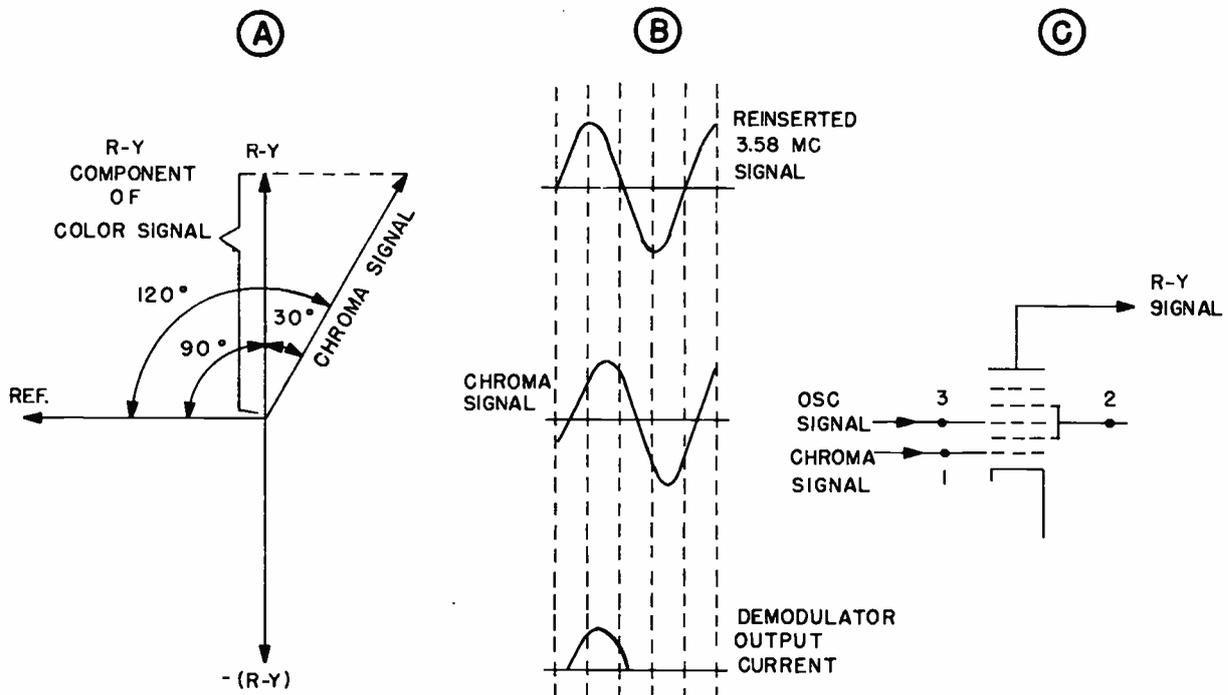
Fig. 17. Carrier reinsertion at the demodulator.

we must control the axis on which the color demodulator operates. This is done by controlling the frequency and phase of the color oscillator in the receiver. The burst signal transmitted on the back porch of the horizontal synchronizing pulse is used to control the frequency and phase of the color oscillator in the receiver. Therefore, in order to reproduce the correct colors, the burst signal must be processed so that it can be used to perform this function. Thus the burst amplifier is an important stage in the operation of the color receiver.

A SINGLE-STAGE BURST AMPLIFIER

A single-stage burst amplifier is shown in Fig. 18. In the circuit in which this amplifier is used, the color signal is taken directly from the video amplifier and fed through the capacitor, C_1. The capacitor has a relatively small value so that low-frequency video signals are prevented from getting into the circuit. The capacitor, C_1, and the coil, L_1, are tuned to resonance at 3.58 mc and hence we have a series-resonant circuit. The signal fed to the bandpass amplifier is taken off from the tap on L_1 whereas the signal across the entire coil is fed through C_2 and R_3 to the grid of the burst amplifier, V_1.

A strong pulse from the horizontal output transformer is also fed to the grid of V_1. This pulse, which occurs during the horizontal retrace interval, is a positive pulse and it drives the grid of V_1 positive. This causes the tube to conduct heavily in the grid circuit and charge C_2 with the polarity shown on the diagram. The horizontal pulse is a short duration pulse so during the balance of the cycle, capacitor, C_2, discharges through R_2. The time constant of C_2 and R_2 are selected so that the voltage across R_2 is always sufficient to keep V_1 cut off.

When the positive pulse arrives from the horizontal output circuit, it is fed through R_1 and it drives the tube into conduction. This pulse arrives at the same time as the 8-cycle color burst is transmitted by the station. Therefore the color burst is amplified by V_1 and fed to the primary of T_1. The secondary of T_1 is inductively coupled to the primary so that out-of-phase signals which can be fed to the phase detector are developed across the secondary of the transformer.

We'll go into phase detectors later in this lesson. The important thing for you to see now is that V_1 is cut off, except during the interval when the positive pulse from the horizontal output transformer is present, and during this interval the 8-cycle color burst transmitted by the station is also present. Thus the color burst is amplified and all the rest of the color signal is removed so that in the burst transformer, T_1, the only signal getting through will be the color burst.

A CHROMA AMPLIFIER AND BURST GATE

A chroma amplifier and burst gate is shown in Fig. 19. In this circuit, the color signal is taken from the video amplifier and fed to the color input transformer, T_1. Both the primary and secondary of T_1 are tuned to resonance at approximately 3.58 mc. The entire color signal is fed to the grid of V_1 and amplified by this stage. The amplified signal current flows through the primary of another color transformer, T_2, and is inductively coupled to the secondary. The secondary of T_2 is connected to the cathode of V_2. In the cathode circuit of V_2 we have a potentiometer, R_3. The center terminal on the potentiometer is connected to the color demodulator stages. Thus we have a color signal taken off at this point and fed to the color demodulators. At the same time, the entire color signal is fed to the cathode of V_2.

A large positive pulse from the horizontal output transformer is fed through C_4 and R_6 to the grid of V_2. This high positive pulse, which occurs during the horizontal retrace interval, causes the tube to draw grid current so that C_3 is charged to place a high negative voltage on the grid of V_2. During the interval between pulses C_3 can discharge through R_4 and L_1, but the time constant of the C_3 - R_4 combination is chosen so that the capacitor discharges very little and the tube will be held at cutoff.

Meanwhile, when the high positive pulse arrives at the grid of the tube it drives the tube in the conduction region. At this instant the color burst is also transmitted and the color burst is applied to the cathode and is amplified by the tube and an amplified burst signal is developed in the plate circuit. In the plate circuit we have a coil, L_2, which is tuned to resonance at 3.58 mc. The amplified color burst signal developed across L_2 is then fed through C_6 to the 3.58-mc crystal.

We'll study the crystal circuit later. The important thing for you to see in this circuit is that V_1 amplifies the entire color signal; it amplifies the burst signal plus the I and Q signals being transmitted by the transmitter. The amplified signal is fed to the cathode of V_2 and the color control is located in the cathode circuit of this tube. A color signal is taken off the potentiometer and fed to the color demodulators. V_2 acts as a gate to gate out or cut out all of the color information except the burst signal which passes through the stage when the stage is gated on by the positive pulse from the horizontal output stage.

3.58mc INPUT   HORIZONTAL INPUT
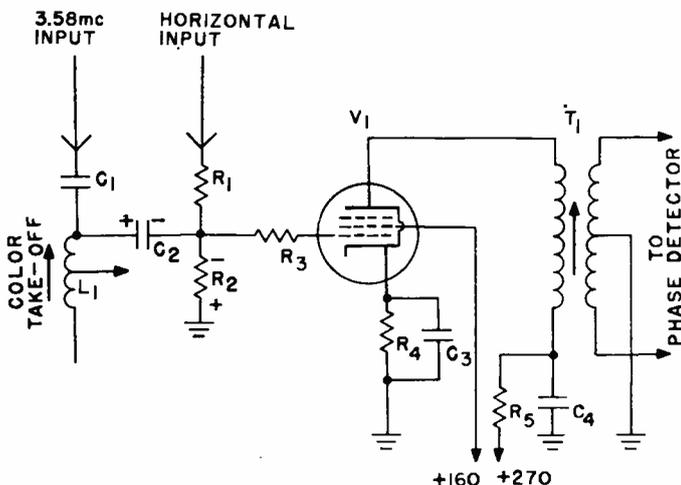
Fig. 18. A single-stage burst amplifier.
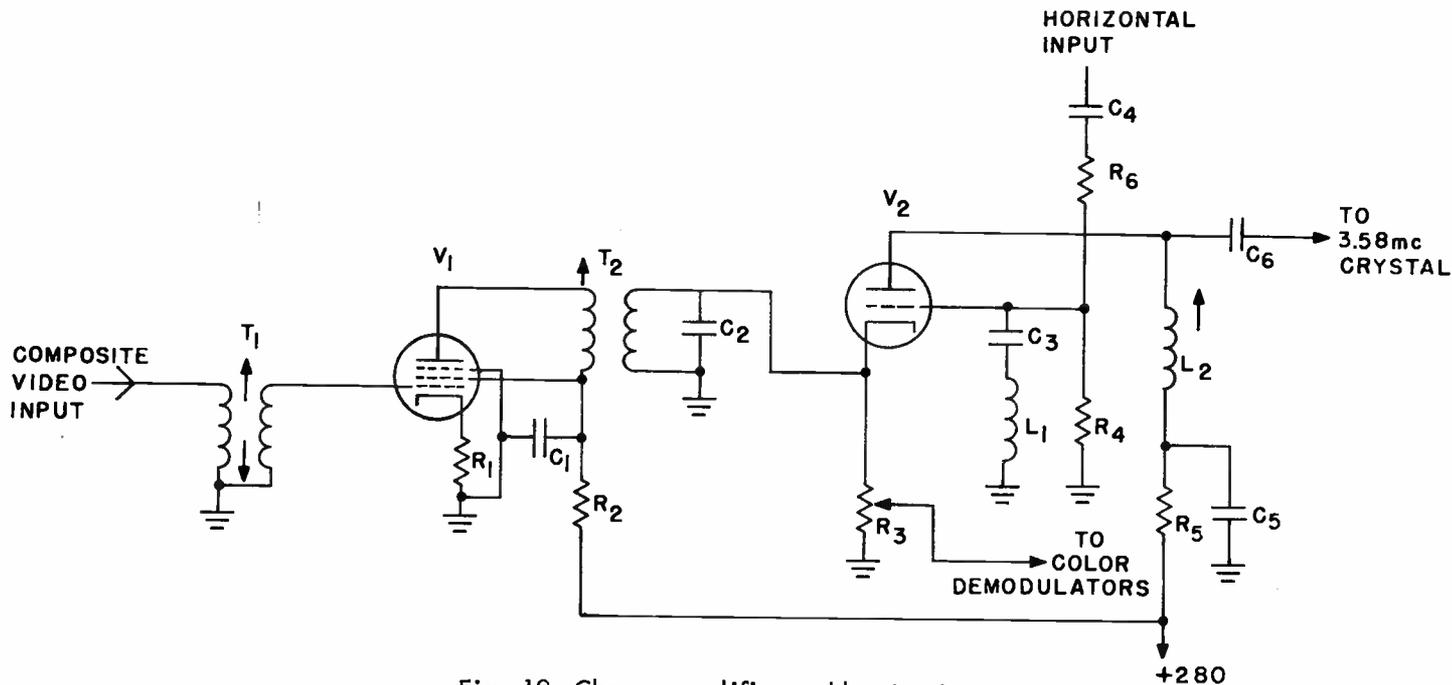
Fig. 19. Chroma amplifier and burst gate.

A TRANSISTOR BURST AMPLIFIER AND COLOR BURST GATE

A transistor burst amplifier and color burst gate is shown in Fig. 20. This circuit is quite interesting. At first, it might look somewhat complicated, but it is really no more complicated than the circuits we examined previously.

The burst amplifier is the transistor, Q_1. At first glance it might appear that there is a forward bias placed on this transistor by the network consisting of R_2 and R_1. However, R_2 is a 39K-ohm resistor and
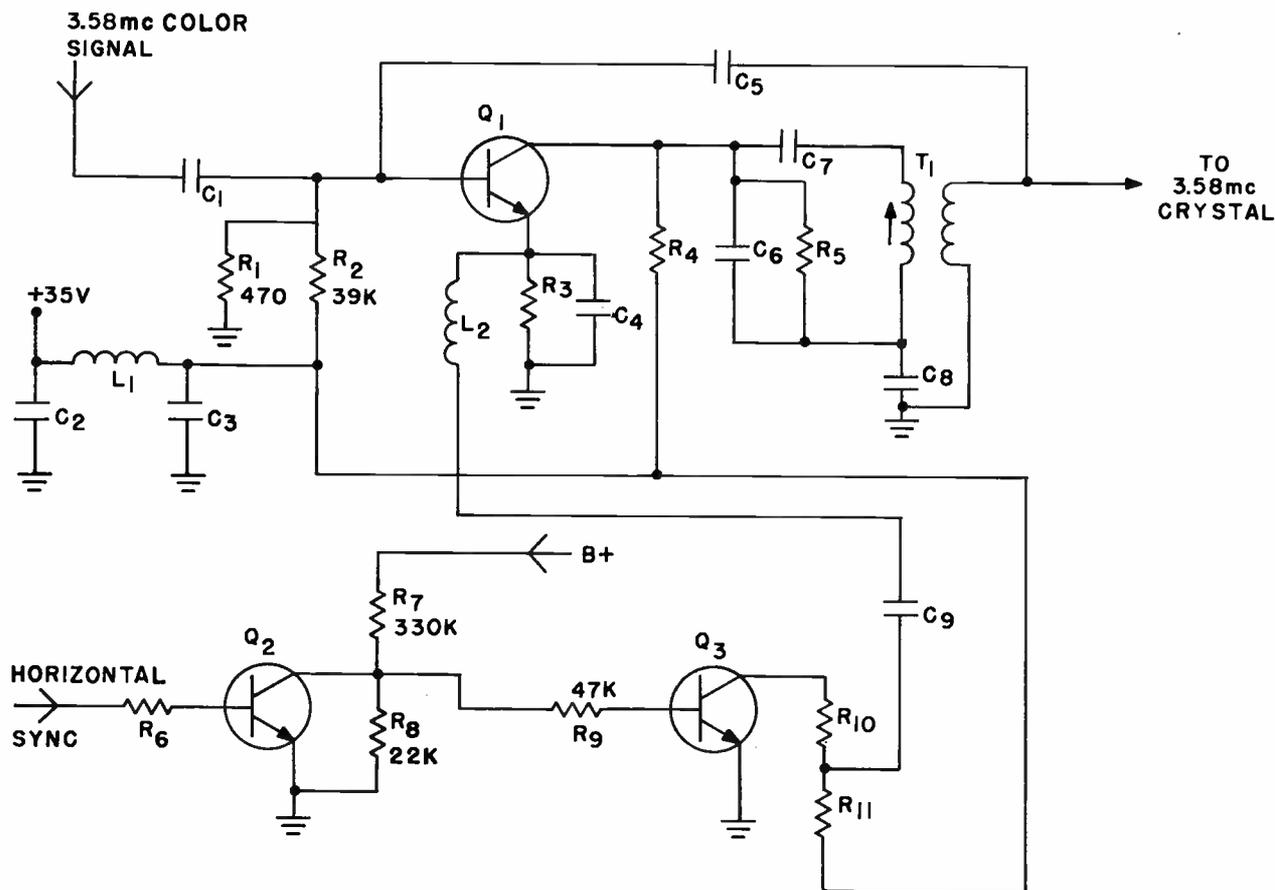
Fig. 20. A transistor burst amplifier and color burst gate.

R_1 has a value of only 470 ohms. Therefore almost the entire 35 volts applied across the network consisting of R_2 and R_1 is dropped across R_2. This means that there will be very little voltage across R_1 and therefore, for all practical purposes, the base of Q_1 is at dc ground potential. Thus with no forward bias applied to Q_1 there will be no current flow through the transistor.

Now notice that the entire 3.58-mc color signal is fed through C_1 to the base of Q_1. In the receiver in which this circuit is used, the 3.58-mc color signal has been amplified by the first color amplifier stage. Thus we have the entire color signal fed to the base of the transistor Q_1, but the transistor is not conducting because there is no forward bias across the emitter-base junction.

The transistor, Q_1, is turned on during the horizontal retrace by the one-shot multivibrator made up of Q_2 and Q_3. Since the 8-cycle color burst is transmitted on the rear porch of the horizontal sync pulse, which occurs during the retrace, the color burst is amplified by Q_1 and fed through C_7 to the burst transformer, T_1. Since Q_1 is keyed on only during the horizontal retrace interval, the stage amplifies only the color burst, and the rest of the color information is gated off so it does not reach the burst transformer, T_1.

The combination of Q_2 and Q_3 works in the following manner. The base of Q_2 is returned to the collector of the sync output stage through the resistor, R_6. There is a comparatively high positive voltage on the base of Q_2 (from the collector circuit of the sync output stage). The collector of Q_2 feeds through the 330K resistor, R_7, back to B+. Because there is a comparatively high current flow through the transistor Q_2 due to the high forward bias, the collector voltage of Q_2 will be quite low. In effect, Q_2 is operated at current saturation and there will be a high voltage drop across the collector resistor, R_7. Notice also the relative values of R_7, R_8 and R_9. These values are chosen so that most of the B-supply voltage will be dropped across R_7; the net result is that the base of Q_3 is operated at a very low voltage. Therefore for all practical purposes there is no forward bias on the transistor, Q_3, and there will be very little conduction through the transistor. This means that the voltage at the collector of Q_3 will rise to almost 35 volts; in other words the full positive 35 volts from the power supply will appear at the collector of Q_3.

During the horizontal retrace, two things happen. A negative horizontal pulse is fed to the base of Q_2. This lowers the bias across the emitter-base junction of Q_2 and causes the collector current flowing through Q_2 to decrease. This alone would cause the voltage drop across R_7 to decrease and hence the voltage at the collector of Q_2 to increase. At the same time, a positive pulse from the horizontal output circuit is fed through R_7 to the collector of Q_2. This causes the positive voltage on the collector of Q_2 to rise still further. Thus we have a comparatively large positive pulse fed from the collector of Q_2 through R_9 to the base of Q_3. This causes Q_3 to conduct. In fact, the positive pulse has sufficient amplitude to drive Q_3 to

saturation so that the collector voltage on Q_3 drops to a low value. Thus we have a large negative pulse produced at the collector of Q_3. The portion of this negative pulse across R_{11} is fed through C_9 and L_2 to the emitter of Q_1. Driving the emitter of Q_1 in a negative direction has the same effect as driving the base in a positive direction. We have placed a forward bias across the emitter-base junction; the transistor conducts and amplifies the color burst.

By feeding both the negative sync pulse to the base of Q_2 and the positive pulse to the collector of Q_2, Q_2 in effect acts as a pulse shaper and controls the amplitude and shape of the pulse that is used to turn Q_3 on. Thus the pulse produced by Q_3 can be shaped so that its amplitude can be made high enough to turn on Q_1 and its width wide enough to turn the transistor on only for the interval required to pass the 8-cycle color burst.

TWO-STAGE BURST AMPLIFIER

A schematic diagram of a two-stage color burst amplifier is shown in Fig. 21. Notice that in this circuit the complete color signal is fed to the cathode of the first stage, V_1. At the same time, strong positive horizontal pulses are fed through C_1 and R_1 to the grid of V_1. These positive pulses, which occur during the retrace interval, will cause the grid of the tube to draw a high current and charge the capacitor C_1 with the polarity shown. C_1 will discharge through R_2 developing a voltage across the resistor with the polarity shown. The high negative voltage developed across R_2 will keep the tube cut off. The only time the tube will conduct is when the high amplitude horizontal pulses are present. Since this occurs during the horizontal retrace interval and this is when the color burst signal is transmitted, the color signal is the only part of the color signal that will get through the amplifier stage.

The 8-cycle color burst is amplified by V_1 and fed through the burst transformer, T_1, to the grid of V_2.

Notice that in the grid circuit of V_2 we have a network consisting of C_6, L_2, P_1, C_8, L_3, D_1 and C_7. This network allows us to shift the phase of the color burst signal slightly. This will permit us to make small changes in the phase of the 3.58-mc color signal generated in the receiver. We need to be able to do this because some small phase shifts will occur due to parts tolerances. As a result the phase of the color signal fed to the color demodulators may not be exactly what it should be. The phase shift network in the grid circuit of V_2 allows us to compensate for these variations and bring the oscillator phase more closely to the exact value it should be. Phase controls such as these are often called hue controls or tint controls.

Notice that the anode of the diode, D_1, in the grid circuit of V_2 is connected to B+ through R_6. Also notice that the cathode of the diode is connected to B+ through L_2, P_1, and R_{11}. The voltage on the cathode will depend on the setting of P_1. With maximum positive voltage on the cathode, the cathode becomes positive with respect to the anode and the diode does
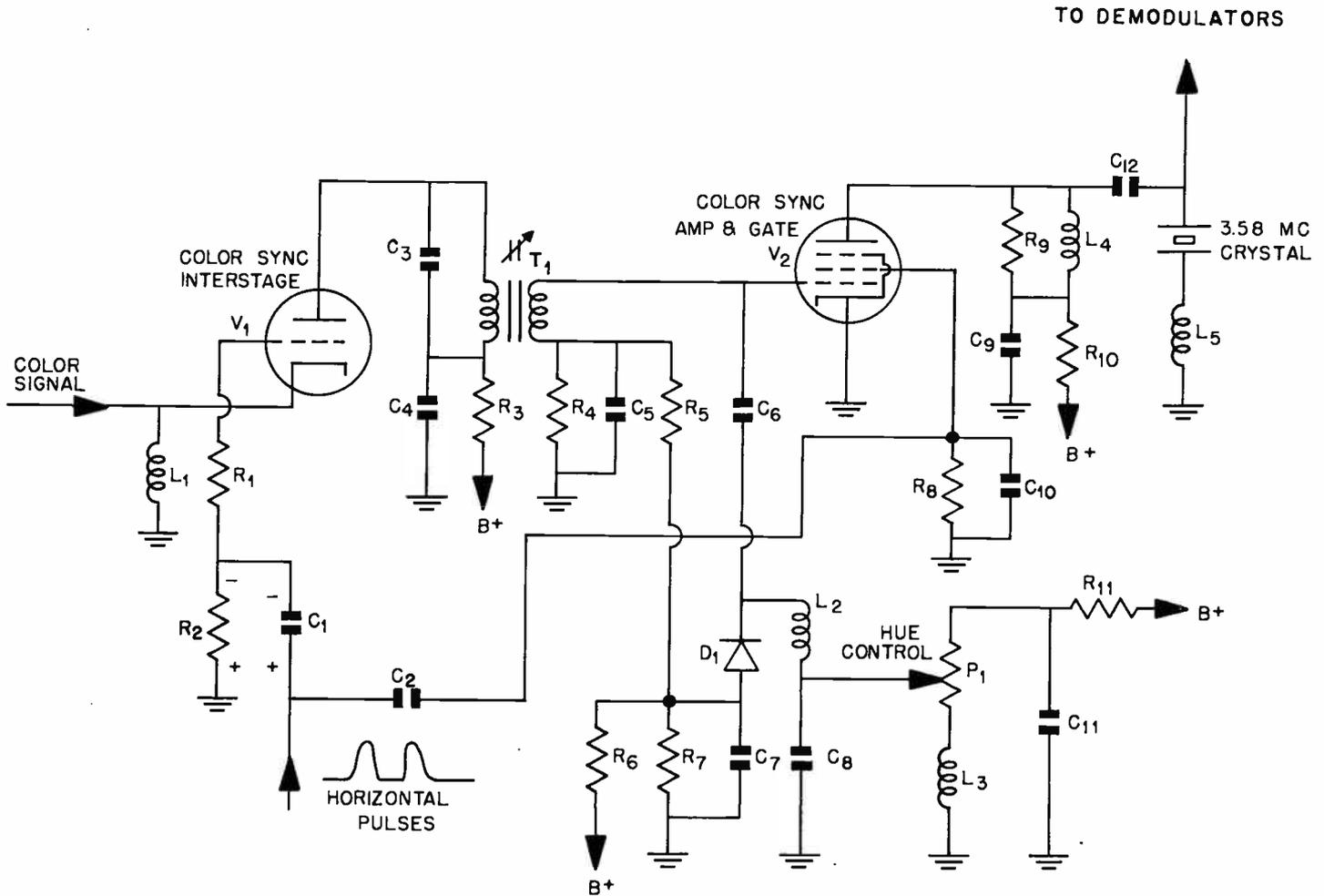
Fig. 21. Two-stage color burst amplifier and ringing circuit supplies the continuous wave signal to the demodulators.

not conduct. C_7 is then isolated from the grid circuit of V_2. As the voltage on the cathode of D_1 is lowered by changing the setting of P_1, the diode begins to conduct on peaks of the color burst and thus C_7 has an effect on the grid circuit. As the cathode voltage is lowered still further the diode conducts for a greater part of each cycle and the effect of C_7 becomes more pronounced. This change in the effectiveness of C_7 in the grid circuit shifts the phase of the color burst.

The color burst signal is amplified by V_2 and then fed through C_{12} to a 3.58-mc crystal. We'll go into this circuit and other circuits used to generate the 3.58-mc color carrier signal in a later section of this lesson.

A COMBINATION CHROMA AMPLIFIER AND BURST AMPLIFIER

A rather interesting circuit which uses a dual grid controlled pentode tube and performs the two functions of chroma amplifier and color burst amplifier is shown in Fig. 22. Notice that in this circuit we have the complete color signal fed from the video amplifier through C_2 and L_1 to the grid of V_1. At the same time

we have high amplitude negative horizontal pulses fed to the No. 3 grid of the tube. These high amplitude negative pulses are developed during the horizontal retrace interval. Thus we are feeding two signals into the stage; one is a complete color signal which is fed to the No. 1 grid of the tube and the other is the negative horizontal pulses which are fed to the No. 3 grid.

In addition to these signal voltages we are also feeding some dc control voltages to V_1. We are feeding an automatic color control bias voltage to the No. 1 grid of the tube. The amplitude of this signal varies with the strength of the color signal. If we have a high amplitude color signal we'll produce a fairly high negative automatic color control voltage and this when fed to the No. 1 grid of V_1 will reduce the gain of the stage. On the other hand, if the strength of the color signal is low, the amplitude of the automatic color control voltage developed may be low and very little negative voltage will be fed to the grid of V_1. This will permit the tube to operate at maximum sensitivity.

We are also feeding a control voltage into the No. 3 grid of the tube. During a black-and-white program the color killer stage develops a high negative voltage. This negative voltage is fed through R_2 to the No. 3 grid of V_1. The negative voltage is high enough to cut
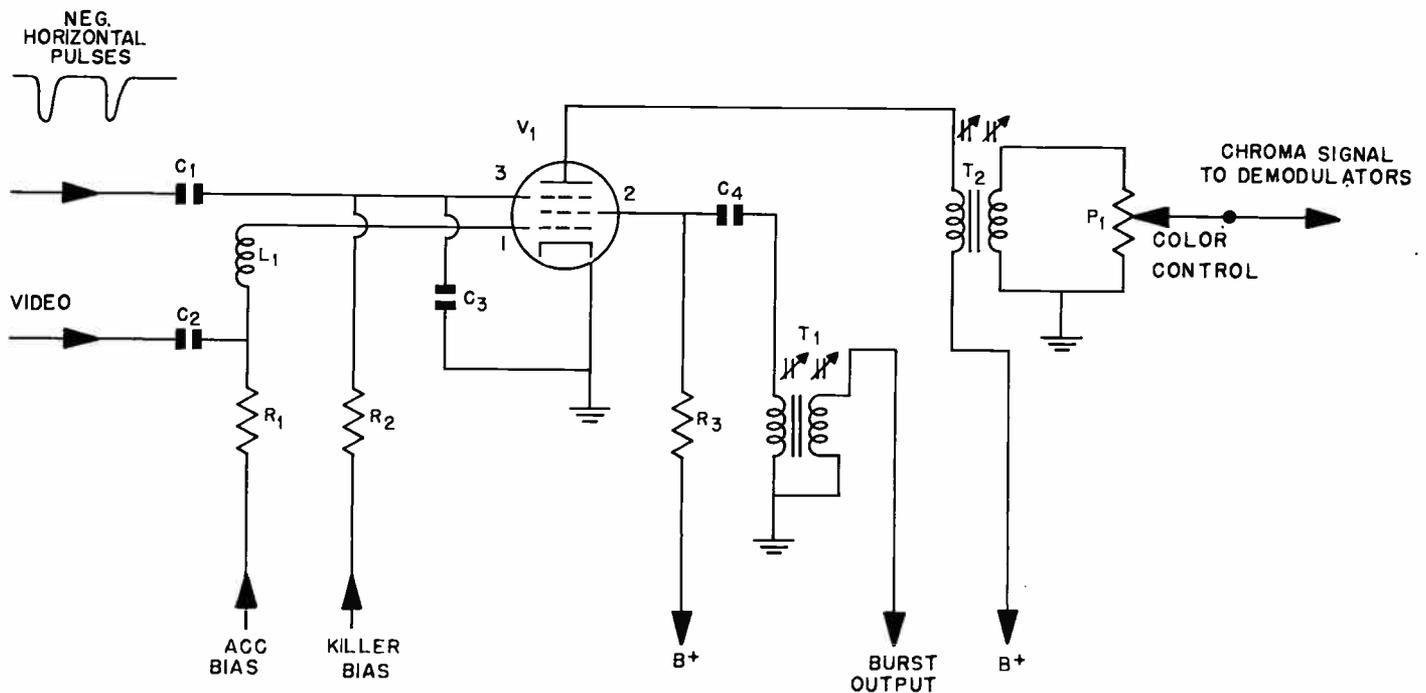
Fig. 22. Dual grid controlled pentode circuit combines chroma bandpass amplifier and burst keyer circuit.

off the flow of plate current through the tube so that there will be no interference signals getting through the stage and reaching the color transformer, T_2, during black-and-white programs. As soon as a color signal is received, the killer bias will drop to zero and permit the flow of plate current through V_1.

During a color broadcast, the composite color signal which includes the 8-cycle color burst plus the I and Q color signals is fed to the No. 1 grid of V_1. The signal is amplified by V_1 and the amplified color signal is developed in the plate circuit in the color output transformer, T_2. You will remember that during the horizontal retrace period we transmit the color burst. At the instant the color burst signal arrives at the No. 1 grid of V_1 the high amplitude negative pulse from the horizontal output transformer will arrive at the No. 3 grid of the tube. This will prevent any current from reaching the plate of the tube; in other words, the high negative voltage on the No. 3 grid cuts off the flow of plate current. The amplified current produced by the 8-cycle color burst therefore cannot reach the plate of the tube and instead turns back and flows to the screen grid of the tube because the screen grid has a comparatively high positive voltage applied to it. Therefore the 8-cycle color burst signal flows through C_4 to the color burst transformer, T_1. Thus a color burst signal is taken off T_1. As soon as the 8-cycle color burst has been transmitted, the negative pulse applied to the No. 3 grid of the tube will disappear, plate current will begin to flow and the balance of the color signal will be amplified by V_1 and an amplified color signal developed in the plate circuit.

Let's summarize the operation of this stage. During the retrace period when the burst signal is transmitted, the flow of current from the cathode to the plate of the tube is cut off by high negative voltage

applied to the No. 3 grid of the tube. Meanwhile, the color burst signal fed to the grid of the tube is amplified and a color burst signal current will flow to the screen grid or No. 2 grid of the tube and through C_4 to the burst transformer T_1. After the retrace interval and after the color burst signal has been transmitted, the I and Q signals will be transmitted. During this interval there is no high negative voltage on the No. 3 grid of the tube and therefore plate current flows and an amplified color signal is developed in the color output transformer, T_2.

SELF-TEST QUESTIONS

(q) If a color demodulator is to work on the R - Y axes, what must the phase of the signal fed to it be in reference to the color burst signal?

(r) What type of color signal is fed to the grid of the burst amplifier stage shown in Fig. 18?

(s) Why is the color burst signal so important in color television?

(t) In the two-stage amplifier circuit shown in Fig. 19, in which stage is the burst signal separated from the color signal?

(u) At what dc potential is the base of Q_1 in the circuit shown in Fig. 20 operated?

(v) In the circuit shown in Fig. 20, is Q_2 normally conducting?

(w) In the circuit shown in Fig. 20, is the transistor, Q_3, normally conducting?

(x) What is the purpose of the network consisting of C_6, L_2, P_1, L_3, C_8, C_7 and D_1 in the circuit shown in Fig. 21?

(y) In the circuit shown in Fig. 22, from what element of V_1 is the burst signal removed?

(z) Will an amplified color burst signal appear at the plate of V_1 in the circuit shown in Fig. 22?

Reinserting the Color Subcarrier

In the color TV transmitter, the 3.58-mc color subcarrier is generated by a very stable oscillator. The signal from the oscillator is shifted 57° and fed to the I modulator. The color modulating signals produce color sidebands. These sidebands are transmitted and the 3.58-mc carrier fed to the modulator is suppressed. We also take a 3.58-mc signal from the shifted signal fed to the I modulator and shift it another 90° and feed it to the Q modulator. Once again the color modulating signals fed to the Q modulator produce sidebands which are transmitted and the color subcarrier is suppressed.

In order to demodulate the color signal, we must reinsert the missing carriers which were suppressed at the transmitter. Therefore we must generate a 3.58-mc signal in the receiver. There are several methods used to generate this continuous wave 3.58-mc signal. We will study the most widely used methods.

3.58-MC CRYSTAL OSCILLATOR

The continuous wave 3.58-mc reinsertion signal for the demodulators is produced in most receivers by a precision crystal oscillator. The crystal insures that the oscillator will operate at the proper frequency and will be very stable. However, in a color receiver this is not enough. The output of the oscillator must maintain a fixed phase relation to the 3.58-mc subcarrier signal at the transmitter. The burst signal is a sample of the transmitter 3.58-mc subcarrier signal. The burst is compared to the output of the oscillator, and any phase difference in the two signals produces a correction voltage that controls the phase of the oscillator signal. This system of maintaining the exact phase of the oscillator signal is known as the automatic frequency and phase control (afpc). It will be covered in detail later in this lesson.

In a few receivers a somewhat different arrangement is used to generate the 3.58-mc insertion signal. In this method the 3.58-mc burst signal is used to shock excite a crystal into oscillation. The output may be used as a reinsertion carrier or used to control another oscillator which generates the carrier. We'll study the crystal oscillator method first.

We tend to think of the crystal-controlled oscillator as having a rock-solid output frequency. However, its frequency can be controlled over a narrow range of frequencies. If we think of the crystal as a very high Q tank circuit made up of inductance and capacitance, it will help us to see how it operates.

The crystal is the main frequency-determining component of the oscillator. By connecting a reactance tube in parallel with the crystal, the frequency of the oscillator can be "pulled" a small amount away from the natural frequency of the crystal. Most receivers use this type of arrangement to synchronize the output of the oscillator with the phase of the burst signal.

Fig. 23 shows a typical 3.58-mc oscillator circuit from a late model color TV receiver. The 3.58-mc crystal parallels the control grid circuit of the oscillator stage, V_2. The cathode, control grid, and screen grid act as a triode oscillator in this circuit. The screen grid acts as a plate and the 3.58-mc signal developed across R_7 is fed back to the crystal to maintain oscillations. C_8 is a very small capacitor that provides a small phase shift, so that the energy fed back to the crystal will be of the proper phase to maintain the oscillations in the crystal circuit.
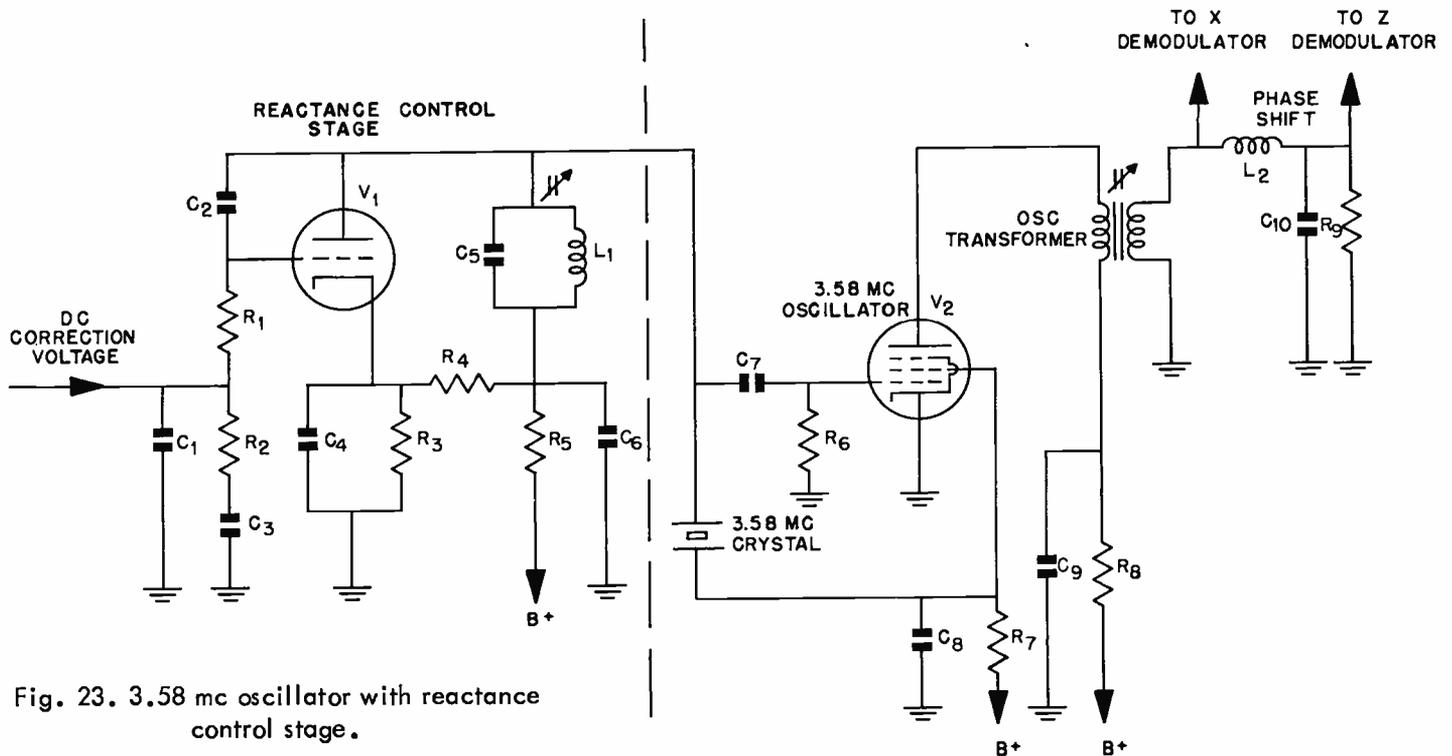
Fig. 23. 3.58 mc oscillator with reactance control stage.

The signal across the crystal is coupled through C_7 to the control grid. Since the crystal is a high Q circuit, the signal amplitude is large enough to drive the control grid into conduction, and the grid develops grid leak bias. The tube conducts pulses of current at the 3.58-mc rate. These electrons that strike the screen grid provide the feedback energy to maintain oscillation. Those electrons that pass through the screen grid and suppressor grid arrive at the plate. These pulses of plate current flow through the primary of the tuned oscillator transformer. The 3.58-mc signal developed in the primary of the transformer is coupled to the secondary.

One output from the secondary is coupled to the "X" demodulator to provide the continuous wave 3.58-mc reinsertion signal for the "X" demodulator. The output from the secondary is also fed to the "Z" demodulator through a phase shift network consisting of L_2, C_{10}, and R_9. This network must provide a fixed phase shift of 62.1°, because the X and Z axes as shown in Fig. 15 are displaced by this phase angle. Thus the "Z" demodulator always receives a correctly phased reinsertion signal when the "X" demodulator signal is correct. In receivers that have an R - Y and a B - Y detector, the phase-shift network is designed to provide a 90° phase shift.

REACTANCE CONTROL

The reactance control stage, V_1 in Fig. 23, controls the phase of the oscillator signal in response to a dc voltage on its grid. The stage acts like a variable capacitance across the 3.58-mc crystal in the oscillator circuit. Let's examine the circuit in detail to determine how it works.

A fixed bias is applied to the cathode circuit of V_1 through the voltage divider network (R_3, R_4, and R_5). The bleeder current that flows through R_3 and R_4 is much greater than the cathode current flowing through R_3, so the cathode bias on V_1 is relatively independent of the tube current. The dc correction voltage is applied to the grid through R_1 and a filter network made up of C_1, R_2 and C_3. Capacitor C_1 is a large value so the junction of resistors R_1 and R_2 is effectively at ac ground potential.

The oscillator signal across the 3.58-mc crystal is coupled through C_2 to the grid of V_1. Capacitor, C_2, is a very small value (about 3 pf), so its reactance is high to a 3.58-mc signal. Grid resistor, R_1, is a low value (about 1500 ohms). Capacitor, C_1, is a large capacitor, and therefore its reactance will be low to the 3.58-mc signal. Thus the circuit made up of C_2, R_1, and C_1 is largely capacitive, and because of the high reactance of C_2, current through the circuit leads the voltage applied across it by 90°. Thus the signal voltage from the oscillator causes a current in the grid circuit that leads the oscillator signal voltage by 90°. The current through R_1 produces a voltage drop across R_1 that is in phase with the current. The current through C_1 produces a voltage that lags the current by 90°, but this voltage is very small because of the small reactance of C_1.

Therefore the signal applied to the grid of V_1, which is the vector sum of the voltage across R_1 and C_1, is for all practical purposes equal to the voltage across R_1, and leads the oscillator signal by 90°.

Since the tube passes current in response to the grid signal, there will be a 3.58-mc signal current superimposed on the dc plate current of the tube. This 3.58-mc current will lead the oscillator signal by 90°. In a tank circuit such as the crystal, current through the capacitive leg of the tank leads the voltage across the tank by 90°. Since the signal current of V_1 also leads the voltage by 90°, it acts like a capacitor across the crystal. Changing the amplitude of the signal is the same as changing the size of a capacitor across the tank circuit.

A change in the dc correction voltage applied to the grid of V_1 changes the 3.58-mc signal current through V_1 and changes the phase of the oscillator signal. When the dc voltage is made more negative, the current through V_1 decreases. A decrease in current acts as if a smaller capacitor were placed across the tuned circuit; therefore the oscillator tends to speed up to operate at a higher frequency. Likewise a positive dc correction voltage to the grid of V_1 will increase the tube current and act as if a larger capacitor were placed across the tuned circuit. This tends to make the oscillator slow down and operate at a lower frequency.

In the grid circuit of V_1, the filter network (C_1, R_2, and C_3) acts as an anti-hunt circuit. If the control circuit responded too quickly to changes in the correction voltage, the oscillator frequency would be over-corrected and the circuit would "hunt" or swing above and below the correct phase. The filter network responds slowly to the changes and smoothes out the correction voltage.

The reactance control circuit in Fig. 23 can be explained by the use of vectors. Consider the circuit in operation but with no current through V_1. We have a 3.58-mc signal across the crystal, representing the natural phase and frequency output of the oscillator. Now consider the operation of the reactance stage alone. The reactance control stage would not operate without the oscillator, but we can assume its operation for circuit analysis. The 3.58-mc signal current flowing through V_1 is fed to the parallel resonant circuit consisting of C_5 and L_1. This tank circuit develops a 3.58-mc sine wave. This sine wave is displaced 90° from the sine wave across the oscillator crystal, because of the 90° phase shift in the grid circuit. The amplitude of the sine wave depends on the amount of V_1 tube current, which in turn is controlled by the dc correction voltage. When the oscillator circuit and the reactance tube circuit are considered together, these two sine waves add vectorially to produce a resultant sine wave. Only the resultant sine wave actually appears in the circuit.

Fig. 24 shows the phase relation of the various signals in the circuit discussed above. The signals are shown graphically in Fig. 24A and vectorially in Fig. 24B. The grid signal of V_1 leads the natural frequency of the oscillator by 90°. The grid signal causes a plate current flow which will be in phase with the
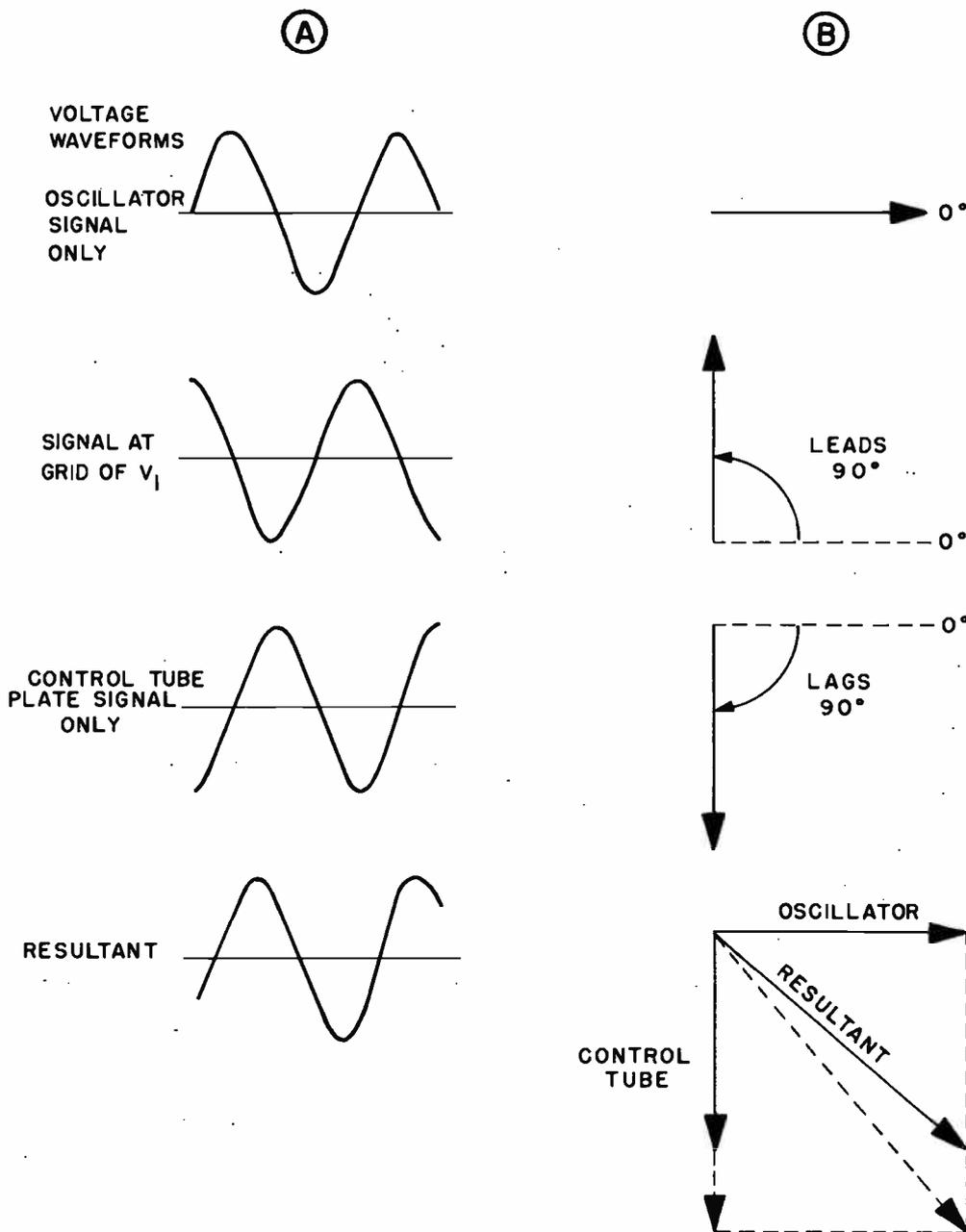
Fig. 24. Phase relation of the natural frequency of the oscillator, the control tube signals and the resultant signal shown graphically at (A) and vectorially at (B).

grid voltage. This will produce a voltage across the tank circuit that lags the oscillator signal by 90°. The combination of the oscillator signal and the control tube signal produces the resultant waveform, which lags the original oscillator signal by about 45°.

The dotted line in the last vector drawing in Fig. 24B shows how the control tube affects the phase of the oscillator signal. A positive dc correction voltage will increase the current in V_1 and thereby increase the amplitude of the reactance tube sine wave output. This is shown as a longer dotted vector.

Notice that the resultant dotted vector now lags the original oscillator signal by a greater amount. This action corresponds to a lower frequency due to a larger capacitance across the tank circuit. In operation, the reactance tube supplies a larger correction

than is apparent from Fig. 24. The signal fed back to the grid of V_1 is always displaced 90° from the resultant signal across the oscillator (instead of the original oscillator signal shown). Therefore small changes in the control tube signal have a large effect on the phase of the oscillator output.

RINGING CIRCUIT

Some color receivers do not use an oscillator to produce the continuous wave 3.58-mc reference signal for the demodulators. Instead, the color burst signal is amplified and used to shock excite a 3.58-mc ringing circuit. The circuit oscillates at the correct phase and frequency for the duration of one horizontal line. This continuous wave signal is used as the reference signal for the demodulator.
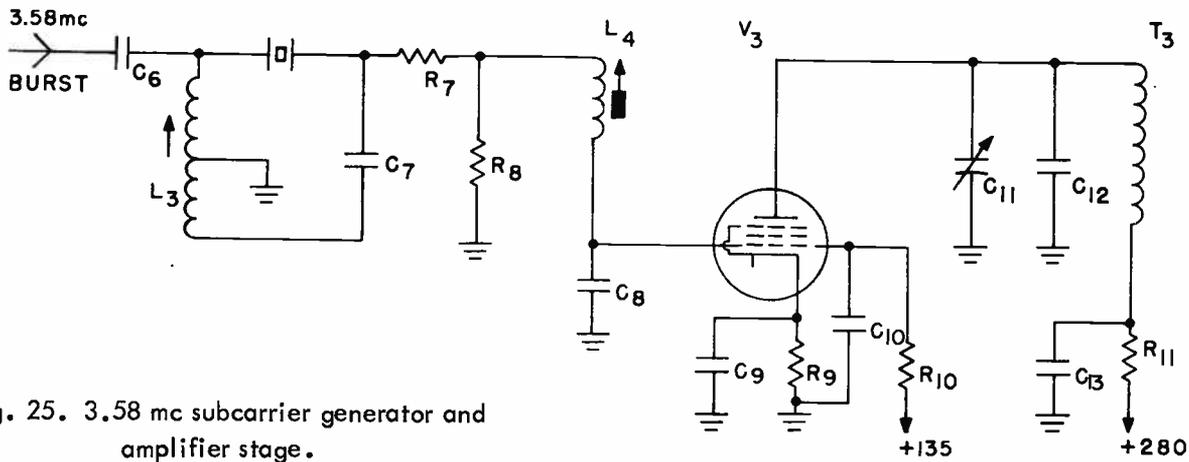
Fig. 25. 3.58 mc subcarrier generator and
amplifier stage.

Fig. 21 is an example of a ringing circuit used in a color TV receiver. You will remember that the color video signal is developed across L_1 and applied to the cathode of V_1. The gated color sync interstage, V_1, is normally biased cutoff by grid leak bias. Large positive horizontal pulses are coupled through C_1 and R_1 to the grid of V_1, bringing the tube into conduction during the horizontal retrace interval when the color burst is present on the cathode.

The color burst signal is amplified and applied to the tuned transformer, T_1. The burst signal is coupled by the secondary winding of T_1 to the control grid of V_2. The color sync amplifier and gate stage, V_2, is gated on by horizontal pulses coupled through C_2 to the screen grid. The color burst signal is amplified and developed in the plate circuit across L_4.

The amplified color burst is coupled through C_{12} to the 3.58-mc crystal ringing circuit. The 3.58-mc crystal is shock excited into oscillation exactly in phase with the amplified color burst signal that is coupled through C_{12}. The crystal circuit continues to ring after the end of the short duration of the color

burst signal. The output of the ringing circuit is a damped sine wave. However, its amplitude is essentially constant for the duration of one horizontal line, after which another burst signal again shock excites the circuit.

The hue control, located in the grid circuit of V_2 in Fig. 21, permits small changes in the phase of the color burst signal applied to the control grid of V_2. Changing the setting of the hue control shifts the phase of the 3.58-mc burst signal applied to the grid of V_2. This phase-shifted signal is amplified by V_2 and coupled through C_{12} to the crystal ringing circuit. In this way the phase of the signal from the ringing circuit is shifted by the setting of the hue control. This in turn sets the demodulation axis of the demodulator.

Another somewhat similar arrangement where a ringing circuit is followed by an amplifier stage is shown in Fig. 25. In this circuit the 3.58-mc color burst is fed through C_6 to L_3, the crystal and C_7. The combination of L_3 and C_7 form a circuit which is resonant at 3.58 mc. The burst sets the crystal and the resonant circuit to ringing and this ringing
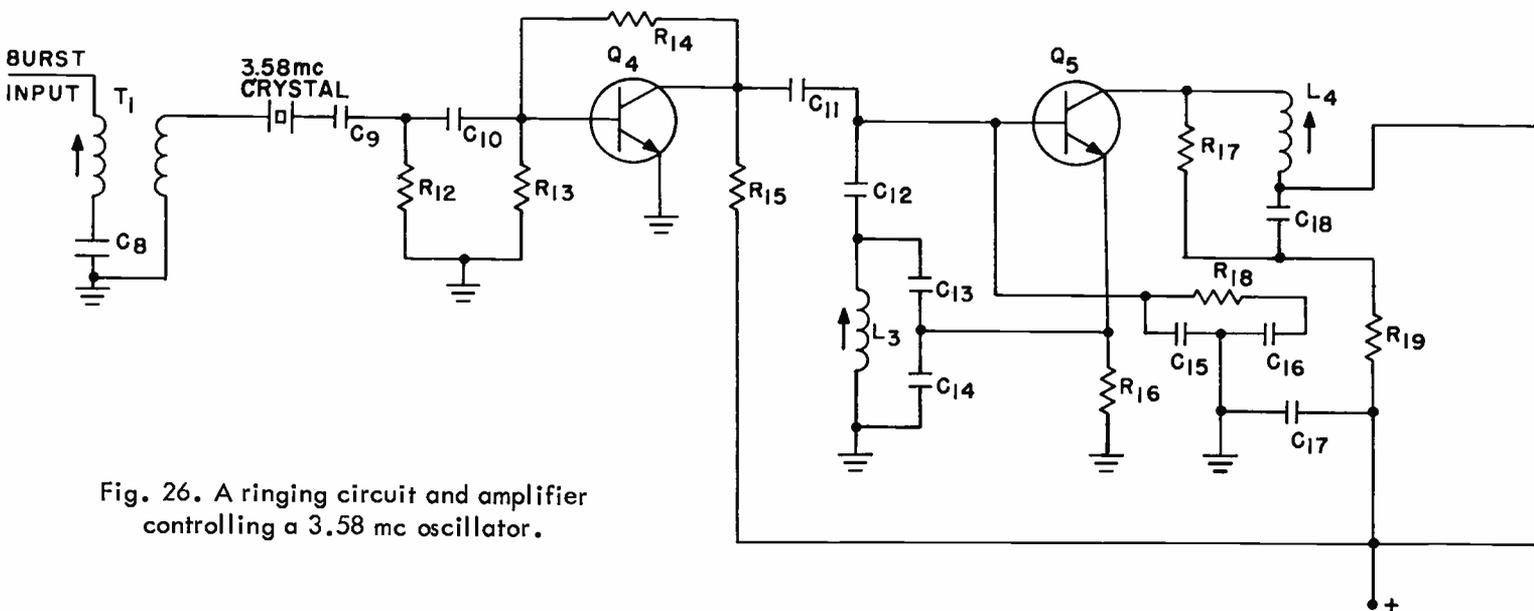
Fig. 26. A ringing circuit and amplifier
controlling a 3.58 mc oscillator.

continues with very little attenuation throughout a complete line. At the end of the line the next color burst is received and the ringing continues.

This circuit is used with the chroma amplifier and the burst gate shown in Fig. 19. The capacitor labeled C_6 is the same capacitor in both circuits.

In the circuit shown in Fig. 25, the output from the crystal ringing circuit is fed through R_7 to the series resonant circuit consisting of L_4 and C_8. The circuit is tuned to 3.58 mc and a high voltage will be built up across C_8. This is applied to the grid of the amplifier stage, V_3, and the 3.58-mc signal is amplified by this stage and fed to T_3 in the plate circuit of V_3. We have shown only the primary winding of this transformer, the secondary winding feeds through the appropriate networks to the color demodulators.

The capacitor, C_{11}, is the hue control. Adjusting this capacitor shifts the phase of the 3.58-mc signal slightly and sets the demodulator axes.

A TRANSISTOR OSCILLATOR CIRCUIT

A rather interesting transistor color oscillator circuit is shown in Fig. 26. This circuit is used with the burst amplifier and burst gate shown in Fig. 20. You'll notice that in Fig. 20 the output from the burst gate is fed through T_1 to the 3.58-mc crystal. In Fig. 26, T_1 is the same transformer and C_8 the same capacitor as shown in Fig. 20. From T_1 the burst sync signal is fed to the 3.58-mc crystal which is shock excited into oscillation. The oscillation is fed through C9 and C_{10} to Q_4. Q_4 is an amplifier which amplifies the signal from the 3.58-mc crystal.

Q_5 is a separate oscillator. This oscillator is designed to operate at approximately 3.58 mc. The signal from Q_4 is fed to the base of the transistor Q_5 through C_{11} and locks the oscillator in phase and in frequency with the signal generated by the crystal. The crystal oscillation is in turn controlled by the

burst signal and therefore the oscillator, Q_5, will be locked into the burst signal.

The transistor circuit, Q_6, is referred to as a phase splitter. Actually the circuit is arranged so that R_{25} can be used as a hue control. The phase of the signal at the junction of C_{22} and R_{25} can be varied by varying the setting of R_{25}. Thus the signal phase of the demodulators can be controlled by this control.

The 3.58-mc color is fed through C_{23} to Q_7 which amplifies the signal and feeds it through C_{27} to the color demodulator circuits. The diode, D_1, is used as a limiter in order to limit the amplitude of the signal fed to the color demodulators.

SELF-TEST QUESTIONS

(aa) What kind of a circuit is used to compare the phase difference of the 3.58-mc oscillator signal and the burst signal?

(ab) What is the phase relation of the 3.58-mc oscillator signal to the burst signal when the dc error voltage from the phase discriminator is zero volts?

(ac) What is the phase difference between the 3.58-mc reinsertion signals to the R - Y and B - Y demodulators?

(ad) What circuit generates the continuous wave reinsertion signal for the color demodulators?

(ae) What control shifts the exact phase angle of the reinserted subcarrier signal to the demodulators?

(af) What is the main frequency-determining component of the 3.58-mc reference oscillator?

(ag) What is the function of the anti-hunt circuit in the grid circuit of the reactance control tube?

(ah) Does a positive dc correction voltage to the reactance control tube raise or lower the frequency of the oscillator?
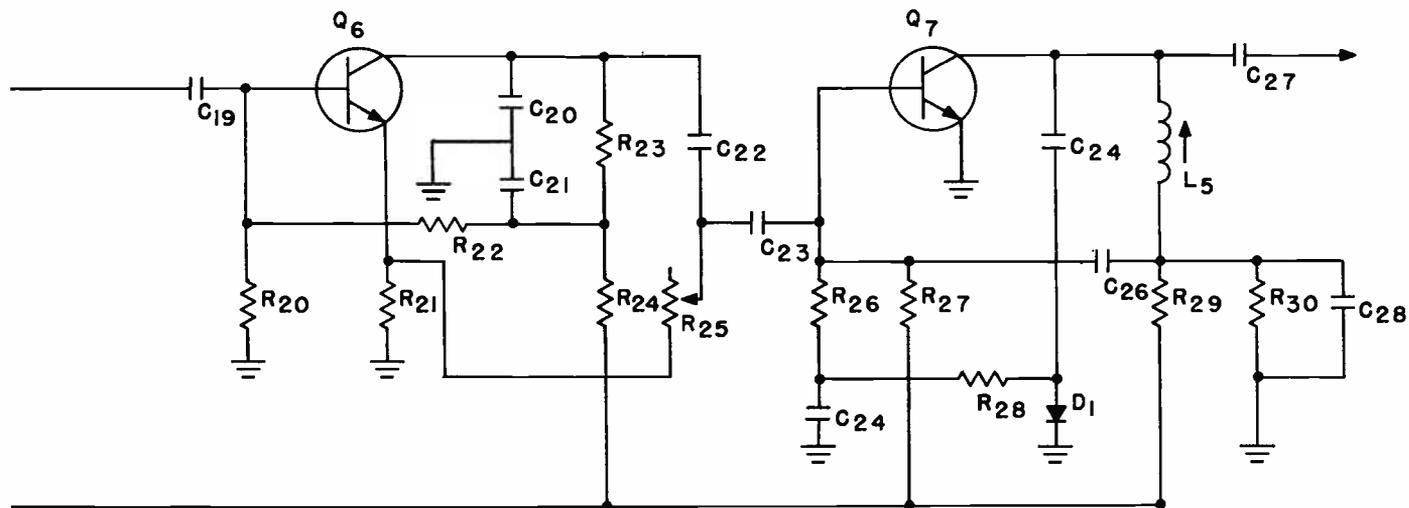
Automatic Frequency and Phase Control Systems

Automatic frequency and phase control (afpc) systems are used to hold the 3.58-mc oscillator in synchronism with the subcarrier signal at the transmitter. This keeps the displayed color information synchronized with the transmitter color information.

Fig. 27 shows a block diagram of the functions of a typical afpc system. The gated color burst amplifier separates the color burst from the rest of the video signal and amplifies the burst. The amplified color burst signal is fed to a phase detector, where it is compared with the phase of the continuous wave 3.58-mc signal from the crystal oscillator.

Any phase difference of the two signals produces a dc correction voltage which is applied to the reactance control tube. This stage corrects the phase of the 3.58-mc crystal oscillator in response to the dc correction voltage. In this way the 3.58-mc oscillator output signal is maintained in synchronism with the color subcarrier at the transmitter.

The frequency of the oscillator output is maintained at 3.58-mc by the crystal. The 3.58-mc crystal is the principal frequency-determining component of the oscillator. While other components in the circuit can affect the frequency slightly, the crystal assures that the oscillator output will be very nearly the exact subcarrier frequency. You can think of the crystal as the device that determines the approximate frequency of the oscillator. Then when the phase detector and reactance control stage lock the oscillator into phase, the frequency of the oscillator must, of course, be exactly correct.

Most color TV receivers use an arrangement similar to that shown in block form in Fig. 27. An exception is the ringing circuit shown in Figs. 25 and 26. This circuit does not use an afpc system. Instead it relies on the stability of the ringing circuit. The phase relation of the continuous wave signal is synchronized with the burst signal at the start of each horizontal line and the ringing circuit signal stays essentially in the correct phase for the duration of one line.

PHASE DETECTOR

The phase detector, also called a phase discriminator, is the circuit that compares the phase of the 3.58-mc oscillator signal with the phase of the received burst signal. The circuit produces a dc voltage that is proportional to the phase difference of the two signals. The dc voltage from the phase detector circuit is used as a control voltage, to control the reactance tube, which will shift the phase of the 3.58-mc oscillator and thereby hold the two signals in phase.

A basic circuit of the phase detector is shown in Fig. 28. A continuous wave signal from the 3.58-mc oscillator is applied to cathode 5 and plate 7 of the diodes. On negative signal peaks D_1 conducts, and on positive signal peaks D_2 conducts. With only the 3.58-mc oscillator signal applied to the circuit, both diodes conduct the same amount.

When the signal drives the cathode of D_1 negative, current flows from the cathode to the plate of D_1, down through R_1 and R_4 to ground. At the same time, electrons flow from the plate into the one side of C_1, and out the other side to ground, charging C_1 as shown. During the next half-cycle, when the plate of D_2 is positive, current flows from ground through R_4, R_2, to the cathode of D_2, and through D_2 to the plate.

At the same time, C_2 is charged with the polarity shown. Resistors R_1 and R_2, as well as capacitors C_1 and C_2, are of equal value, so equal voltages are developed across the resistors. This is because the diode currents as well as the currents due to C_1 and C_2, discharging between each half-cycle, are equal. Therefore the junction of R_1 and R_2, where the dc voltage is taken off, is at zero potential with respect to ground when D_1 and D_2 conduct equal amounts.

The amplified burst signal is applied to the detector
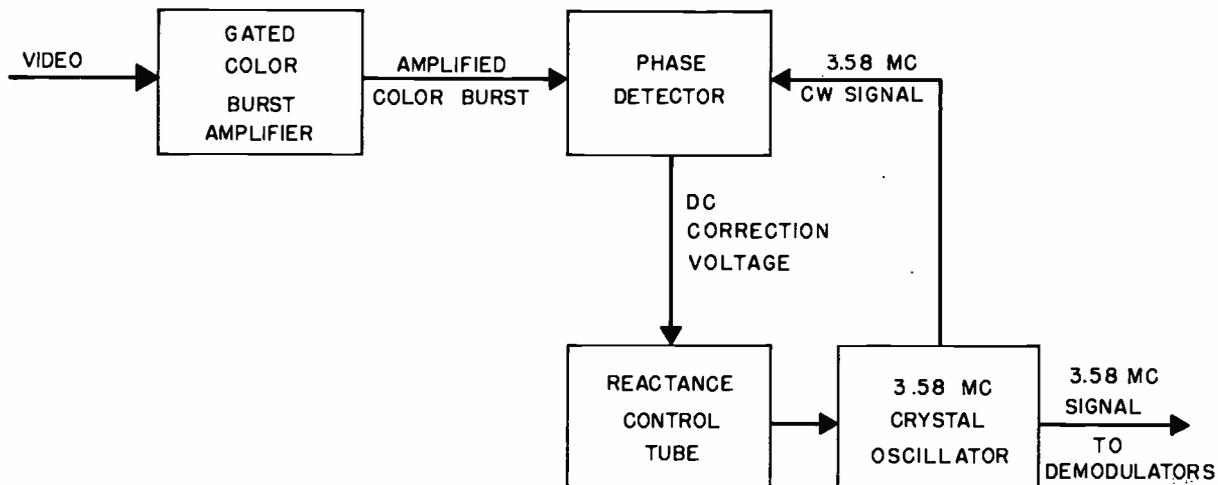
Fig. 27. Block diagram of typical afpc system.
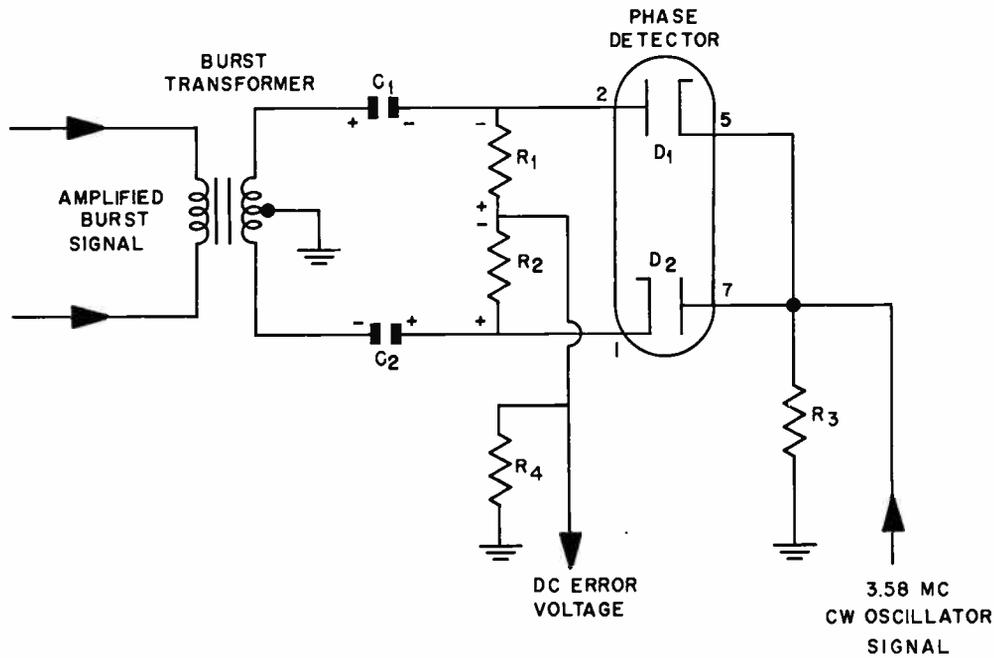
Fig. 28. Basic circuit of chroma sync phase detector.

diodes through the burst transformer. The burst signal that is coupled through C_1 to the plate of D_1 is 180° out-of-phase with the burst signal coupled through C_2 to the cathode of D_2. The burst signal tends to cause both diodes to conduct on the same half-cycle of the burst signal. This occurs on the half of the cycle that makes plate 2 of D_1 positive and cathode 1 of D_2 negative. With only the burst signal applied, the diodes would conduct equal amounts.

The burst signal and the oscillator signal are both present on the diodes during the time the burst signal is received. The diodes will conduct equal amounts only at one phase relation of the two signals. Three different conditions are illustrated in the waveforms in Fig. 29. The condition shown in Fig. 29A produces a zero dc error of voltage.

As shown, the burst signal at the plate of D_1 is 180° out-of-phase with the burst signal at the cathode of D_2, because the signals are taken off the opposite ends of the secondary of the burst transformer. During the
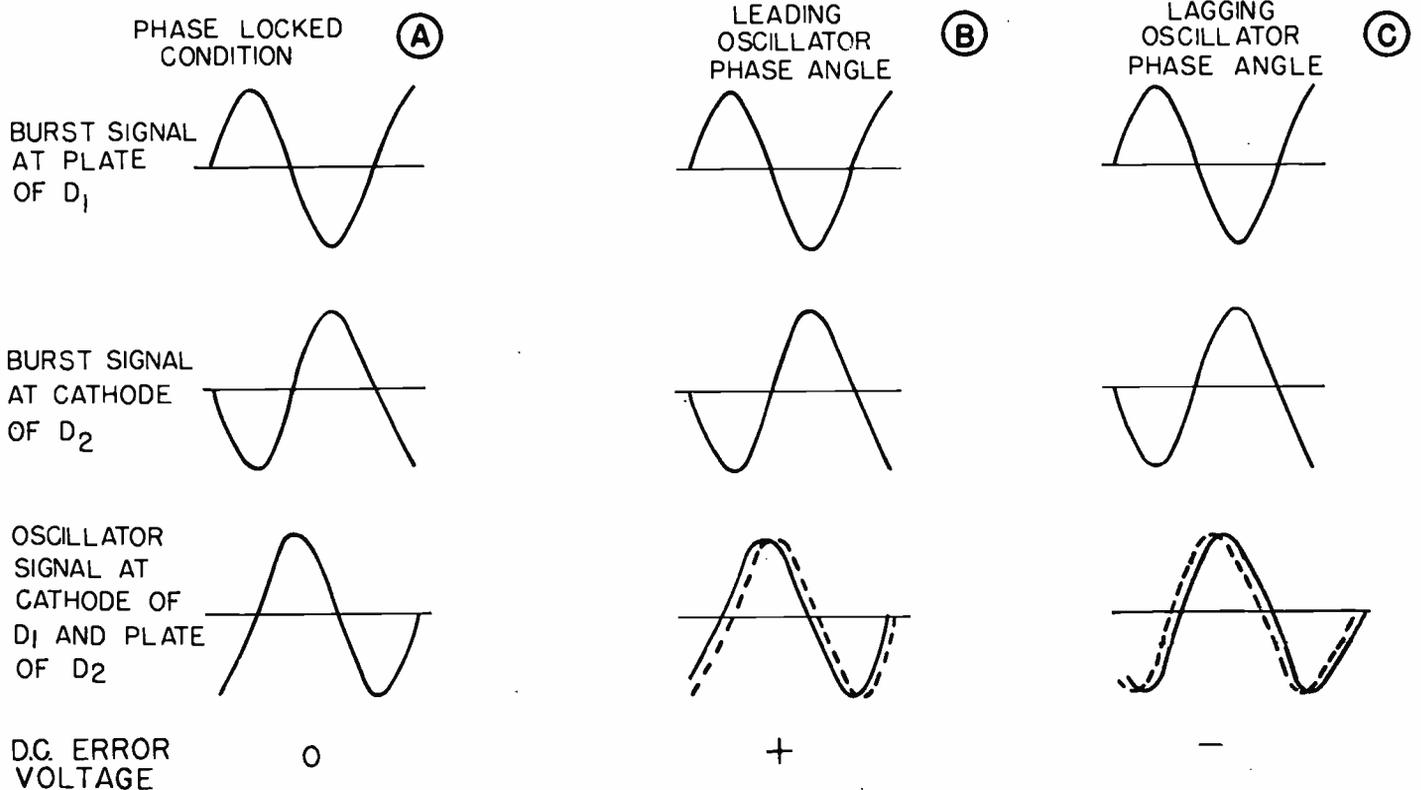
Fig. 29. The phase relation of the burst signal and the oscillator signal determines the error voltage for a phase locked condition (A), a leading oscillator phase angle (B) and a lagging oscillator phase angle (C).

first half of each burst cycle both diodes tend to conduct because the plate of D_1 receives a positive signal and the cathode of D_2 receives a negative signal. During the next half cycle, the diodes do not conduct because the signal to the plate of D_1 is negative and the signal to the cathode of D_2 is positive.

Now consider the effect of the 3.58-mc signal from the oscillator in the receiver, during the conducting half-cycle in Fig. 29A. At the start of the half-cycle, the 3.58-mc signal is maximum negative so that it will prevent D_2 from conducting (negative signal to the plate), and it will increase the conduction of D_1 (negative to the cathode).

At the end of the first quarter-cycle, the 3.58-mc oscillator signal is crossing zero, so it has no effect on the conduction of D_1 and D_2. During the next quarter-cycle, the 3.58-mc signal is increasing to maximum positive, so it will increase the conduction of D_2 and decrease the conduction of D_1.

The increased conduction of D_1 during the first quarter-cycle is equalled by the decreased conduction of D_1 during the next quarter-cycle. Likewise the decreased conduction of D_2 during the first quarter-cycle is equalled by the increased conduction of D_2 during the second quarter-cycle. The result is that the average conduction of D_1 and D_2 is the same for each cycle. This results in equal charges being maintained on C_1 and C_2 and equal voltages across R_1 and R_2. Therefore the dc error voltage remains zero.

Let's examine the circuit operation illustrated in Fig. 29B when the oscillator signal is slightly ahead of the oscillator signal in Fig. 29A. The dotted waveform shows the phase of the 3.58-mc signal for a zero error voltage. The solid waveform shows the leading 3.58-mc signal. D_1 conducts less and D_2 conducts more with a leading oscillator signal. Notice that the cathode of D_1 is negative for a smaller portion and positive for a larger portion of its conducting half-cycle. Therefore its average current is less for each half-cycle. In a similar manner D_2 is made to conduct more with the leading phase shift. The plate of D_2 is positive for a larger portion of the conducting half cycle, so its average current is larger.

Thus the average current is greater for D_2 and smaller for D_1. The added current for D_2 is drawn from ground through R_4 and R_2 to the cathode of D_2 (Fig. 28). The current through R_4 produces a voltage drop, making the dc error of voltage positive. A larger leading phase angle produces a greater unbalance of diode current and a larger positive dc error voltage.

Now consider the circuit operation illustrated in Fig. 29C. The oscillator signal is shown lagging the zero error voltage position represented by the dotted waveform. The cathode of D_1 receives a negative oscillator signal for a larger portion of the conducting half-cycle, thereby increasing the average current for D_1. The plate of D_2 also receives a negative oscillator signal for a larger portion of the connecting half-cycle. This decreases the average conduction of D_2.

Thus the average current is increased for D_1 and decreased for D_2 during the lagging phase condition. The additional current for D_1 flows from the plate of

D_1 down through R_1 and R_4 to ground. The voltage drop across R_4 makes the dc error voltage negative (Fig. 28). A larger lagging phase angle produces a greater unbalance of diode current and a larger negative dc error voltage.

As you recall, the error voltage from the phase detector is applied to the reactance control tube as a dc correction voltage. A negative correction voltage decreases the conduction of the reactance control tube. Decreased conduction is the equivalent of less capacitance across the tuned oscillator circuit. Less capacitance causes the oscillator circuit to be resonant at a higher frequency.

The change is sufficiently small so that it only shifts the phase of the oscillator output signal. The oscillator response to changes in error voltage maintains a nearly fixed phase relation between the phase of the burst signal and the phase of the oscillator signal.

The explanation associated with Fig. 29 shows that the oscillator signal will consistently lag the burst signal by $90°$ when the error voltage is at zero volts. This is the phase difference that exists for the proper operation of the phase detector circuit. However, you know that a particular phase difference must exist between the transmitter subcarrier and the reinserted subcarrier at the demodulator so that the receiver will reproduce the correct colors. In practical color TV circuits, many phase shifts exist in the circuits between the burst amplifier and the demodulators. These various phase shifts need not be accounted for individually.

In practice, the circuit is aligned so that the phase shift is correct to display the transmitted color signals on the receiver.

An adjustable phase shift called the hue or tint control enables the user to adjust the phase shift a small amount. This control takes care of small changes in the circuit operating conditions (for example decreased emission of one of the diodes) and enables the user to adjust picture hues to his personal preference.

Vector Representation.

Operation of the phase detector can be analyzed by the use of vectors. The vector diagrams in Fig. 30 are for the circuit in Fig. 28 and the three different conditions are the same three conditions represented graphically in Fig. 29. You will find phase detector circuits where the two signals (burst signal and oscillator signal) are combined and applied to just two elements of the diodes. In these circuits it is usually easier to explain the operation by the use of vectors.

Fig. 30A shows a vector diagram of the phase detector circuit conditions producing the zero error voltage. Vectors OA and OB are $180°$ out-of-phase with each other, representing the burst signal applied to the diodes D_1 and D_2. Vector OC represents the 3.58-mc oscillator signal. It leads the burst signal to D_1 by $90°$ and lags the burst signal to D_2 by $90°$. These are the same conditions shown graphically in Fig. 29A.

Vectors OA and OC combine to produce vector OD_1 which is the resultant voltage applied to diode D_1. Likewise, vectors OB and OC combine to produce the vector OD_2 which is the resultant voltage applied to diode D_2. Since OD_1 and OD_2 are equal lengths, both
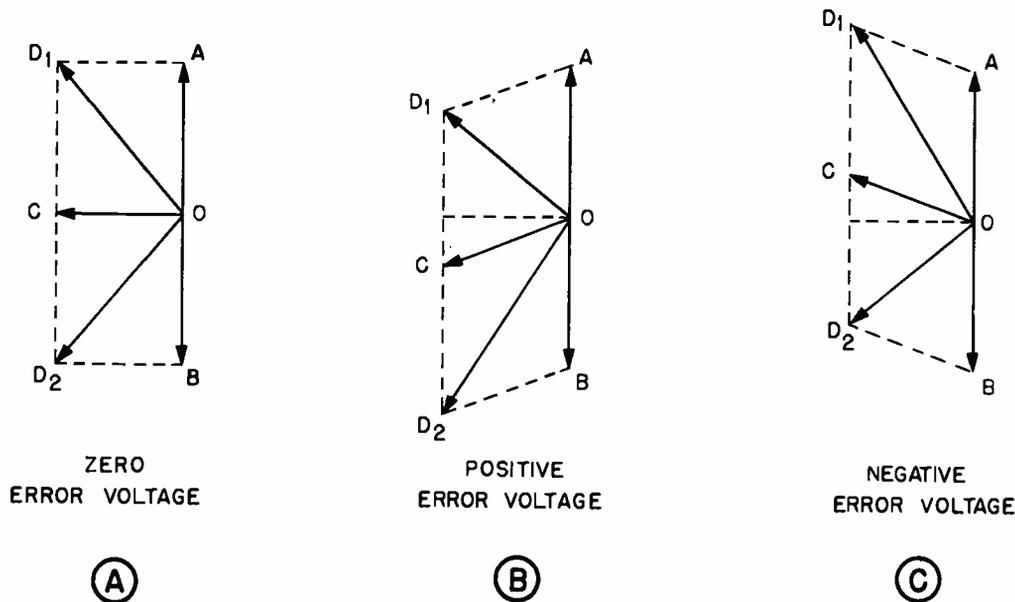
Fig. 30. Vector representation of the burst signal and oscillator signal in the phase detector circuit.

diodes conduct the same amount and the error voltage at the junction of R_1 and R_2 in Fig. 28 is zero volts.

Fig. 30B shows the vector relationship when the 3.58-mc oscillator voltage leads the zero error voltage condition. Vector OC represents a leading phase angle of the 3.58-mc oscillator voltage. The resultant vector OD_1 is now shorter and the resultant vector OD_2 is longer.

These resultant voltages produce an unbalanced condition, with diode D_1 conducting less and diode D_2 conducting more. The unbalanced diode conduction produces a current from ground up through R_4 and R_2 to diode D_2 (Fig. 28). Current through R_4 develops a positive error voltage.

Fig. 30C shows the vector relationship when the 3.58-mc oscillator voltage lags the zero error voltage condition. Vector OC represents the lagging phase angle of the 3.58-mc oscillator voltage. The resultant vector OD_1 is now longer and the resultant vector OD_2 is now shorter. The larger voltage to D_1 increases its current and the smaller voltage to D_2 decreases its current. The unbalanced diode conduction produces current flow from the plate of D_1 through R_1 and R_4 to ground (Fig. 28). Current through R_4 in this direction develops a negative error voltage.

TYPICAL COLOR SYNC CIRCUIT

A typical circuit for processing the color burst signal to provide color sync is shown in Fig. 31. The synchronizing circuits include the burst amplifier, the phase detector, reactance control, and the 3.58-mc oscillator. The color signal from the first color amplifier is coupled through C_1 and R_2 to the control grid of the burst amplifier, V_1. Positive horizontal pulses applied through R_1 and R_2 to the control grid of V_1, gate on the burst amplifier during horizontal retrace.

The amplified color burst signal is developed in L_1

at the plate of V_1. The adjustable inductance, L_1, is the hue control for this receiver. Adjusting the slug in L_1 shifts the phase of the burst signal that is coupled through C_5 and L_2 to the center-tapped inductor, L_3. The signal developed across L_3 provides the burst signals to the phase detector. The signal coupled through C_6 to the plate of V_{2A} is 180° out-of-phase with the signal coupled through C_7 to the cathode of V_{2B}.

The 3.58-mc oscillator stage, V_4, generates the subcarrier reinsertion signal. The 3.58-mc crystal is connected in the feedback circuit between the screen grid and the control grid. The 3.58-mc signal at the plate of V_4 is developed in the primary winding of the quadrature transformer, T_1. The signal in the primary of T_1 is coupled to two secondary windings, each of which is tunable.

One secondary winding provides a 3.58-mc signal to the B - Y demodulator. The center tapped secondary provides a signal to the R - Y demodulator. The transformer slugs are adjusted so the secondary voltages are 90° out-of-phase. This is the reason it is called a quadrature transformer.

A center tap on one secondary winding of T_1 provides a sample of the 3.58-mc oscillator signal. This signal is 90° out-of-phase with the burst signal. It is coupled through C_{16} to the cathode of V_{2A} and the plate of V_{2B} where it is compared with the received burst signal.

As long as this 90° phase relationship between the burst signal and the sample oscillator signal is maintained, the phase detector produces a zero dc correction voltage. Any change in this phase relation will unbalance the conduction of V_{2A} and V_{2B}. In this phase detector the dc correction voltage is developed at the junction of C_8, R_9, the cathode of V_{2A}, and the plate of V_{2B}.

A leading phase angle will increase the conduction of V_{2A} and decrease the conduction of V_{2B}, producing a positive dc correction voltage. Likewise a lagging
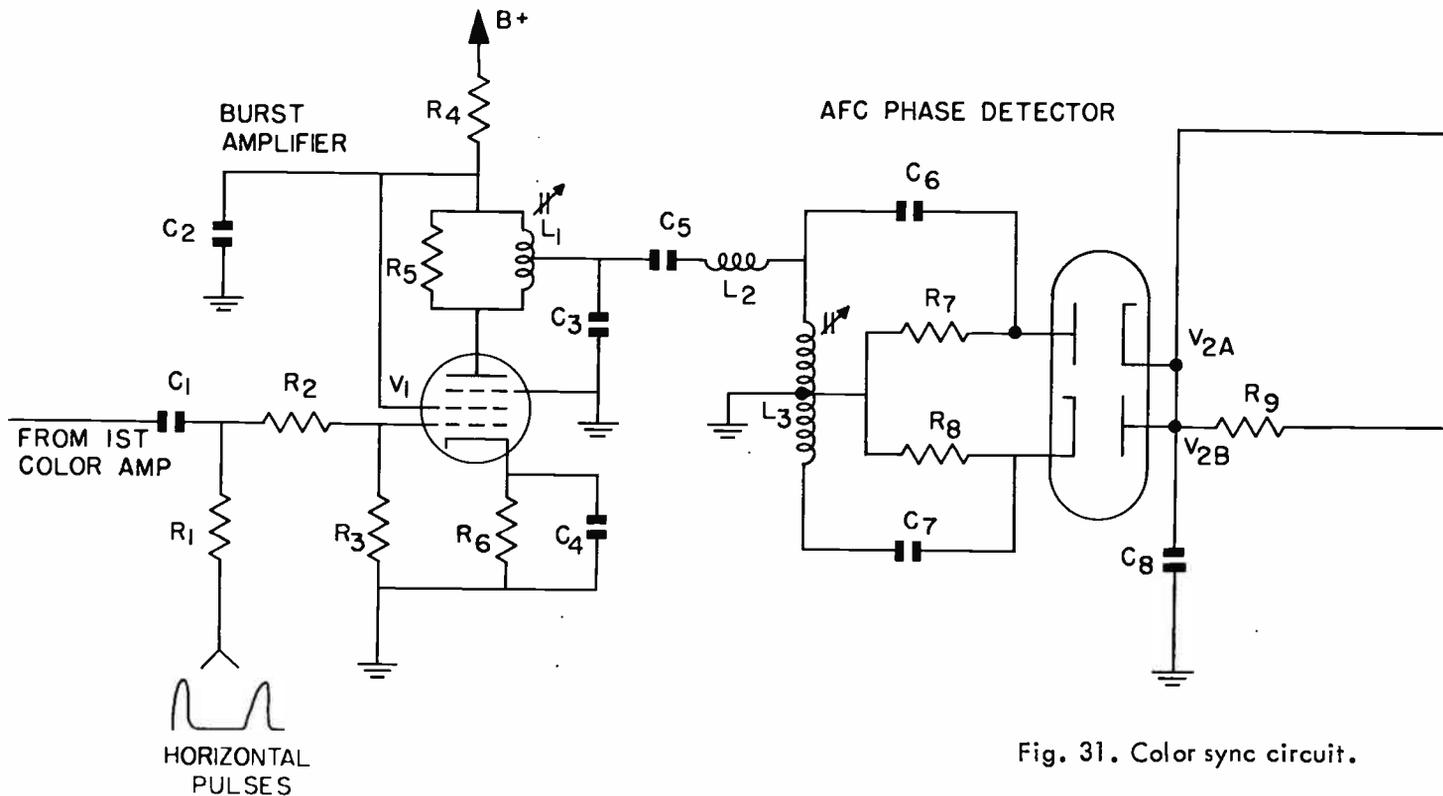
Fig. 31. Color sync circuit.

phase angle will decrease the conduction of V_{2A} and increase the conduction of V_{2B}, producing a negative dc correction voltage.

The dc correction voltage from the phase detector is filtered and applied to the reactance control tube, V_3. The components between the plate of V_{2B} and the grid of V_3 form a filter network that smoothes out the correction voltage and acts as an anti-hunt circuit. A negative dc correction voltage decreases the conduction of V_3, thereby decreasing the effective capacitance in parallel with the frequency-determining components of the oscillator.

Decreased capacitance tends to increase the oscillator frequency and compensate for the lagging phase angle that caused the negative dc correction voltage to be produced. Likewise a positive correction voltage increases the conduction of V_3, increasing the effective capacitance across the oscillator. Increased capacitance tends to lower the oscillator frequency and compensate for the leading phase angle that caused the positive dc correction voltage to be produced. In this way the oscillator is synchronized with the received burst signal and the demodulators are fed the correctly phased 3.58-mc reinsertion signal.

SELF-TEST QUESTIONS

(ai) What circuit produces the dc correction voltage that controls the reactance stage in the afpc circuit?

(aj) What is the received signal that synchronizes the color information in a color TV receiver?

(ak) When both diodes conduct equal amounts in a phase detector, what is the dc output voltage from the circuit?

(al) In the basic phase detector circuit, Fig. 21, what will be the polarity of the dc error voltage when D_1 conducts more than D_2?

(am) Except for the operation of the hue control, how are the various phase shifts in the color circuits of a TV receiver corrected?

(an) What component is used for the hue control in Fig. 24?

ANSWERS TO SELF-TEST QUESTIONS

(a) At the output of the bandpass amplifier.

(b) Tuned circuits that respond to a narrow band of frequencies around 3.58 mc.

(c) Yes, because the frequency of the burst signal is in the center of the band of frequencies amplified by the bandpass amplifier.

(d) It loads transformer T_1 and broadens the circuit response.

(e) By changing the size of the horizontal pulses to the grid of the bandpass amplifiers, thereby changing the grid leak bias and the gain of the stage.

(f) So color just disappears from the noise pattern with no signal to the TV antenna.

(g) Mistakes noise for burst signal when signals are weak.

(h) A 3.58-mc oscillator must be phase locked to the burst signal.

(i) Amplitude of the color burst signal.

(j) Color distortion.

(k) When no color burst is present in the received signal.

(l) The 3.58-mc oscillator signal causes V_{1A} and V_{1B} to conduct, producing a positive voltage at the cathode of V_{1A}. This positive voltage is ap-

B+

REACTANCE CONTROL TUBE R_{11}

3.58 MC OSCILLATOR C_{16}

T_1 QUADRATURE TRANSFORMER

TO R-Y DEMODULATOR

C_{13}

V_3

V_4

R_{15}

TO B-Y DEMODULATOR

C_{11}

L_5

C_{14}

L_4 R_{10}

R_{16} R_{12}

C_9 C_{10} C_{12} R_{13}

C_{15} R_{14}

3.58 MC CRYSTAL C_{16}

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plied to the cathode of D_1 as back-bias.

(m) The power required to blank the bandpass amplifier would load the flyback circuit.

(n) The color burst could get into the demodulators and produce visible color during retrace.

(o) Delayed acc. The diode prevents the automatic color control from reducing the gain of the bandpass amplifier on weak signals.

(p) Eliminates the need for readjusting the color gain control as you change channels.

(q) $90°$ lagging. The R - Y detector operates on an axes that lags the color burst signal by $90°$. Therefore if we want a color demodulator to work on a R - Y axes, we must feed a 3.58-mc signal to it which lags the burst signal by $90°$.

(r) The entire color signal is fed to the grid of the burst amplifier. The burst amplifier stage itself operates as a gate and amplifies the burst signal and rejects the remainder of the color signal so that the only signal appearing in the plate circuit will be the amplified color burst signal.

(s) The color burst signal is needed to synchronize the 3.58-mc oscillator in the receiver. Unless the oscillator in the receiver operates at exactly the same frequency and phase as the oscillator in the transmitter, you will be unable to reproduce the color being transmitted by the transmitter.

(t) In the second stage, V_2. The entire color signal is amplified by V_1. V_2 is used as a gate to permit the color burst signal to pass through this stage while the balance of the color signal is blocked.

(u) At essentially zero potential. Even though the divider network consisting of R_1 and R_2 con-

nects to the 35-volt power supply, R_2 is so large compared to R_1 that practically the entire 35 volts are dropped across R_2 so that the voltage applied to the base of Q_1 is practically zero. Thus there is no dc forward bias applied across the emitter-base junction of Q_1.

(v) Yes. Q_2 is normally conducting very heavily. In fact the collector current is so high that we say that the transistor is saturated. The collector current in the transistor drops during the horizontal retrace interval when negative horizontal sync pulses are fed to the base of the transistor.

(w) No. Transistor Q_2 is conducting so heavily that the collector voltage on Q_2 is very low. As a result, there is little or no forward bias across the emitter-base junction of Q_3 so normally the transistor does not conduct. However, during the retrace interval when a high amplitude negative pulse is fed to the base of Q_2 and a high amplitude positive pulse is fed to the collector, forward bias develops across the emitter-base junction of Q_3 so that the transistor does conduct and develops a high amplitude negative pulse in the collector circuit. This pulse is fed to the emitter of Q_1 causing this transistor to conduct and amplify the color burst signal.

(x) This is a phase shift network. The network permits us to shift the phase of the burst signal slightly. We must be able to control the phase of this burst signal to make up for parts tolerances in the circuit. This enables us to adjust the burst signal so that it will control the oscillator in the receiver and cause it to operate at exactly the correct phase. If the oscillator does not operate at exactly the correct phase, the

reproduced color signals will have the wrong hue or color.

(y) The No. 2 grid. When the high amplitude negative horizontal pulses are fed to the No. 3 grid of V_1 these pulses cut off the flow of plate current. Current therefore flows from the cathode to the No. 2 grid. During the interval when the negative pulses are present, the burst signal is transmitted and therefore the amplified burst signal is taken off at the No. 2 grid of the tube.

(z) No. During the time interval when the color burst signal is being transmitted there will be a high negative signal on the No. 3 grid of V_1. This will prevent current from flowing from the cathode to the plate. Since there will be no signal current reaching the plate there will be no burst signal developed in the plate circuit of V_1.

(aa) Phase discriminator circuit.

(ab) The oscillator signal lags the burst signal by 90°.

(ac) 90°.

(ad) 3.58-mc crystal oscillator.

(ae) Hue control.

(af) The 3.58-mc crystal.

(ag) Prevents the system from over correcting the phase of the 3.58-mc oscillator.

(ah) Lower.

(ai) Phase discriminator circuit.

(aj) Burst signal.

(ak) Zero volts.

(al) Negative.

(am) By alignment of the circuits so the receiver reproduces the transmitted colors.

(an) Inductance L_1.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. Which of the following signals appear in the output of the bandpass amplifier: color burst? blanking? horizontal sync pulses? chrominance? composite video?

2. What is the normal bias condition of the burst amplifier?

3. What is the approximate center frequency of the band of frequencies amplified by the bandpass amplifier?

4. What stage in a color receiver holds the bandpass amplifiers cut off during horizontal retrace?

5. What is the function of the 3.58-mc crystal in the subcarrier oscillator of a color TV receiver?

6. Since the frequency of the 3.58-mc subcarrier oscillator is crystal-controlled, why is a reactance control circuit needed?

7. In Fig. 24, will a negative dc signal to the grid of V_3 cause the oscillator output frequency to increase or decrease?

8. What two signals are compared in the phase detector of a color afpc system?

9. What will be the effect on the displayed color picture of shifting the phase of the 3.58-mc oscillator signal?

10. What circuit in the afpc system prevents overcorrecting the oscillator signal?

B514

COLOR DEMODULATORS AND AMPLIFIERS

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STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

☐ **1. Introduction** . . . . **Pages 1-3**
This lesson continues the detailed study of the color circuitry of color TV receivers. Color demodulator and color amplifier circuits are covered in this lesson.

☐ **2. I and Q Demodulators** . . . . **Pages 3-11**
This type demodulator performs the demodulation and matrix functions "step-by-step". Therefore it is studied first as a basis for understanding all other demodulator circuits.

☐ **3. Color Difference Demodulators** . . . . **Pages 12-30**
Numerous types of demodulator circuits are covered in this section including: R – Y, B – Y demodulators; R – Y, G – Y demodulators; B – Y, G – Y demodulators, Twin Pentode demodulator; "X" and "Z" demodulators; and Beam Switching demodulators.

☐ **4. Color Amplifiers** . . . . **Pages 31-38**
The circuitry that handles the color signals from the demodulators to the picture tube is discussed in this section. Matrixing and dc restoration of the color signal are covered.

☐ **5. Answer the Lesson Questions.**

☐ **6. Start Studying the Next Lesson.**

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COLOR DEMODULATORS AND AMPLIFIERS
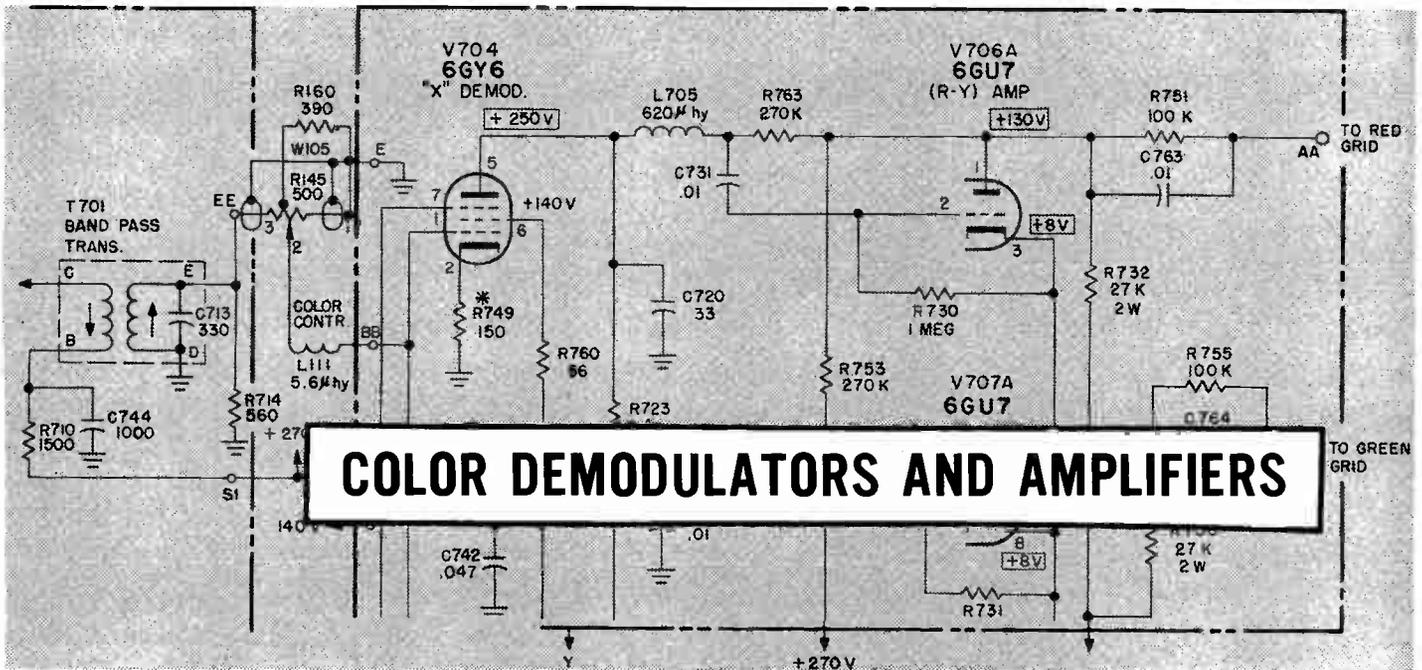
In this lesson you continue a detailed study of the color circuits of a color TV receiver. The circuit analysis of typical color circuits will increase your understanding of color receivers. You will get a feel for the special problems associated with different sections of the receiver. These studies build a background of knowledge about color circuitry that will help you in all phases of color TV servicing.

Fig. 1 is a familiar block diagram of the color section of a typical color TV receiver. We have shaded in the blocks that are covered in this lesson. You have already studied much of the circuitry that handles the color signal. Earlier lessons covered the tuners, i-f amplifiers, video detectors and video amplifiers used in color receivers. You learned how these circuits differed from the circuits used in black-and-white
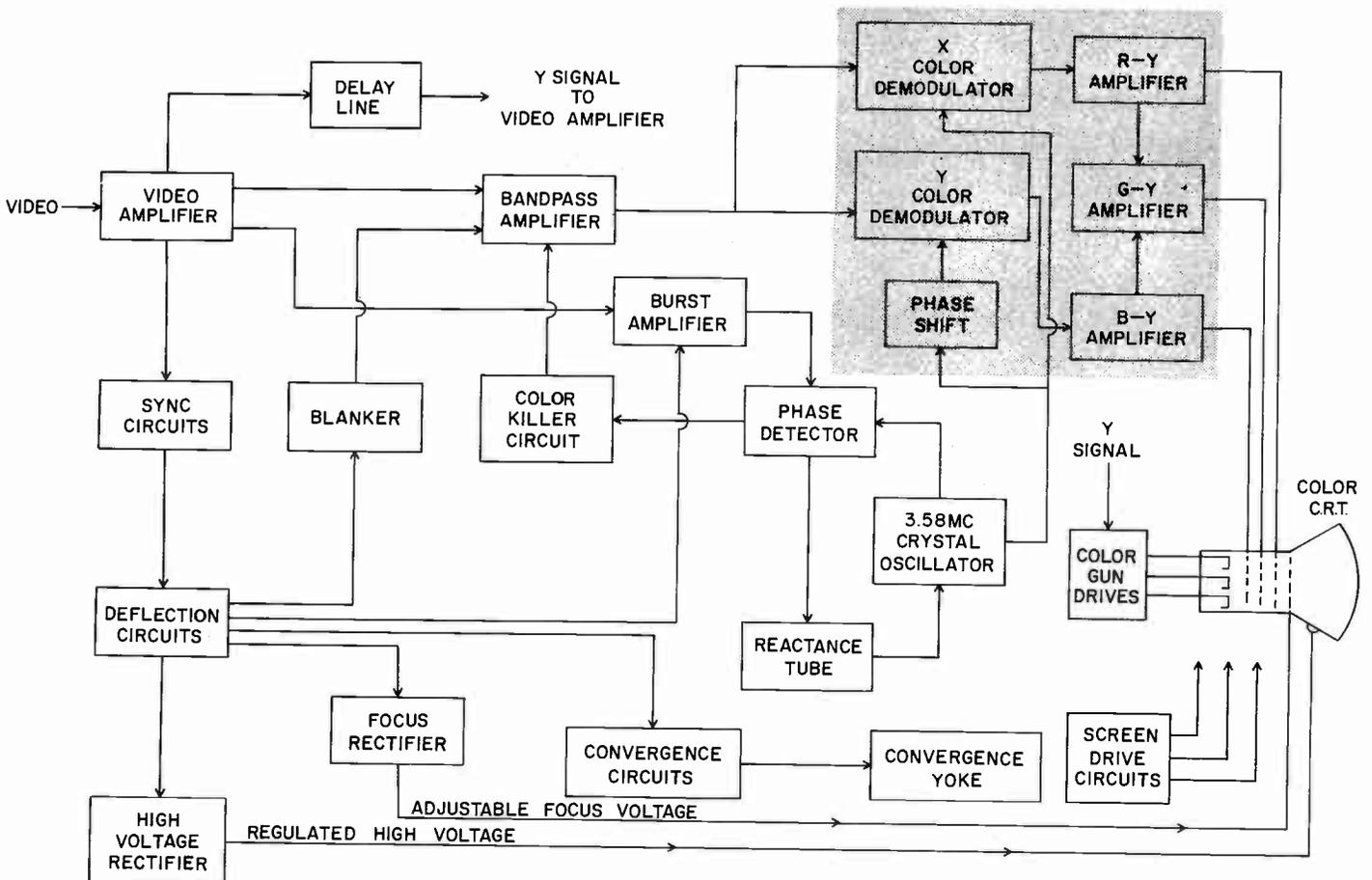
Fig. 1. The shaded blocks in the diagram show the circuits covered in this lesson.

In the system shown in Fig. 1 we have used two color demodulators to obtain two color signals and then have combined the correct proportions of these two color signals to obtain a third color signal. In the example in Fig. 1 we are dealing with color difference signals but these actually are color signals.

This is not the only method of getting the three signals required to drive the three guns in the tri-color tube. In Fig. 2 we have shown a block diagram where three separate color demodulators are used. Here we have color demodulators each operating on the color difference axes so that at the output of the demodulators we'll have an R-Y signal, a B-Y signal and a G-Y signal. The different signals can be obtained simply by introducing the correct phase shift in the 3.58 reference signal. For example the output of the 3.58-megacycle crystal oscillator is adjusted so that it is in phase with the G-Y axis and the signal is then fed into the G-Y color demodulator. The 3.58-mc oscillator signal is then fed to a phase shift network which shifts it to the B-Y axis and the shifted signal is then fed to a B-Y color demodulator. The signal from the crystal oscillator is also fed to a second phase shift network which shifts it to the R-Y axes and feeds the signal to the R-Y color demodulator.

The output from the demodulators are fed to amplifiers and the signals are then fed to the grids of the tri-color tube. Meanwhile the Y signal is fed into an appropriate amplifier and fed to the cathode of the picture tube. The picture tube matrixes the signals,

Fig. 2. Block diagram of alternation color demodulation system using three color demodulators.

receivers. Other lessons covered the generation of voltages and signals used to operate the three gun color picture tube. In your last lesson you studied bandpass amplifiers, burst amplifiers, and the color sync section of the color receiver. You learned how the color signal was separated from the video signal and processed for use in the color demodulators. You learned how the color burst signal was processed and used to synchronize the 3.58-mc ocillator that generates the reinsertion signal for the demodulators.

Now you will study the circuitry that demodulates the color signal and processes it for display on the CRT. You will study the principle of synchronous detection that is used in all types of color demodulators. Representative circuits of the various types of demodulators are presented. You will also study typical demodulator circuits found in color receivers.

The demodulated color signals are handled in several different ways in different receivers. Fig. 1 shows color difference amplifiers between the demodulators and the grids of the picture tube. Some receivers use high-level demodulators having outputs of sufficient amplitude to drive the picture tube directly. Other receivers combine the color difference signals with the Y signals in a matrix to produce the color signals. In Fig. 1 the picture tube is used to matrix the Y signal with the color difference signals.

Fig. 3. Block diagram of color demodulators and amplifier system where matrixing of the color difference signals and the Y signal is done in the color demodulators.

so that the red gun will be driven by the R signal, the blue gun by the B signal and the green gun by the G signal.

It is also possible to use the color demodulation system shown in the block diagram in Fig. 3. Here the color demodulators not only demodulate the color signal, but also perform a matrixing function so that the signal at the output of each demodulator is a color signal rather than a color difference signal. For example, notice that the color signal from the color bandpass amplifier is fed to three color difference detectors. The Y signal from the video amplifier is also fed to the three color demodulators. The 3.58-mc crystal oscillator is adjusted to operate on the - (G-Y) axis so the signal from this oscillator is fed directly to the - (G-Y) color detector. The color detector will detect on the G-Y axis. It also matrixes the G-Y signal with a -Y signal so that at the output we will have a signal which is - (G-Y) -Y = - G + Y - Y = -G, or in other words a negative green signal. This signal is amplified and fed to the cathode of the green gun in the picture tube.

Meanwhile, a signal from the crystal oscillator is fed to a phase shift network which shifts the signal to the - (B-Y) axis. This signal is then fed to the - (B-Y) color oscillator which detects signals on this axis and matrixes them with the -Y signal so that at the output of the - (B-Y) color demodulator we have a negative blue signal.

We have another phase shift network which takes the signal from the 3.58-mc oscillator and shifts the signal to the - (R-Y) axis. This signal is then fed into the - (R-Y) color demodulator which matrixes the signal with the -Y signal producing a negative red color signal in the output which is fed through the red amplifier to the cathode of the red gun in the picture tube. We'll study this circuit in detail later.

Numerous types of demodulator circuits have been used in color TV receivers. Quite a number of different types are covered in this lesson. However, it is impossible to show all the circuit variations that will be found in color receivers. These circuit variations should not give you any trouble as far as servicing color receivers. In most cases you will be able to figure out what the circuit variations accomplish. The circuit variations often affect the adjustment procedure. For this reason, you should always refer to the manufacturer's instructions when adjusting the color section of the receiver. Your study of the demodulators and amplifiers will help you to fully understand the instructions for adjusting these sections of the receiver.

I and Q Demodulators

You will remember that the I signal was produced by matrixing .28G - .60R + .32B. This I signal is used to modulate a 3.58-mc subcarrier which is displaced 57° from the 3.58-mc color burst. This is called the I axis of the modulation or simply the I axis. Similarly, the Q signal was made up of - .52G + .21R + .31G and was used to modulate a 3.58-mc subcarrier on the Q axis, which is displaced 90° from the I axis. It would seem logical for color receivers to demodulate on these axes. However, very few receivers using I and Q demodulators have been marketed. The reasons for this are the increased complexity and cost of I and Q demodulators compared to simpler color difference demodulators. I and Q demodulators are capable of recovering more undistorted color information than other types of demodulators. Also the I and Q circuitry processes the color signal step-by-step making it an easy circuit to study. Other demodulators combine several functions in single stages so that it is not as obvious to observe what the stages are doing.

The color vector diagram is reproduced in Fig. 4. As you recall, the zero axis represents the phase of the 3.58-mc reference subcarrier which is also the phase angle of the color burst signal at the receiver. Since the I and Q demodulators operate on the I axis and the Q axis, the reinserted subcarrier must lie on these axes. The reinserted 3.58-mc signal to the I demodulator must lag the phase of the burst signal by 57°. The 3.58-mc signal reinserted to the Q demodulator must be shifted an additional 90°. In this way, the demodulators are able to recover the I and Q color signals from the one phase and amplitude modulated color subcarrier.
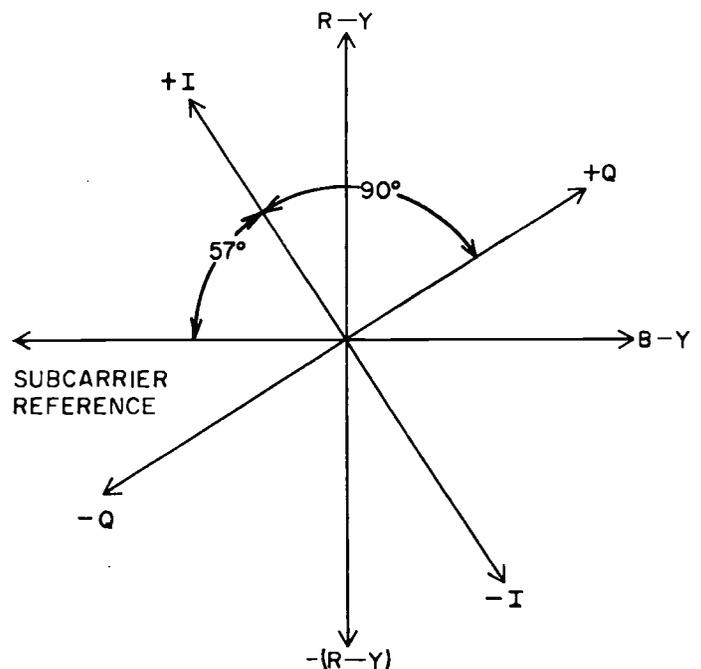
Fig. 4. Location of the I and Q color axes.
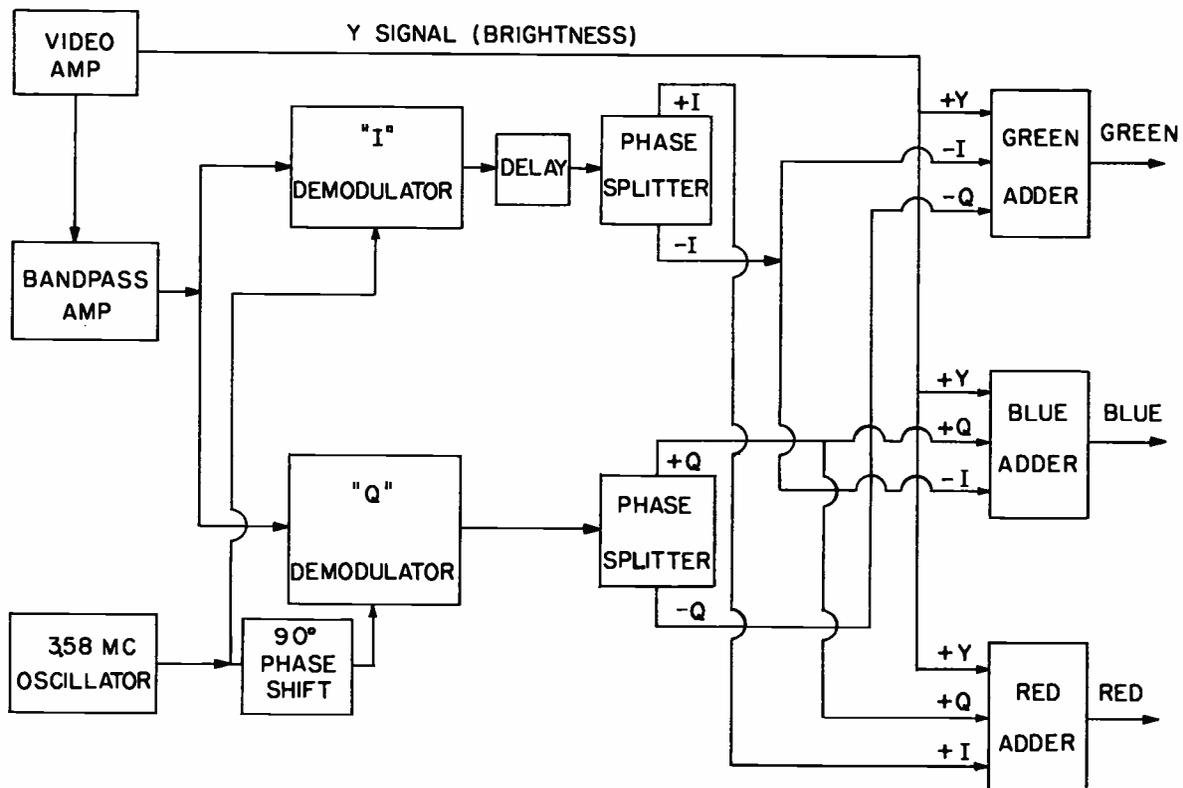
Fig. 5. Functional block diagram of the demodulator section of an I and Q color receiver.

Fig. 5 shows a functional block diagram of the demodulator section of a color receiver that uses I and Q demodulators. A video signal from the first video amplifier is applied to the bandpass amplifier where the chrominance signal is separated from the rest of the video signal. The color signal is then applied to both the I and Q demodulators.

Both demodulators are supplied a continuous wave of 3.58-mc signal from the 3.58-mc oscillator. The output of the oscillator is phase locked to the burst signals with a constant 57° phase shift. This signal is fed directly to the I demodulator. A phase shift network provides an additional 90° phase shift to the 3.58-mc continuous wave signal fed to the Q demodulator.

The output of the Q demodulator is restricted to frequencies up to .5 mc. The output of the I demodulator is restricted to frequencies up to 1.5 mc. Since the signals will pass through the I section faster than the Q section because of its wider bandwidth, a delay network is inserted in the I channel to compensate for the longer delay of the Q signal.

The demodulated I and Q signals are applied to phase splitters to develop positive and negative quantities of both signals. The Q phase splitter produces -Q signals and +Q signals while the I phase splitter produces -I signals and +I signals. The -Q signal is simply the Q signal inverted 180°. Similarly, the -I signal is the I signal inverted 180°.

The adder circuits combine the brightness (Y) signal with the color signals to produce the three primary color signals. The green adder circuit is fed a +Y signal, a -Q signal and a -I signal. These signals are combined in their proper proportions to produce the G signal which is applied to the green gun of the tri-color picture tube.

The blue adder circuit is fed a +Y signal, a +Q signal and a -I signal. These signals are combined in the proper proportions to produce the B signal which is applied to the blue gun of the tri-color picture tube. Likewise, the red adder circuit combines the proper proportions of +Y, +Q, and +I to produce the R signal which is fed to the red gun of the picture tube. Thus the three guns of the picture tube are supplied the three primary color signals of the televised scene. The picture tube produces colored light in response to the three color signals. The eye combines the three colors and sees the original televised scene in its proper hues.

SYNCHRONOUS DETECTION

You will recall that at the transmitter a process of amplitude and phase modulation is used in a pair of doubly-balanced modulators to put the color information on the color subcarrier. The I color information is fed to one modulator and the Q color information is fed to the other modulator. The subcarrier signals fed to the two modulators are in quadrature or displaced 90° from each other. In the modulation process, the subcarriers are suppressed leaving only the sidebands. The outputs from the two modulators are then combined to produce a single chrominance signal. This single chrominance signal consists of amplitude and phase modulated sidebands of the 3.58-mc signal. The phase of the signal carries the hue information and its amplitude carries the saturation information of the color being transmitted. A color burst sample of the original subcarrier frequency is also transmitted along with the chrominance signal to permit exact synchronization of the 3.58-mc oscillator in

the TV receiver. The receiver uses the process of synchronous detection to reverse the transmitter process and therefore recover the original color information.

Fig. 6 shows a pentagrid vacuum tube circuit suitable for performing synchronous demodulation. The stage is self-biased by the unbypassed cathode resistor, R_3. The screen grids, grids 2 and 4, are bypassed by C_2 and supplied a positive potential from B+ through R_1. Grids 1 (pin 1) and 3 (pin 7), are both control grids and both control the flow of current through the tube. The 3.58-mc continuous wave reinsertion subcarrier signal is fed to grid 3 (pin 7). The color sideband signal is applied to grid 1 (pin 1). The instantaneous plate current depends upon the phase and amplitude of the two signals.

C_1 is a plate bypass and provides a low impedance bypass for the 3.58-mc signals. The detected color signal currents flowing through R_2 develop a color signal voltage across the resistor. L_1 is a series peaking coil and L_2 a shunt peaking coil. Together with C_1, they form a filter network to limit the response of the stage from zero to .5 mc.

The signal is coupled through C_3 to the phase splitter stage. In the circuit in Fig. 6, the response is limited to signals in the zero to .5 mc range because it is a Q demodulator stage. If the stage were the I demodulator, the response would be extended to 1.5 mc by the correct selection of C_1, L_1 and L_2.

Let's examine the operation of the demodulator stage under different signal conditions. With no color signal applied, plate current is controlled by the oscillator signal only. The tube conducts on positive peaks of the oscillator signal and is cut off during the negative half cycle. The plate current pulses are bypassed by C_1 and
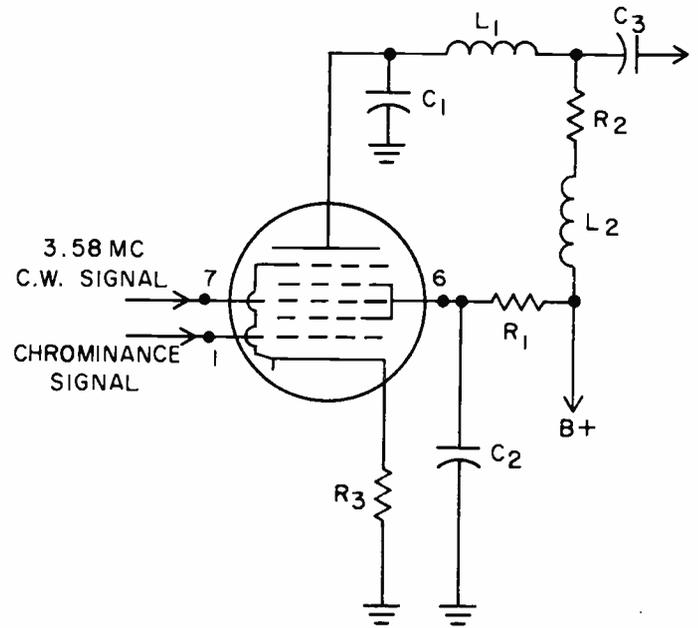
Fig. 6. Synchronous demodulator.

the plate voltage assumes an average value. No signal is coupled out of the demodulator under these conditions.

Fig. 7 illustrates the action of the demodulator under different signal conditions. Fig. 7A illustrates the no color signal conditions with the oscillator signal producing pulses of plate current. Fig. 7B shows the operation with an in phase color signal. The positive swing of both the oscillator signal and the color signal occurs at the same time so each pulse of the plate current is larger. Large plate current pulses produce
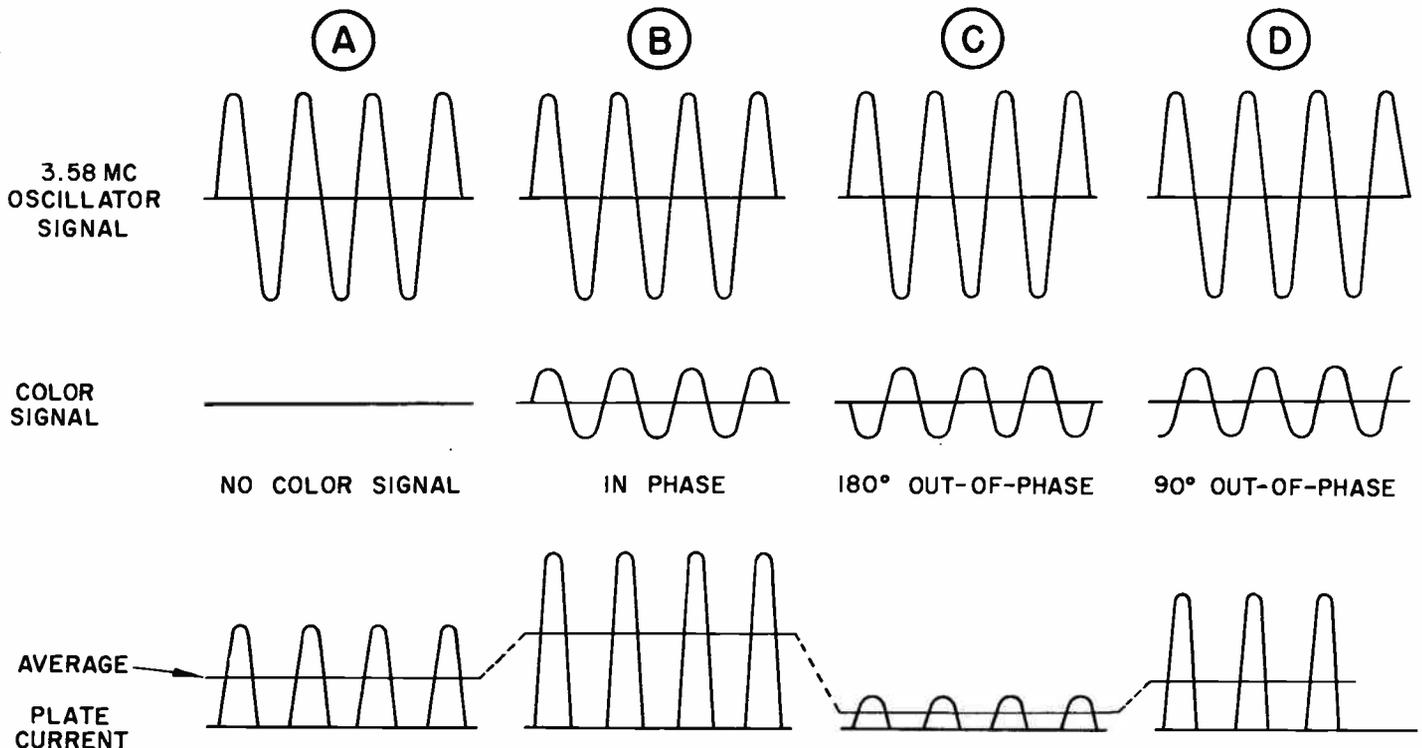
Fig. 7. Operation of a synchronous demodulator with no color signal (A), an in phase color signal (B), an 180° out-of-phase color signal (C) and a 90° out-of-phase color signal (D).

a higher average plate current. This results in a greater voltage drop across R_2, so the plate voltage swings in a negative direction. This negative voltage change is the color signal which is coupled through C_3 to the next stage.

Fig. 7C shows the operation of the demodulator with the color signal 180° out-of-phase. During the time the oscillator signal is swinging positive, the color signal is swinging negative so plate current is decreased. The small plate current pulses produce a small average plate current. This in turn produces a smaller voltage drop across R_2 so that the plate voltage increases above the average no-color signal level. The positive swing above the average represents a color signal.

Fig. 7D shows the demodulator operation with a color signal 90° out-of-phase. The color signal produces decreased current on the first half of each plate current pulse and increased current during the last half of each plate current pulse. This results in pulses that are somewhat higher than those in Fig. 7A, but narrower so that the average plate current is the same as in Fig. 7A when no color signal is applied to the demodulator. Fig. 7D shows the color signal lagging the oscillator signal by 90°. The same results would be obtained if the color signal were leading the oscillator signal by 90°. Under this condition, the current would be increased during the first half of each current pulse and decreased an equal amount during the last half of each current pulse. The average plate current would be the same as if the signal lagged by 90°. In any event, since a color signal 90° out-of-phase with the 3.58-mc oscillator does not produce any change in average plate current, it will not produce a color signal in the detector output.

An examination of Fig. 7 shows that demodulation produces maximum plate current when the color signal is exactly in phase with the 3.58-mc oscillator signal and minimum plate current when the color signal is exactly 180° out-of-phase. Color signals that are exactly 90° out-of-phase have no effect on the average plate current. Color signals between zero and 90° produce a higher than average plate current and signals between 90° and 180° produce lower than average plate current. The amount of plate current also depends on the amplitude of the color signal. A large amplitude color signal sine wave in Fig. 7 will produce a larger change in plate current than a small amplitude sine wave. Therefore the average plate current will depend on both the phase and amplitude of the color signal.

The plate current through the demodulator tube produces the color signal recovered by the demodulator. As previously mentioned, the tube current is filtered in the plate circuit by the bypass capacitor C_1. In fact, the value of C_1, L_1 and L_2 are selected to filter out all frequencies above .5 mc (for the Q demodulator). Also you know that the color signal is a constantly changing signal depending on the color being transmitted. Therefore the signal coupled out of the demodulator is a voltage that changes in accordance with the changes in average plate current. The rate at which the circuit is able to respond to these changes is limited by the network in the plate circuit. In the case of the Q demodulator, these changes are
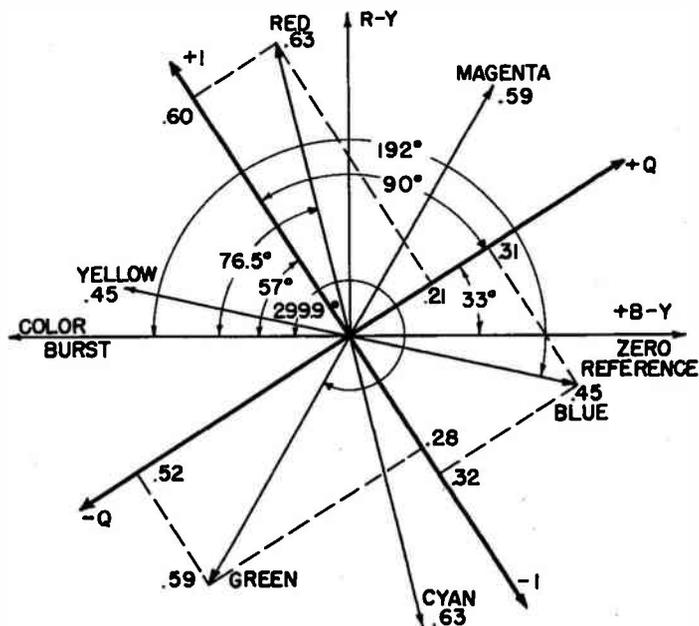
Fig. 8. Phase relationships of color signals.

limited to rates that correspond to frequencies up to .5 mc. In other words, this represents the rate at which the demodulator can respond to changes in color. This in turn limits the color detail that can be displayed by signals out of the Q demodulator.

Vector Analysis.

The operation of the color demodulators can be examined by showing the vector relation of the various signals in the demodulator. Fig. 8 shows the phase relation of the color signals. The vector labeled color burst is the reference against which all other signals are plotted. The +Q vector is plotted 147° (57° + 90°) from the color burst vector. The Q demodulator operates on this axis. This axis represents the phase of the reinserted 3.58-mc oscillator signal that is applied to the demodulator. The Q demodulator breaks up the color signal into components along the +Q, -Q axis.

Let's examine the Q demodulator operation when the received color signal represents a saturated bright red color. The instantaneous red color signal is a sine wave having an amplitude of .63 and a phase of 76.5° in relation to the burst signal. Since this color signal is 70.5° (147° - 76.5° = 70.5°) out-of-phase with the reinsertion signal in the Q demodulator; the change in plate current is small. As shown in Fig. 8, the projection of the red vector onto the +Q axis produces a +Q signal of .21 or we say the Q component of the .63 red signal is +.21. We know this is correct because the Q signal is made up of .21R + .31B - .52G.

Now observe in Fig. 8 how the Q demodulator responds to a green signal. A saturated green signal is a sine wave that lags the subcarrier by 299.9° and has an amplitude of .59. Notice that this signal lags the Q axis by 152.9° (299.9° - 147° = 152.9°). Or it lacks only 28° from being 180° out-of-phase. In the demodulator the signal produces less than average plate current which means that the output will be a -Q signal. As shown in Fig. 8 the projection of the green signal on the -Q axis is .52 or we say the Q axis component of the green color vector is -.52. Fig. 8 also

shows how the Q demodulator responds to a blue signal to produce a +.31 component in the Q axis.

The color signal applied to the Q demodulator can have a phase angle anywhere from zero degrees to $360°$. From the example shown in Fig. 8, you can see that each particular color signal will produce a corresponding output somewhere on the Q axis. If the color signal is exactly $90°$ out-of-phase with the Q axis there will be no Q demodulator output. A signal exactly in phase with the +Q axis will produce a maximum +Q output while a signal exactly $180°$ out-of-phase will lie on the -Q axis and will produce a maximum -Q output. Signals having phase angles in between these extremes will produce corresponding outputs along the Q axis.

Operation of the I demodulator can be examined by studying Fig. 8. The reinsertion 3.58-mc signal to the I demodulator lags the burst signal by $57°$ so the demodulator operates on the I axis. The output of the I demodulator is the projection of the color signal vector onto the I axis. For example, the red color signal, represented by the .63 red vector, projects onto the I axis to produce a .60 component. Or we say that the I demodulator produces a +.60 output when a saturated red color signal is received. Fig. 8 shows the projection of the other primary colors, blue and green, on the I axis.

The received color signal is applied to both the I and Q demodulator at the same time so they both process the same signals. Thus when a red signal is being received, the Q demodulator has a +.21 output and the I demodulator has a .60 output. Likewise when any particular color signal is being received, each demodulator produces its corresponding output.

Fig. 9 shows the I and Q demodulator outputs for
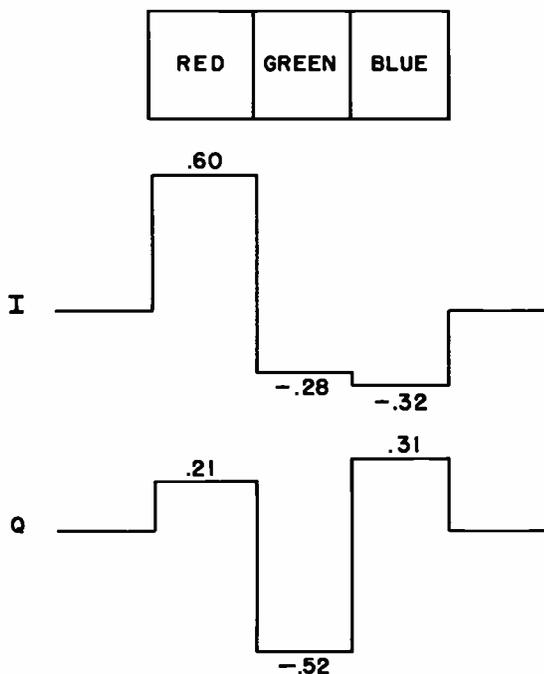
Fig. 9. The primary color signal components in the I and Q chrominance signals when bars containing saturated colors are scanned.

color signals representing the three primary colors; red, green, and blue. By comparing Fig. 9 with Fig. 8, you can see that each demodulator output in Fig. 9 corresponds to the vector solution in Fig. 8.

I AND Q DEMODULATOR CIRCUIT

An example of an I and Q demodulator circuit is shown in Fig. 10. Notice that the demodulator stages are labeled "-Q" and "-I" demodulators because the tubes invert the signals during demodulation. The filter network in the plate circuit of the Q demodulator has an upper frequency limit of about .5 mc. The Q signal is then coupled to the Q phase splitter stage that produces the +Q and -Q signals required in the matrix section.

The output from the I demodulator stage is fed to a time delay circuit. The demodulated I signal has an upper frequency limit of about 1.5 mc. Since the Q demodulator has a narrower bandpass it is delayed more than the I signal. Therefore the time delay in the I channel is required to equalize the delay of the I and Q signals.

An amplifier stage is used in the I channel to equalize the amplitude of the I and Q signals. The high frequency components of the I signal are carried in a single sideband while the entire Q signal uses double sideband transmission. Therefore the Q demodulator produces a relatively larger output. Also the I signal is attenuated somewhat in passing through the delay line. To compensate for the resultant differences in amplitudes of the signals, an amplifier is placed in the I channel ahead of the phase splitter. The amplitude of the I signal is adjusted by the gain control in the grid circuit of the I amplifier. The output of the I amplifier is fed to the phase splitter stage to produce the +I signals and the -I signals required in the matrix section.

MATRIX CIRCUIT

The demodulated I and Q signals recovered by the demodulators are combined in a matrix circuit to produce the red, green, and blue color signals. Fig. 11 shows the matrix and output circuits for an I and Q color receiver. The matrix functions of combining in the proper proportions the Y signal, I signal and the Q signal are performed in the grid circuits of the three adder stages. The Y signal and the correct polarities of the I and Q signals are applied to the resistor networks in the grid circuit of each adder stage.

The resistor network or matrix, mixes the three signals to each adder. The size of the resistors are selected to give the correct proportions of each of the signals. Also, the resistor sizes are adjusted to restore the color signals to the proper relative amplitude. Remember that at the transmitter, the chrominance signals were attenuated to prevent over-modulation of the transmitter. This is the place in this receiver where they are restored to their proper relative amplitudes.

The green adder stage, V135A, combines with a Y signal, a -I signal and a -Q signal in a resistor
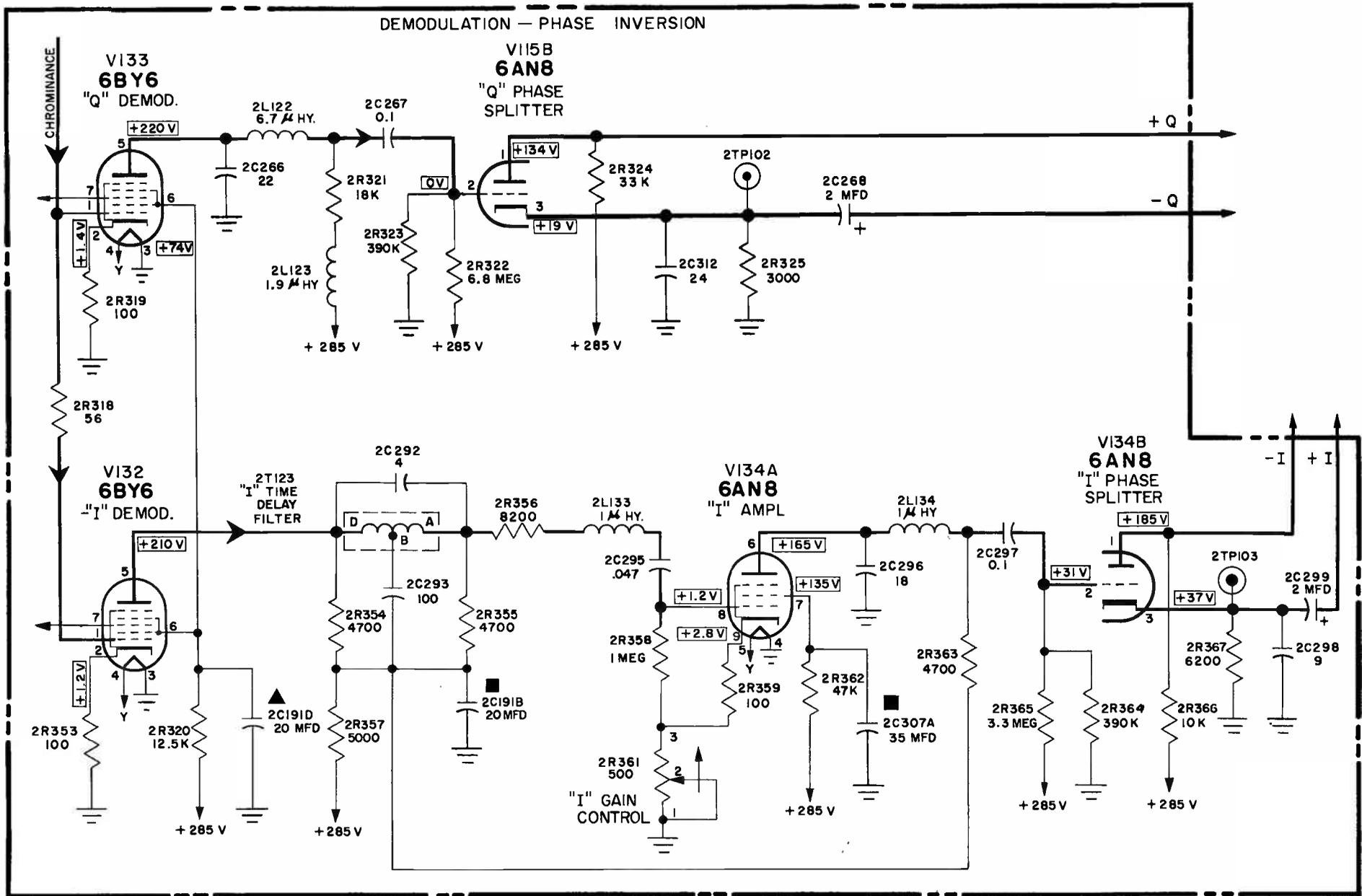
Fig. 10. Demodulation-phase inversion section of an RCA color TV receiver.
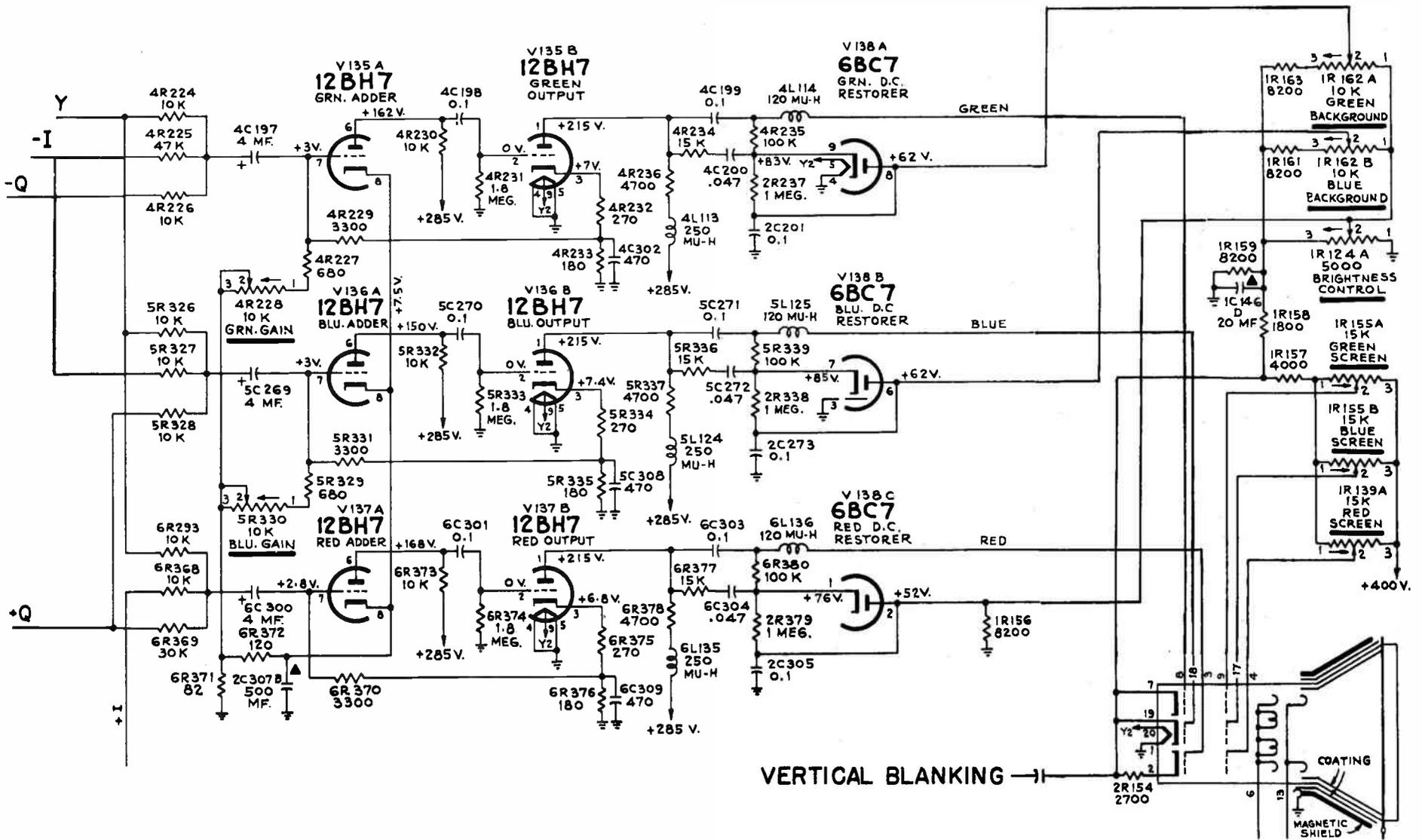
Fig. 11. Matrix and output circuits for the I and Q demodulator.

Courtesy RCA

B514 - 9

network. This resultant signal is applied to the control grid of the green adder stage. The green gain control in the grid circuit adjusts the amplitude of the signal applied to the stage.

The signal at the plate of the green adder stage is coupled to the grid of the green output stage, V135B. The feedback circuit couples a signal from the cathode of V135B to the grid of V135A. Since the cathode signal is 180° out-of-phase with the signal on the grid of the preceding stage, this circuit provides negative feedback. The feedback circuit provides more negative feedback for low frequency signals than for high frequency signals. The high frequency video signals are bypassed by the 470-ohm capacitor in the cathode circuit of V135B. As a result, the amplitude of the high frequency signals developed across the 180-ohm cathode resistor is much lower than the amplitude of the low frequency signals. In this way the circuit provides more feedback for low frequency signals. This compensates for the loss of high frequency response due to shunt capacitance in the plate circuit. The result is a flat response across the band of video frequencies handled by the circuit.

The blue adder stage is almost identical to the green adder stage. The only difference is the size of the resistors in the signal combining network. The blue adder stage combines the Y signal, -I signal and the +Q signal to produce the blue signal.

The red adder stage does not have a gain control like the other color adder stages. When this circuit was designed, the red phosphors in the picture tube required much greater excitation than the blue and green phosphors. Therefore, the red signal was applied with full amplitude. The red phosphor in modern tubes has a much higher light output and requires much less drive. This might present a problem in replacing the picture tube in a set using this circuit. The green and blue signals are attenuated by the green and blue gain controls. The gain control adjustments are necessary to get the proper portions of the three colors on the picture tube. This is usually referred to as black-and-white tracking because improper color balance produces a black-and-white picture with color in it. The blue and green gain controls are adjusted to the position that gives satisfactory black-and-white pictures when receiving a black-and-white telecast. This means that the light from the adjacent three color dots combine to form white light and various shades of gray.

If you replace the picture tube, and then try to adjust the set for black-and-white picture, you may find that the picture has a reddish color even with the green and blue gain controls in the maximum positions. This is due to the higher sensitivity of the red phosphor in the new picture tube. You can correct this situation by adding a red gain control in the grid circuit of the red adder. Use a 10K-ohm potentiometer and a 680-ohm resistor connecting them in the same way as the green and blue gain controls are connected. Another way of correcting this problem is to find which of the blue and green phosphors requires the most drive. If you can do this, disconnect the gain control from the circuit requiring the most drive and switch it over to the red adder. You can do this simply by disconnecting the 680-ohm resistor from the grid of the one tube and connecting it to the grid of the red adder. The control now becomes the red gain control.

DC RESTORATION AND PICTURE TUBE CIRCUITS

The dc component of the color signals is lost in passing through the capacitor coupled stages of the color circuits. Therefore it is necessary to reinsert a dc component that will reference the signals to a fixed level. The negative sync tips of the video signal are used to establish the reference level. Sync pulses are part of the Y signal that was applied to the matrix circuit in Fig. 11. These sync pulses have a negative polarity at the output stages. The signal is applied to the cathode of each of the diode dc restorer stages. The diodes conduct on the negative sync pulse peaks. Diode current produces a positive potential at the cathode of the diodes. This positive dc potential is applied to the grids of the picture tube and establishes a dc operating level for the picture tube guns.

The operation of the dc restorer can best be understood by referring to Fig. 12. The Y signal fed to the adders will have a negative sync pulse polarity as shown at A. The complete video signal which consists of an ac signal superimposed on the dc component will look like the two examples shown in Fig. 12A. In the case of a bright scene, the video will approach zero voltage; this represents the brightest picture. Remember the sync pulses represent blacker than black. In the case of a dark signal, the video portion will have a fairly high negative value, almost as high as the blanking level in the case of a very dark scene. This signal will be inverted by the adder and then inverted again by the output so that at the cathode of the dc restorers we should have a signal with negative-going sync pulses as shown.
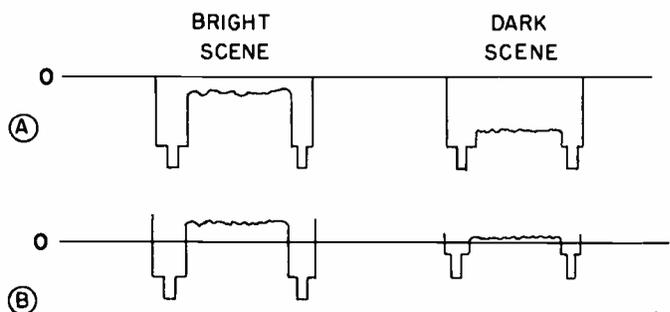
Fig. 12. Video signals for bright and dark scenes are shown at A. Same scenes with dc component missing are shown at B.

However, the adder and output stages are capacitive coupled. You know that the dc component of the signal cannot go through the capacitors so the signals will average out as shown in Fig. 12B. Notice that in the bright scene we have a fairly large excursion above and below the zero voltage whereas in the dark scene the positive and negative excursions from the axis is quite limited. Therefore the amplitude of the sync pulse actually fed to the dc restorer will be consider-

ably higher in the case of a bright signal. This will cause the dc restorer to conduct more on a bright signal than on a dark signal. In other words, the dc voltage developed at the output of the dc restorer will be higher for a bright signal than it will be for a dark signal.

Looking at the green dc restorer, V138A, the sync pulses which swing in a negative direction are fed to the cathode of the tube through the 15K resistor and the .047 capacitor. The negative-going sync pulses cause current to flow from the cathode of the tube to the plate and then through the 2-meg resistor back to the cathode of the tube. In flowing through the resistor they develop voltage across the resistor having a polarity such that the cathode end is positive. This voltage is then fed through the 100K-resistor and the 120-microhenry peaking coil to the grid of the green gun of the picture tube. The higher the positive voltage developed, the brighter the green gun will be. Therefore, for a bright scene where the sync pulses will have the higher amplitude, a higher positive voltage will be developed and the brightness will be increased. On a dark scene, the positive voltage developed at the cathode will be lower and as a result the brightness of the scene will be reduced.

The synchronizing pulses as they are transmitted, all have the same amplitude, but after going through a capacitor, the signals average out as shown in Fig. 12B, and this is what makes the operation of the dc restorers possible.

A group of controls sets the dc operating levels of the picture tube. The brightness control adjusts the dc level of the plate of the red dc restorer diode. This adjusts the dc operating level of the red dc restorer which sets the dc level of the red gun grid of the picture tube. Setting of the brightness control also affects the dc voltage applied to the blue and green background controls. These controls set the dc voltage to the plates of the blue and green dc restorer diodes. These background controls allow separate adjustment of the grid-to-cathode dc potential of the blue and green grids of the picture tube. Thus the brightness control adjusts the bias on the grids of all three guns while the background controls set the brightness of the blue and green guns in relation to the red gun.

A screen grid control is provided for each gun of the picture tube. The potential on the screen grids must be adjusted so the same grid-to-cathode voltage will cut off each gun. This condition is necessary for balanced operation of the three guns to produce black-and-white tracking.

SELF-TEST QUESTIONS

(a) What is the phase angle of the I axis in relation to the reference burst signal? Of the Q axis?

(b) Why is a delay network needed in the I demodulator channel?

(c) What signal is applied to the control grid of the demodulator in Fig. 10?

(d) What is the function of the phase splitter stages in Fig. 10?

(e) In the I and Q demodulator circuit, where is the brightness signal introduced into the signal that drives the color picture tube?

(f) What does negative feedback accomplish in the color adder stages in Fig. 11?

(g) What is the purpose of the gain controls in the grid circuits of the green and blue adder stages in Fig. 11?

(h) Why doesn't the red adder stage have a gain control in Fig. 11?

(i) What part of the signal in Fig. 11 is used as a reference level?

Color Difference Demodulators

Instead of using I and Q demodulators, most color receivers use two color difference demodulators that produce two color difference signals directly. These demodulators offer several advantages over the I and Q demodulators. The two demodulator channels can be made identical so no time delay network is necessary in one of the channels. Two of the color difference signals are produced by the demodulators so only one matrix is needed to produce the third color difference signal. Separate matrix circuits are not required for combining the Y signals with the color difference signals. The amplified color difference signals can be applied to the grids of the picture tube and the Y signal applied to the cathodes of the picture tube. Thus the picture tube is made to perform the matrix function of combining the Y signal with the color difference signals. All of these advantages make for a less expensive color receiver that is easier to adjust and maintain.
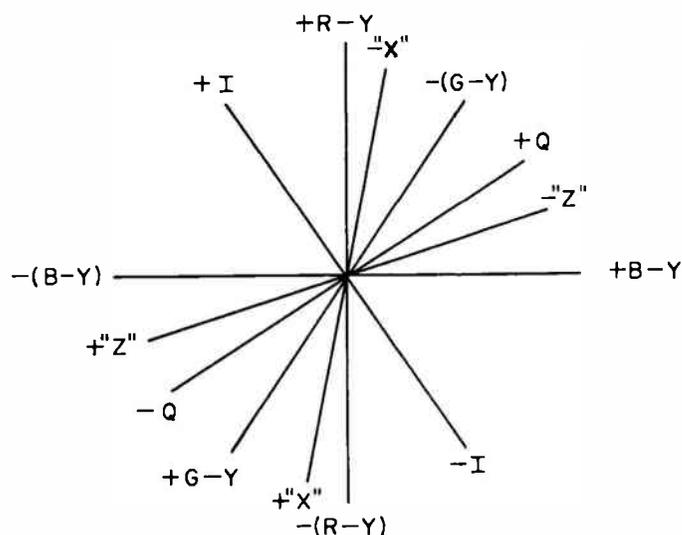
Fig. 13. Color phase diagram with the various axes identified.

As previously mentioned, color demodulators can be made to operate on any desired sets of axes by adjusting the phase of the reinserted 3.58-mc carrier signal. Fig. 13 shows the color phase diagram with the various axes identified. One type of color difference demodulator operates on the R - Y and B - Y axes. Another type demodulates on the R-Y and G-Y axes. Still another type operates on the "X" and "Z" axes. Each of these types is simpler than the I and Q demodulators. Each type takes advantage of certain features of the demodulation process to make a receiver that is either less expensive, easier to adjust, or a combination of both.

B-Y, R-Y DEMODULATOR

One popular type of color difference demodulator is the B - Y, R - Y demodulator. An example of this circuit is shown in Fig. 14. The demodulation process is accomplished in a pair of double diodes. Triode stages form the B - Y and the R - Y amplifiers that follow the demodulators. The outputs from these two amplifiers are matrixed in the grid circuit of the G - Y amplifier to produce the G - Y signal. The three color difference signals are used to drive the three grids of the color tube. Let's examine the circuit in detail.

The chrominance signal from the bandpass amplifier is applied to the grid of the cathode follower stage, V_1, in Fig. 14. The color signal is developed across the tunable transformer, L_1, in the cathode circuit of V_1. Two signals, 180° out-of-phase, are taken from L_1. One signal is coupled through C_7 to pin 6 of V_2 and through C_9 to pin 7 of V_3. The other signal is coupled through C_8 to pin 7 of V_2 and through C_{10} to pin 6 of V_3. Transformer, L_1, is tuned to peak the amplitude of the 3.58-mc color signal.

The 3.58-mc oscillator signal is fed to a plate and cathode, pins 8 and 9 of the R - Y demodulator, V_3, and to the tuned, center tapped coil, L_2. A 90° phase shift of the 3.58-mc oscillator signal is obtained by adjusting the tunable slugs in L_2. The 3.58-mc signal, shifted 90° by L_2 is fed to the plate and cathode, pins 8 and 9 of the B - Y demodulator, V_2.

The twin diode demodulator, V_2, demodulates the incoming chroma signal on the B - Y axis and produces a B - Y color difference signal. With no color signal applied to V_2, the diodes conduct on each half cycle of the 3.58-mc reinserted subcarrier signal applied to the plate, pin 9, and the cathode, pin 8 of V_2. On the positive half cycle the 7 - 9 section of V_2 conducts; on the negative half cycle the 8-6 section of V_2 conducts. Each section of the tube conducts equal amounts of current that flow through R_4 and R_3. Since these resistors are of equal value they have equal voltage drops across them. The voltage at plate pin 6 is negative while the voltage at cathode pin 7 is positive. Thus the junction of R_3 and R_4 is at zero volts with no color signal applied to the demodulator. The output of the demodulator is taken from the junction of R_3 and R_4. This point is connected through L_3 to the grid of the B - Y amplifier, V_4.

When a color signal is applied to the B - Y demodulator, the conduction of each diode section depends on the phase and amplitude of the color signal. For example, if the signal at the cathode, pin 7, swings negative during the positive half cycle of the 3.58-mc reference signal on the plate, pin 9, the 7-9 section of the diode will conduct heavily. Since the color signal at plate pin 6 is 180° out-of-phase, it will swing
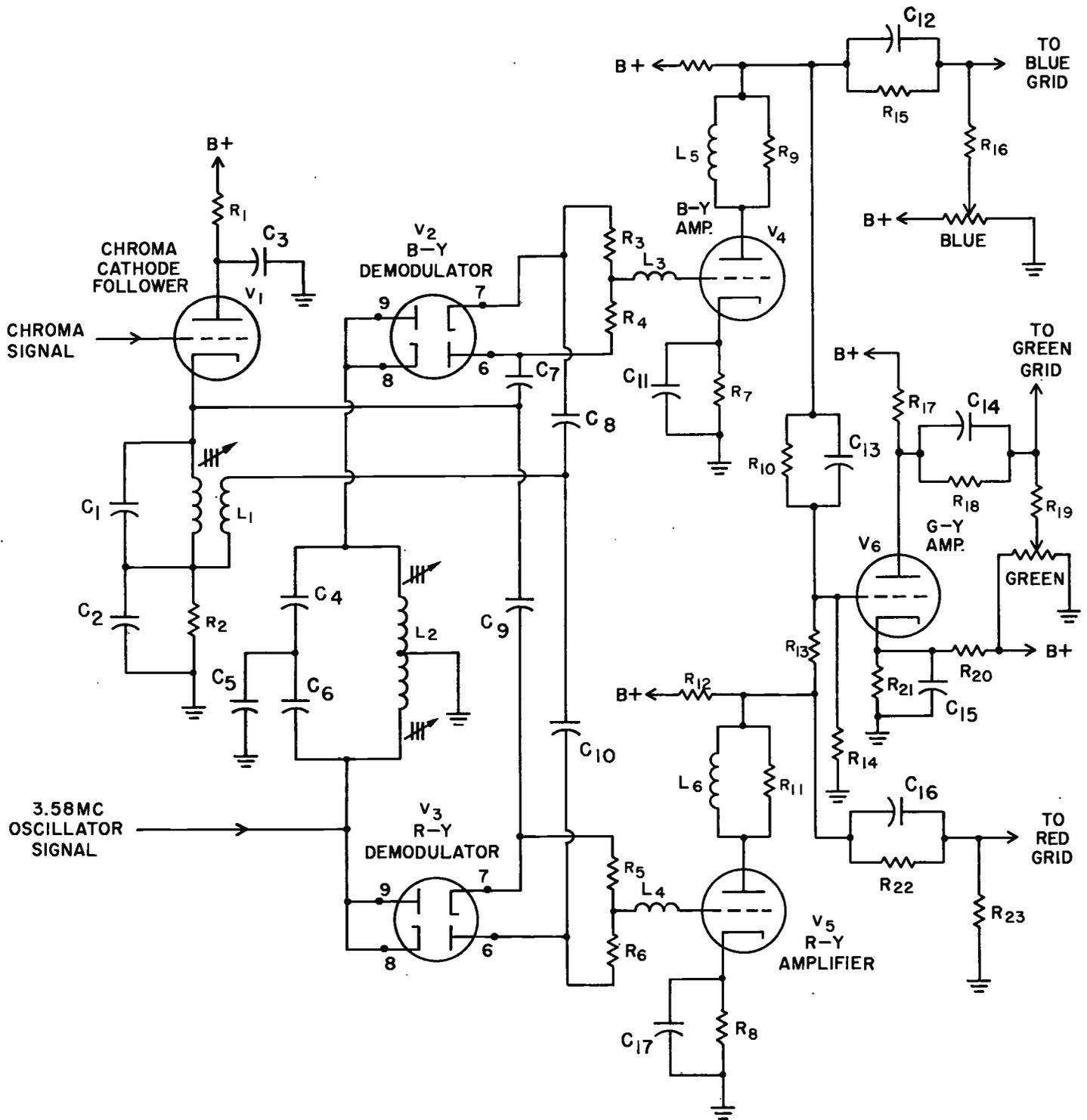
Fig. 14. Color difference demodulator circuit using diodes.

positive, but the cathode, pin 8, will also be positive so this section will conduct very little or none at all. During the next half cycle, when the negative half cycle of the 3.58-mc reference signal swings the cathode, pin 8, of V_2 negative, the plate, pin 6, will also be negative so again this section does not conduct. Therefore the conduction of the 8-6 section of V_2 will decrease. Under these signal conditions, the average conduction of the 7-9 section of V_2 will increase and

the average conduction of the 8-6 section of V_2 will decrease. This unbalanced diode conduction will produce a positive potential at the junction of R_3 and R_4.

If the phase of the color signal shifts $180°$, the 7-9 section of V_2 will decrease conduction and the 8-6 section will increase conduction. This will produce a negative color difference signal at the junction of R_3 and R_4.
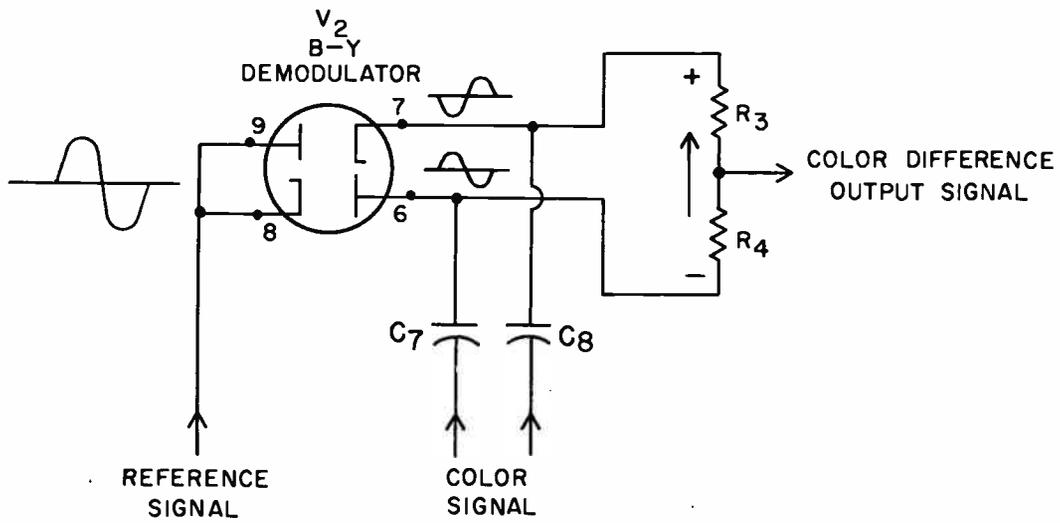
Fig. 15. Operation of diode demodulator under various signal conditions.

Fig. 15 illustrates the operation of the B - Y diode demodulator under different color signal conditions. As previously explained, both diode sections conduct equal amounts with only the reference signal applied to the circuit. On the positive half cycle, plate pin 9 is driven positive so the 7-9 section conducts; on the negative half cycle cathode pin 8 is driven negative so the 8-6 section conducts. Thus the average current for the two diode sections is equal. When the 8-6 section conducts, capacitor C_7 is charged with a negative potential. When the 7-9 section conducts, capacitor C_8 is charged with a positive potential. The diode current flows from plate pin 6 through R_4 and R_3 to cathode pin 7. The potential developed at plate pin 6 is negative while the potential at cathode pin 7 is positive. Since R_3 and R_4 are equal value resistors the potential at the junction of R_3 and R_4 is zero. Therefore the color difference output signal is zero when no signal is applied to the demodulator. Also, the color difference signals will be zero anytime the average conduction of the two diode sections is equal.

Column A in Fig. 15 shows the operation of the demodulator when a color signal that is in phase with the B - Y axis is applied to the demodulator. The color signal to the 7-9 section of V_2 swings negative during the half cycle that the reference signal is swinging positive. Thus plate pin 9 is driven positive and cathode pin 7 is driven negative so the 7-9 section of V_2 conducts heavily. During this first half cycle, the 8-6 section does not conduct because the cathode pin 8 is driven positive by the reference signal. During the second half cycle, the 7-9 section does not conduct because plate pin 9 is driven negative by the reference signal. Cathode pin 8 is driven negative by the reference signal, but at the same time plate pin 6 is driven negative by the color signal. Therefore the 8-6 section of V_2 does not conduct during the second half cycle. The average conduction of the 7-9 section of V_2 is greater than the 8-6 section so the output color difference signal is positive. The amplitude of this positive color difference signal varies with the amplitude of the color signal.

Column B in Fig. 15 illustrates the operation of the demodulator when a color signal in the - (B - Y) axis is applied to the demodulator. The color signal is 180° out-of-phase with the signal shown in column A. As shown in column B, the color signal to cathode pin 7 is positive when the reference signal to plate pin 9 is positive. Therefore the 7-9 section does not conduct. During the second half cycle, the color signal is positive to plate pin 6 while the reference signal is negative to cathode pin 8. Therefore the 8-6 section conducts heavily and the color difference signal is negative at the junction of R_3 and R_4.

Column C in Fig. 15 illustrates the circuit operation when the color signal lags the reference signal by 90°. From the color vector diagram (Fig. 13) you can see that a color signal 90° from the B - Y axis lies on the R - Y axis. Therefore the signal should not produce any output from the B - Y demodulator. As shown in column C, the color signal to cathode pin 7 is negative for part of the first half cycle of the positive reference signal to plate pin 9. Therefore the 7-9 section will conduct a small amount during the first half cycle of the reference signal. During the second half cycle of the reference signal, plate pin 6 is driven positive by the color signal for a portion of the time that cathode pin 8 is driven negative by the reference signal. Therefore the 8-6 section will conduct a small amount during the second half cycle of the reference signal. Under these conditions the average conduction of the 7-9 section equals the average conduction of the 8-6 section and the color difference signal at the junction of R_3 and R_4 is zero. Thus the B - Y demodulator does not produce an output when the color signal is in the R - Y axis.

Column D in Fig. 15 illustrates the circuit operation when the color signal leads the B - Y axis by 45°. During the first half cycle of the reference signal, cathode pin 7 is driven negative for a small portion of the time that plate pin 9 is driven positive. Therefore the 7-9 section conducts a small amount during the first half cycle of the reference signal. During the second half cycle of the reference signal, plate pin 6 is driven positive by the color signal during most of the time that cathode pin 8 is driven negative by the reference signal. Therefore the 8-6 section conducts heavily during the second half cycle of the reference signal. The average conduction of the 8-6 section greatly exceeds the average conduction of the 7-9 section so the color difference signal at the junction of R_3 and R_4 is negative.

An examination of the operation of the demodulator in Fig. 15 shows that the amplitude and polarity of the color difference signal varies with the amplitude and phase of the color signal. The demodulator produces a color difference signal that may be either positive or negative. Color signals in phase with the B - Y axis produce a positive color difference signal while color signals that are 180° out-of-phase produce a negative color difference signal. The negative color difference signal corresponds to the - (B - Y) axis. Color signals that are 90° out-of-phase (either leading or lagging) with the B - Y axis produce zero color difference signals. Color signals at some angles between in phase and 90° out-of-phase produce positive color difference signals. The amplitude of the positive color difference signal increases when the color signal is more nearly in phase with the B - Y axis. Color signals that are at some angle between 90° and 180° out-of-phase produce negative color difference signals. The amplitude of the negative color difference signal increases when the color signal is more nearly 180° out-of-phase with the B - Y axis (or in phase with the - (B - Y) axis). In this way the twin diode B - Y demodulator responds to the phase and amplitude of the received color signal to produce the B - Y color difference signal.

The R - Y demodulation in Fig. 14 is accomplished in the twin diode, V_3. This demodulator operates in the same manner as the B - Y demodulator except that the 3.58-mc reference signal is displaced 90° from the reference signal fed to the B - Y demodulator. The phase of the reference signal to the R - Y demodulator causes the circuit to demodulate on the R - Y axis producing an R - Y color difference signal.

G-Y Matrix.

In Fig. 14, the G - Y signal is recovered by combining portions of the R - Y and B - Y color difference signals. The B - Y color difference signal is available in the plate circuit of the B - Y amplifier, V_4. The R - Y color difference signal is available in the plate circuit of the R - Y amplifier, V_5. Resistors R_{10} and R_{14} form a voltage divider circuit across which the B - Y color difference signal is divided. Ths size of the resistors are selected so the proper proportion of the B - Y signal is developed across R_{14} and applied to the grid of V_6, the G - Y amplifier. Likewise the voltage divider network made up of R_{13} and R_{14} apply a portion of the R - Y signal to the grid of V_6.

You will recall that the color difference signal G - Y can be made up by combining a portion of the blue and red color difference signals. The formula for the G - Y color difference signal is:

$$G - Y = -0.51 (R - Y) - 0.19 (B - Y)$$

The proper fractional proportions of the two signals are obtained by selecting the size of R_{10} and R_{13} in Fig. 14. The signals in the plate circuits are positive values of the color difference signals. That is, they are + (B - Y) and + (R - Y). Therefore the circuit performs the following:

$$- (G - Y) = 0.19 (B - Y) + 0.51 (R - Y)$$

Or we can say that a negative G - Y color difference signal is applied to the grid of the G - Y color difference amplifier. The stage inverts the signal and produces an amplified + (G - Y) color difference signal at the plate. This signal is then applied to the grid of the green gun of the picture tube.

Another circuit using double diode color difference demodulators is shown in Fig. 16. This is the schematic diagram of the detector circuit shown in block diagram form in Fig. 3.

First, let's consider only the color demodulators made up of the diodes D_1, D_2 and D_3, D_4. The signal from the 3.58-mc oscillator is shifted to the - (R - Y) axes by the network consisting of C_7, L_4 and R_5 and fed to the junction of C_5 and C_6. This signal is fed through these capacitors to the diodes D_1 and D_2. The signal from the color i-f amplifier is fed from the primary L_1 of the bandpass transformer, T_1, to the secondary, L_2, and applied to diodes, D_1 and D_2. These diodes operate exactly the same way as the vacuum-tube diodes shown in the circuit of Fig. 14 except that the output from the detector would be a - (R - Y) signal. This is the same as negative R - Y signal. However, notice that the -Y signal is also fed to the junction of L_2, the secondary of the bandpass transformer, T_1. This signal is fed through the two halves of the secondary windings and R_1 and R_2 to the diodes, D_1 and D_2. The -Y signal effectively swings the voltage applied to these diodes in accordance with the am-
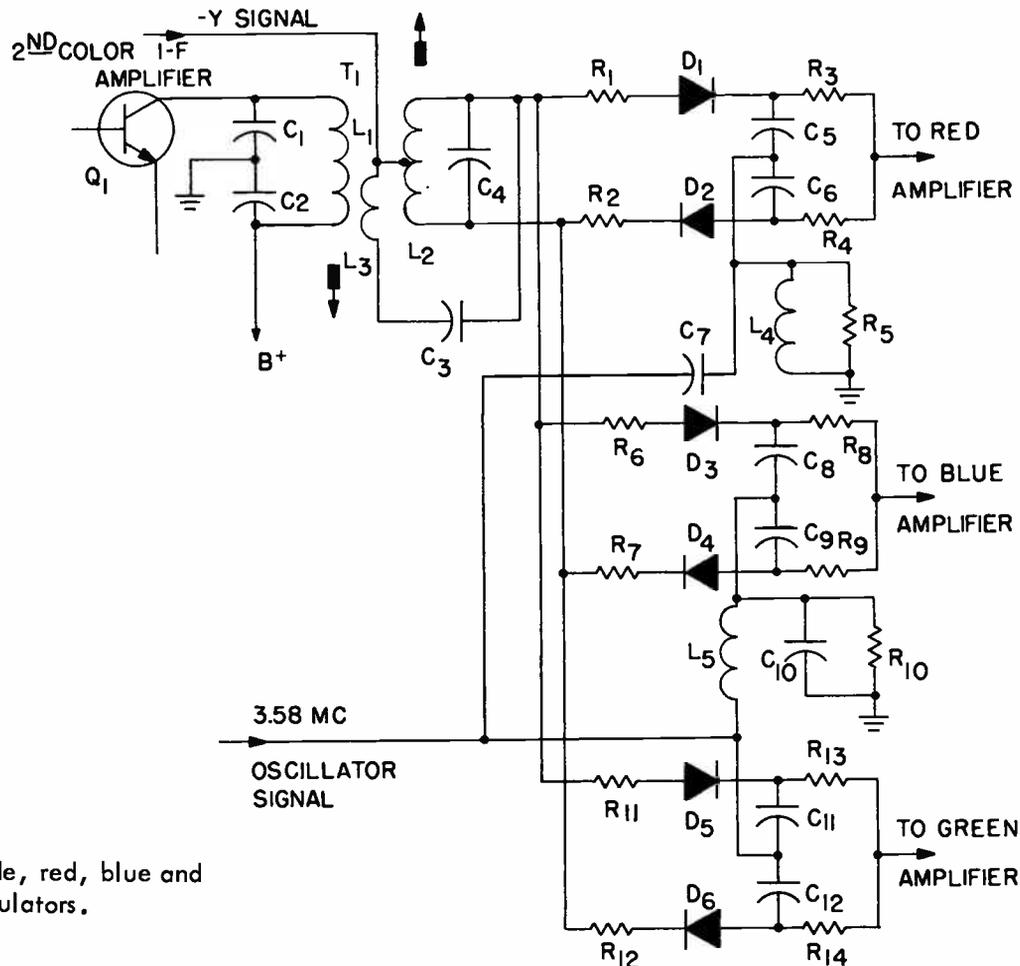
Fig. 16. Double diode, red, blue and green demodulators.
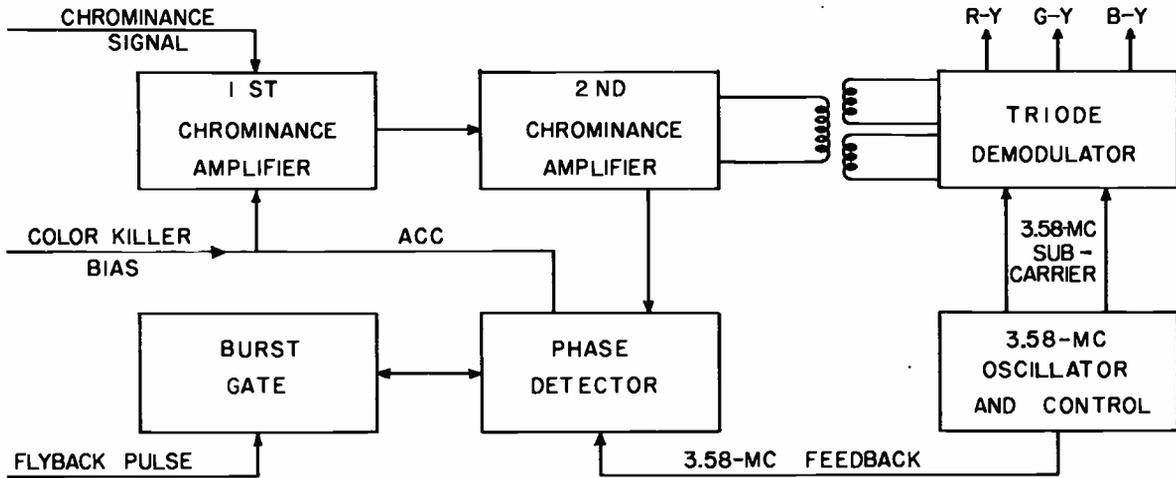
Fig. 17. Block diagram of the circuits associated with the triode demodulator.

plitude of the Y signal. The net effect is that we matrix the -Y signal with the - (R - Y) signal detected by these diodes so that in the output we have the negative red or -R signal. This signal is then fed to an amplifier which amplifies the red color signal. A -R signal is simply an R or red signal that has been inverted.

The signal from the oscillator is also shifted by the phase shift network consisting of L_5, C_{10} and R_{10} and fed to the junction of C_8 and C_9. The oscillator signal fed to this detector is shifted to the -(B - Y) axis and so the detector acts as a - (B- Y) detector. The color signal from L_2 is fed to the diodes, D_3 and D_4, through the resistors, R_6 and R_7. The -Y signal is also fed to the detectors so they matrix the -Y signal with the - (B - Y) signal and consequently in the output we have the negative blue or -B signal.

The output from the oscillator is also fed to a - (G - Y) detector consisting of D_5 and D_6. Since the color signal and the -Y signal are also fed to these diodes the - (G - Y) detector will matrix the - (G - Y) signal with the -Y signal and produce a negative green or -G output signal.

Insofar as the operation of this circuit is concerned, it is exactly the same as the circuit shown in Fig. 14 with the extra detector added. This explains how the color difference signals are produced. Then the addition of the Y signal to the detector circuits enables them to matrix the Y signal with the color difference output signals to produce the three color signals.

TRIODE R-Y, B-Y DEMODULATOR

The color signal can be demodulated by the use of a pair of triode stages. Like other demodulators, they can be adjusted to demodulate on any two desired axes by setting the phase of the reinserted subcarrier signal. The dual triode demodulator presented in this section demodulates on the R - Y, B - Y axis. The G - Y signal is recovered directly from the demodulator circuit. This type of demodulator is also called a high-level demodulator because no color difference amplifiers follow the demodulators. The color difference signals out of the demodulators are large enough to drive the grids of the picture tube directly.

Fig. 17 shows, in block diagram form, the circuits associated with this type of demodulator. Notice that two stages of amplification are used before the chrominance signal is applied to the dual triode tube. You'll find this arrangement in many receivers, particularly older color sets. This additional amplification was necessary to provide sufficient driving power to the demodulator. However, in many late model receivers using very high gain frame grid tubes, you'll find only one chrominance amplifier. These tubes have such a high gain that it is possible to get sufficient signal to drive the demodulators with the single stage.

A simplified diagram of one of the triode sections of the demodulator is shown in Fig. 18. Notice that the locally generated 3.58-mc subcarrier signal is inserted between the cathode and the grid of the tube and that the chrominance signal is inductively coupled into the plate circuit. The operation of this circuit is much like a conventional multi-grid demodulator circuit because the two signals are mixed, or heterodyned, (one in the grid circuit and one in the plate circuit) to produce the difference signal in the output. A filter circuit between the transformer winding and the grid of the color picture tube removes the locally generated 3.58-mc signal and the color subcarrier from the chrominance signal.

The complete circuit diagram of the dual triode
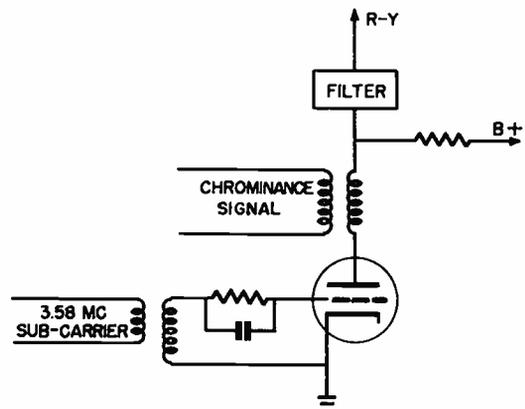
Fig. 18. Simplified diagram of one section of the triode demodulator.
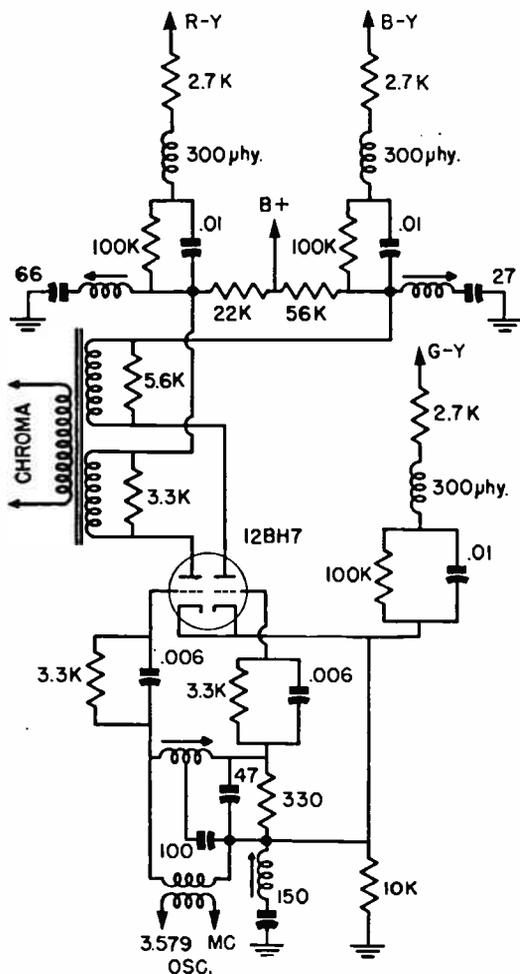
Fig. 19. Complete circuit diagram of the dual-triode demodulator.

demodulator is shown in Fig. 19. The dual-secondary transformer in the plate circuits feeds chrominance signals to the plates of the tube. The transformer in the grid circuits feeds the locally generated subcarrier signals to the grids. An inductance-capacitance network in the grid circuit shifts the phase of the subcarrier signal to the grids of the two triodes. The inductance is adjustable so the subcarrier can be reinserted at the proper phase to demodulate on the B - Y and R - Y axis. The chrominance signal on the plate and the subcarrier signal on the grid are mixed and detected by the tube, producing the color difference signal in the plate circuit.

The signal amplitudes required to reproduce the primary color signal in the color picture tube are not equal, so there must be a variation in the turns-ratio of the two secondary windings of the chrominance transformer and in the values of the two plate load resistors. When the phase and amplitude of the subcarrier signal on the grids and the values of the plate loads and transformer windings are correct, the red and blue color difference signals can be demodulated. The turns-ratio of the transformer also corrects for the unequal attenuation of the color difference signal before transmission.

The circuit in Fig. 19 simplifies the color receiver circuits by eliminating the additional stage necessary

to form the G - Y signal. The green matrixing action is performed directly in the cathode circuit of the tube. The cathodes are connected together and because the total cathode current is determined by the R - Y and B - Y signals, the green color difference signal appears directly at the output of the cathodes. Consequently, the dual triode demodulator performs both demodulation and matrixing.

The common cathode resistor, in Fig. 19, that develops the G - Y signal, introduces this signal into the B - Y and R - Y outputs. In effect, the G - Y signal on the common cathode resistor becomes a part of the grid-to-cathode signal to the triode demodulators. This fact must be taken into consideration in the operation of the circuit. The reinserted subcarrier signals are shifted away from the R - Y and B - Y axis to correct for the effect of the signal across the common cathode resistor. Instead of operating the demodulators in quadrature, the phase angle between the reinserted subcarriers is set at $63.58°$. With this setting, the signal on the cathode resistor just cancels the error caused by operating the demodulator away from the desired demodulation axis. A pure B - Y signal appears in the plate circuit of the B - Y demodulator; a pure R - Y signal appears in the plate circuit of the R - Y demodulator; and a pure G - Y signal appears across the common cathode resistor.

No dc restorer circuits are needed between the demodulator and the picture tube circuits because dc coupling is used throughout the circuit. The three color difference signals are applied directly to the grids of the picture tube, and the brightness signal is dc coupled to the cathode. The Y signal and the color difference signal add inside the picture tube to produce a full color picture.

Another demodulator system that works in the R - Y and B - Y axes is shown in Fig. 20. In this circuit the color signal from the bandpass amplifier is fed to the cathodes of the two color demodulators, V_1 and V_3. The 3.58-mc crystal oscillator signal has been shifted to the R - Y axis and then fed through R_2 to the grid of V_1, the R - Y demodulator. The two signals are mixed in the tube and the resulting output will be the R - Y signal. The demodulated R - Y signal is then fed through L_3 and then through the parallel combination of R_9 and C_7 to the grid of the red gun of the picture tube.

The demodulated R - Y signal is also fed through the peaking coil, L_3, to the voltage divider network consisting of R_5 and R_7. The value of these two resistors is selected so that the correct portion of the R - Y signal is available at the junction of R_5 and R_7 to feed it on through C_5 to the grid of V_2 to produce the G - Y signal.

The signal from the 3.58-mc crystal oscillator is shifted $90°$ by the phase shifting network consisting of L_7, C_{10} and R_{17}. The shifted signal is then fed through R_{15} to the grid of V_3, the B - Y demodulator. The color signal is also fed to the cathode of V_3 and so this demodulator demodulates the color signal on the B - Y axis producing a demodulated B - Y signal at the output. The demodulated B - Y signal is fed through L_4, R_{13} and C_9 to the grid of the blue gun of
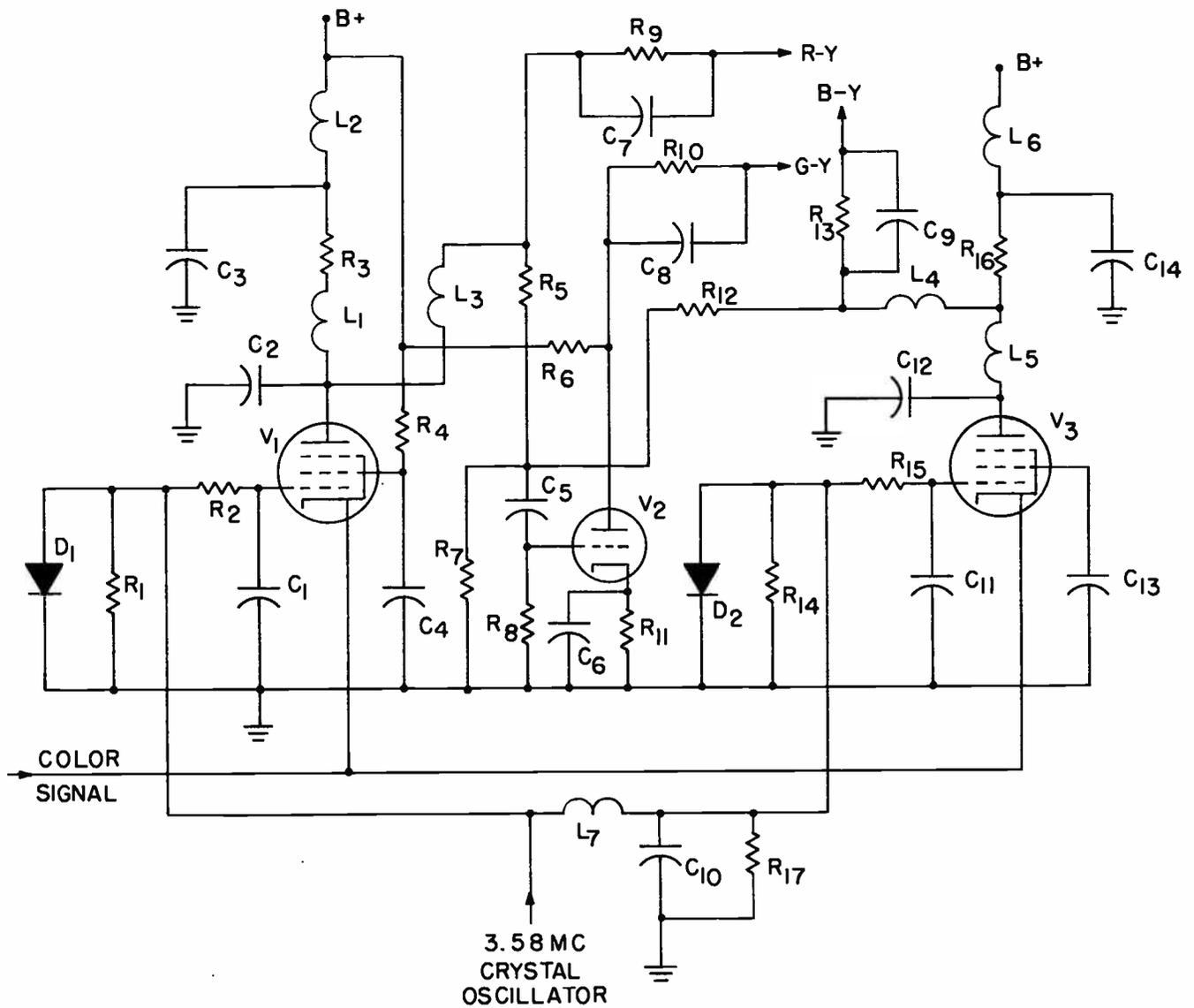
Fig. 20. Circuit diagram of R-Y, B-Y demodulator.

the picture tube. The signal is also fed through L_4 and R_{12} to the junction of R_7 and R_5. Actually R_{12} and R_7 act as a voltage divider network dividing the B - Y signal so that it will mix with the R - Y signal fed through C_5 to the grid of V_2 producing a - (G - Y) signal.

The - (G - Y) signal is amplified by V_2 and inverted in phase so that at the output we have a G - Y signal. This signal is fed through the parallel combination of C_8 and R_{10} to the green gun of the picture tube. Actually the operation of the demodulator is quite similar to the demodulator shown in Fig. 19. In both cases the color signal is actually injected into the plate circuit of the tube. In one case, Fig. 19, the color transformer secondary is actually in the plate circuit of the color demodulator. In Fig. 20, the secondary of the transformer is in a cathode circuit of the color demodulator. Exactly the same effect is produced by injecting the signal in the cathode circuits as in the plate circuits. The color reference is fed into the grid of the demodulators in each case. In the circuit shown in Fig. 20, a separate tube is required to produce the G - Y signal, whereas this signal can be obtained di-

rectly from the cathode circuit of the demodulator in Fig. 19.

The diodes, D_1 and D_2, are used to limit the amplitude of the oscillator signal. As long as the positive peak of the oscillator signal does not exceed the amplitude of the positive bias voltage on the cathode of the tubes, the diodes will not conduct. However, if the oscillator signal voltage does exceed the bias voltage, the diodes will conduct and limit the oscillator signal voltage.

R-Y, G-Y DEMODULATOR

Another type of color difference demodulator that has been used in color receivers is the R - Y, G - Y demodulator shown in block form in Fig. 21. This is a high level demodulator because the R - Y and G - Y outputs from the demodulators are applied directly to the grids of the color tube. A separate B - Y stage amplifies the B - Y signal before it is applied to the blue gun of the picture tube.

As shown in Fig. 21A, the demodulators are not
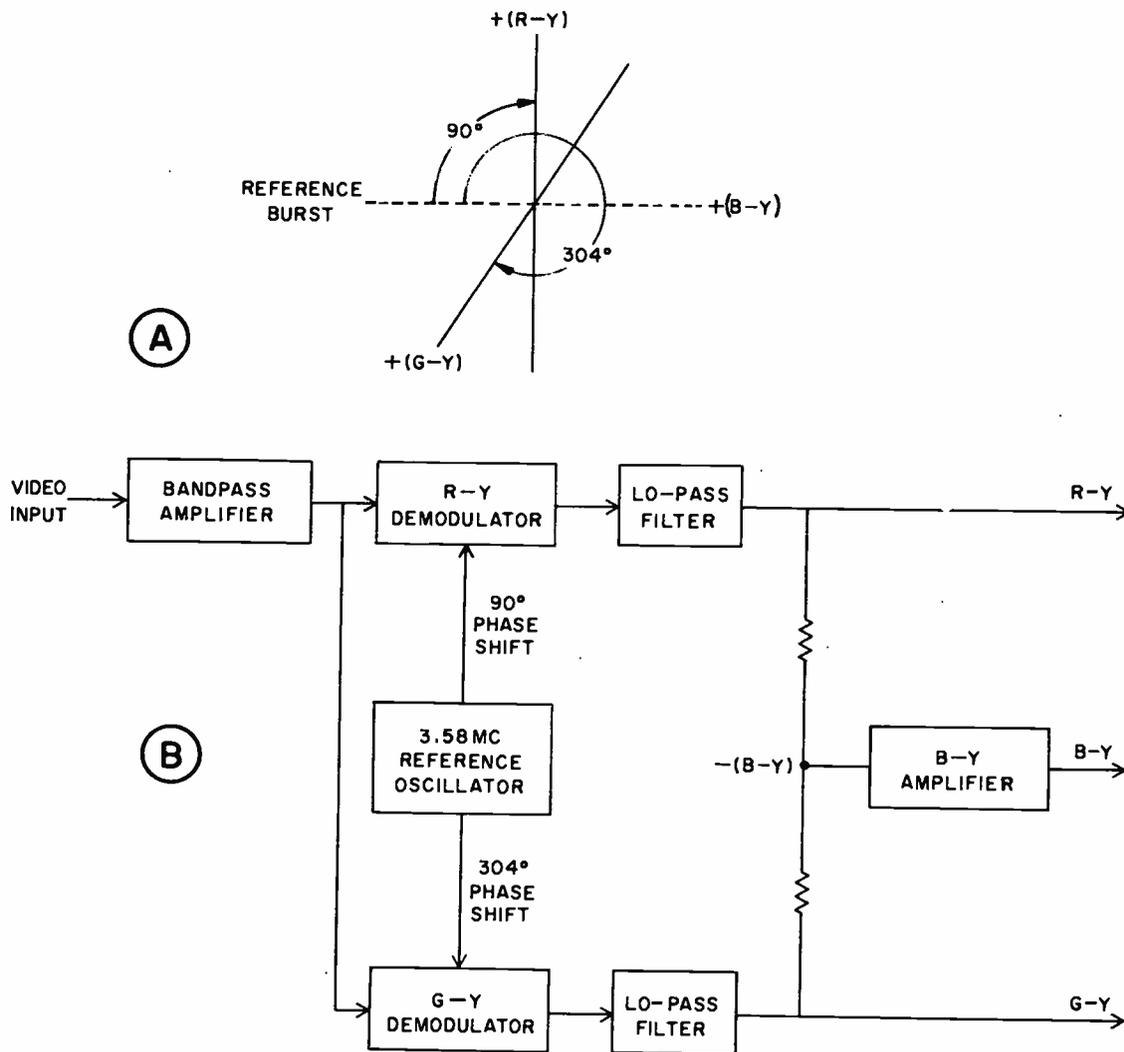
Fig. 21. The axes of demodulation are shown at (A) for the B-Y, G-Y demodulator shown in block form at (B).

operated in quadrature. The R - Y demodulator operates on the R - Y axis which is 90° from the reference burst while the G - Y demodulator operates on the G - Y axis which is 304° from the reference burst. As shown in Fig. 21B, one output from the 3.58-mc reference oscillator is shifted 90° and then applied as the reinsertion subcarrier to the R - Y demodulator. Another output from the 3.58-mc reference oscillator is phase shifted 304° and applied as the reinsertion subcarrier to the G - Y demodulator.

Portions of the R - Y and G - Y signals are combined in a network to produce a - (B - Y) signal. This signal is inverted and amplified by the B - Y amplifier stage to produce the B - Y difference signal that is applied to the grid of the blue gun of the color tube.

The amplitude of the R - Y and G - Y color difference signals are controlled by the amplitude of the chrominance signals applied to the demodulators. As shown in the basic circuit of the R - Y, G - Y demodulator in Fig. 22, the chroma input to the G - Y demodulator is taken from a tap on the chroma transformer secondary. This sets the correct relative amplitude of the R - Y and G - Y color difference signal. You will recall that the B - Y color difference signal was attenuated most at the transmitter to prevent

over-modulation. Therefore, the B - Y signal will have to receive the greatest amplification at the receiver to re-establish the proper relative amplitudes
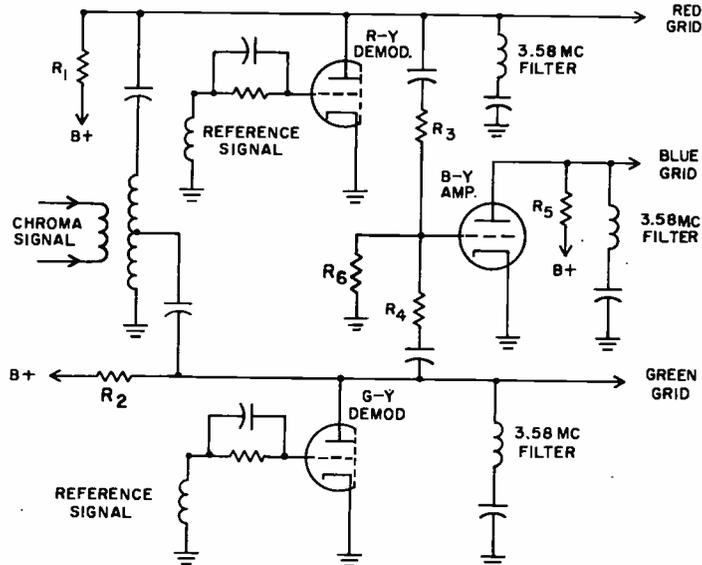
Fig. 22. Basic circuit of R-Y, G-Y demodulator using two triodes.
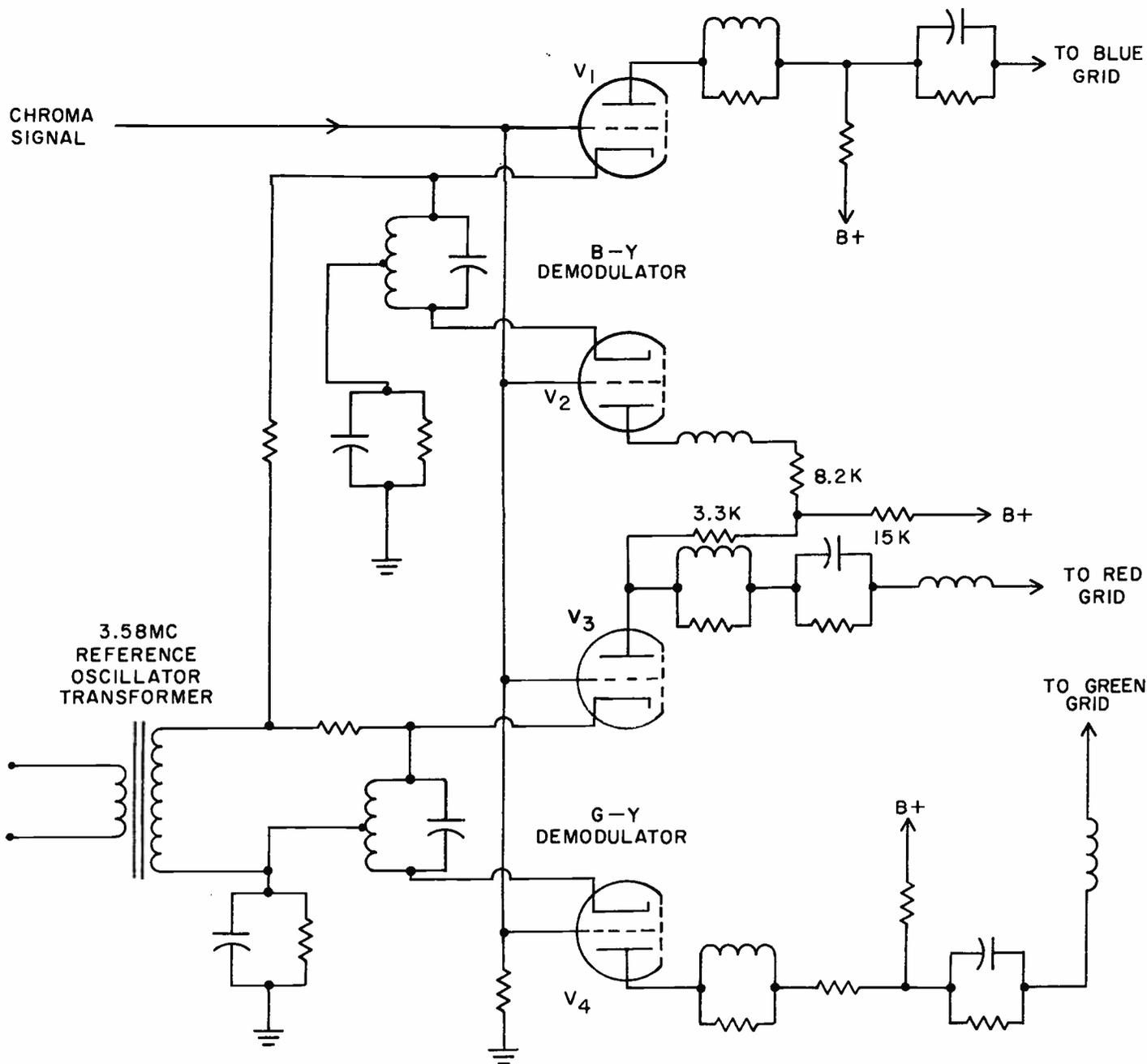
Fig. 23. Simplified schematic of a B-Y, G-Y triode demodulator.

of the three color difference signals. This is accomplished by the separate B - Y amplifier.

The - (B - Y) signal is recovered from the R - Y and G - Y signal by taking .273 (R - Y) + .536 (G - Y); this will give the signal + .03R + .059G - .089B. When this signal is amplified by 10 by the B - Y amplifier and inverted, we have - .30R - .59G + .89B which is the B - Y signal. Thus the matrix circuit combines the correct proportions of the + (R - Y) and + (G - Y) to produce a - (B - Y) signal. The B - Y amplifier inverts this signal and amplifies it to the correct relative level to produce a B - Y color difference signal that can be applied to the grid of the blue gun of the color tube.

The arrangement of the above demodulator has certain advantages. The R - Y and G - Y signals require less amplification than the B - Y signal. Therefore

the demodulators can be operated at a lower level than would be the case if the B - Y signal were demodulated. The receiver that this circuit was taken from uses only a single stage chroma amplifier to get a signal large enough to drive the demodulators.

B-Y, G-Y DEMODULATOR

An interesting variation of a high-level triode demodulator is shown in Fig. 23. This circuit demodulates on the B - Y and G - Y axis. A matrix circuit combines the outputs to produce the R - Y color difference signal. All three color difference signals are produced by the demodulators and no color difference amplifiers are used. The color signals and the reinserted subcarrier are applied to the grid-to-cathode circuit of each tube. Therefore the demodulator stages

provide signal amplification as well as demodulation of the color signals.

In Fig. 23, triodes V_1 and V_2 make up the B - Y demodulator while triodes V_3 and V_4 make up the G - Y demodulator. A chroma signal from the bandpass amplifier is fed to the control grids of all four triodes. The 3.58-mc reference oscillator signal is fed through a transformer and phase shift networks to the cathode of all four triodes. The 3.58-mc reference signal to the cathode of V_1 is shifted in phase so V_1 demodulates on the B - Y axis and a + (B - Y) color difference signal appears at the plate of V_1. The plate signal is dc coupled to the grid of the blue gun of the picture tube.

The 3.58-mc reference signal to the cathode of V_2 is 180° out-of-phase with the reference signal to V_1. Therefore V_2 produces a - (B - Y) color difference signal in the plate circuit. This - (B - Y) color difference signal is combined with a - (G - Y) color difference signal from the plate circuit of V_3 to produce a + (R - Y) color difference signal that is fed to the grid of the red gun of the picture tube. To see how the signals are combined, examine the plate circuits of V_2 and V_3. A 15K-ohm resistor acts as a common plate load resistor for both V_2 and V_3. The 8.2K-ohm resistor in the plate circuit of V_2 and the 3.3K-ohm resistor in the plate circuit of V_3 proportions the correct amount of the two signals that appear at the output.

V_4 in Fig. 23 demodulates the chroma signal on the G - Y axis. The 3.58-mc reference signal to V_4 is 180° out-of-phase with the reference signal to V_3 so V_4 demodulates on the + (G - Y) axis. The G - Y signal developed in the plate circuit is dc coupled through suitable peaking and filter circuits to the grid of the green gun of the picture tube.

TWIN PENTODE DEMODULATOR

The demodulator circuit illustrated in Fig. 24 uses a twin pentode vacuum tube to perform several functions of the demodulation process. The 15LE8 twin pentode has two plates, a common cathode, two grids that are common to both sections and one separate grid for each section. The circuit takes advantage of the operating features of the tube to demodulate the color signal, operate a 3.58-mc oscillator, and to matrix and amplify the color difference signals. Let's examine each function of the circuit separately to see how it works.

The 3.58-mc oscillator is a Hartley type oscillator. Cathode current flows through the tapped section of coil L913. Capacitor C912 and L913 in parallel form a tuned tank circuit that is resonant at 3.58 mc. A signal is coupled from the top of L913 through C911 to control grid pin 9 of the tube. A 3.58-mc reference signal is also applied to grid pin 9. This reference signal is produced in a ringing circuit in another section of the receiver. The ringing circuit is shock-excited by the received burst signal. Therefore the reference signal from the ringing circuit is synchronized with the burst signal and the reference signal

can be used to establish the correct phase of the oscillator.

The hue control is also located in the synchronizing circuit and it adjusts the phase of the reference signal. The main function of this oscillator circuit is to provide the stage with a constant amplitude 3.58-mc reference signal. The exact phase of the oscillator signal is controlled by the reference signal. Thus the oscillator signal causes the tube to conduct pulses of cathode current at the 3.58-mc rate.

Most color demodulator circuits shift the phase of the reference signal to one of the demodulators to demodulate the color signal on two different axes. The circuit in Fig. 24 uses the same reference signal to both demodulators and shifts the phase of the color signals to set the angular difference between the two demodulation axes. Notice that two color signals are taken off from the secondary circuit of the color i-f transformer. One signal is coupled through R908 to grid pin 2 of the R - Y demodulator section of the tube. The other color signal is coupled through C908 to grid pin 7 of the B - Y demodulator section of the tube. The R-C network (R908 and C909) in the grid, pin 2, circuit produces a lagging phase shift to the color signal applied to the R - Y demodulator grid. The L-C network (L904 and C908) in the grid, pin 7, circuit produces a leading phase shift to the color signal applied to the B - Y demodulator grid. The resultant difference in phase of the color signals to the two demodulators provides the correct separation of the two demodulation axes.

The B - Y section of the demodulator stage produces an amplified B - Y color difference signal in the plate pin 6 circuit. With a 3.58-mc reference signal on grid pin 9, and a phase shifted color signal on grid pin 7, the B - Y section of the stage operates as a synchronous detector. The color difference signal in the plate circuit is filtered by C915 and L905 to remove the 3.58-mc signal. (C915 and L905 form a series resonant circuit.) The B - Y color difference signal is dc coupled through a peaking coil and R-C network to the blue control grid of the color picture tube.

The R - Y section of the demodulator stage produces an amplified color difference signal in the plate, pin 1, circuit. This section works like the B - Y section except that the phase shifted color signal on the grid causes the demodulator to demodulate on the R - Y axis. C917 and L907 form a 3.58-mc series resonant circuit and bypass the 3.58 mc at the plate of the tube. Thus the red grid of the color picture tube is supplied an amplified R - Y color difference signal.

A G - Y color difference signal is developed on the screen grid of the demodulator tube in Fig. 24. To see how this takes place we must examine the internal operation of the tube. Since the screen grid pin 8 is common to both sections of the twin pentode, the screen will collect electrons from the tube current to both plates. The amount of screen current at any one instant depends on the signal on the separate grids. For example, a positive going signal on grid pin 7 will accelerate the electrons so only a few will be captured by the screen grid. On the other hand, a negative-
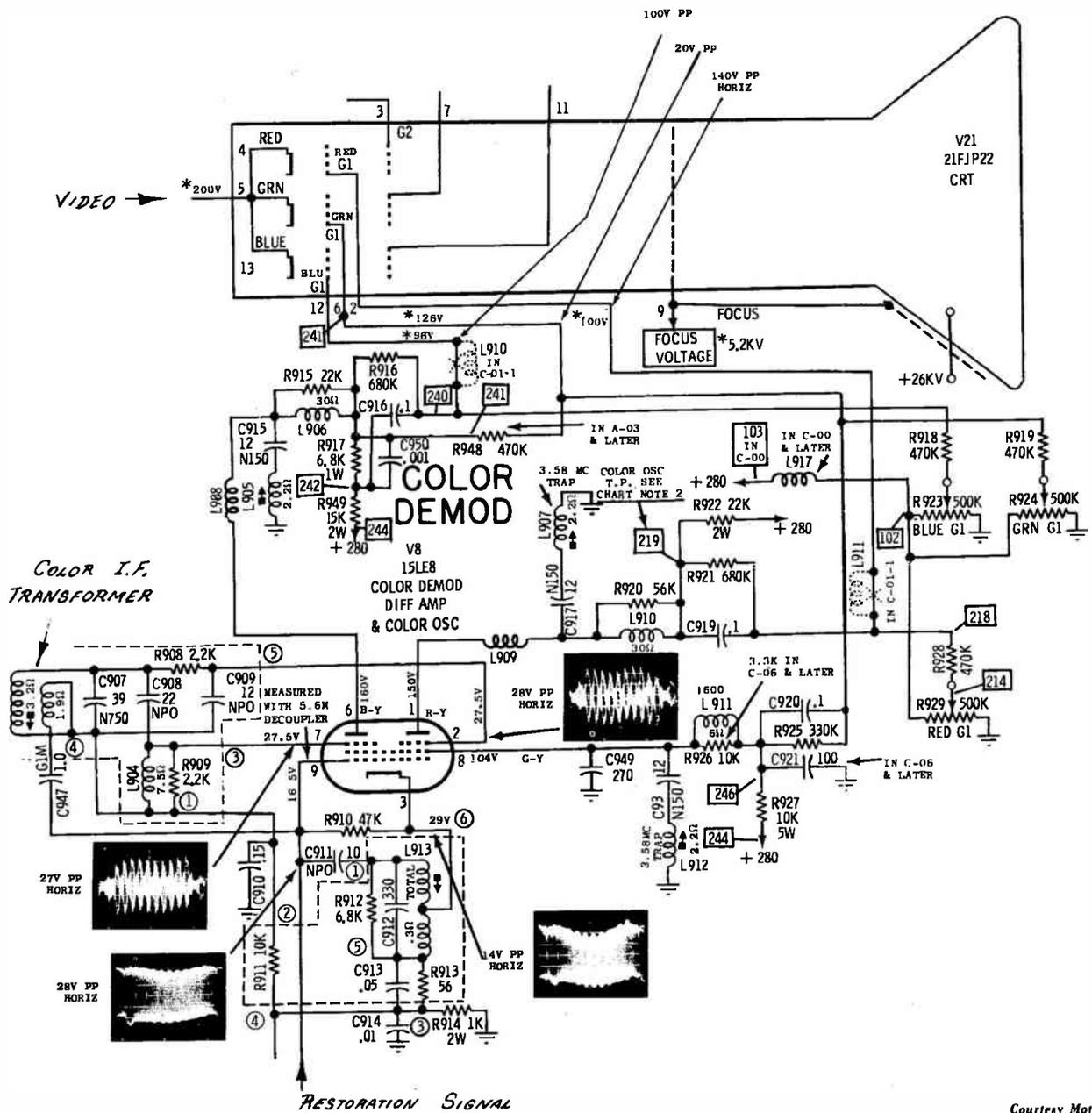
Fig. 24. Color difference demodulator used in a Motorola color TV receiver.

going signal on grid pin 7 will slow down the electrons so the screen grid will be able to attract more of them. The color signal on the grid pin 2 will affect the screen current in the same manner. In effect, the signal developed on the screen grid will depend on the color signals to both the R – Y and the B – Y sections of the tube. Thus the tube matrixes a – (B – Y) and a – (R – Y) component of the color difference signals to produce a G – Y color difference signal on the screen grid. The signal is filtered by the series-resonant circuit made up of L912 and C93 and applied to the green grid of the color picture tube.

An adjustable bias potentiometer is located in each control grid circuit of the color picture tube. These bias controls are labeled red G1, blue G1, and green G1 in Fig. 24. These controls are used to set the proper operating bias for each of the three guns of the tube. Notice the relative peak-to-peak amplitude of the sig-

nal voltages applied to the three grids; 140 volts for the red grid, 100 volts for the blue grid, and 20 volts for the green grid. These values are determined by the relative efficiency of the color phosphors on the picture tube. The bias setting and the different signal amplitudes result in each color phosphor emitting the correct amount of light to produce a balanced color picture. The design of the demodulator takes advantage of the different signal amplitude requirements. Therefore the G – Y signal which is the smallest signal required by the picture tube, is produced on the screen grid of the demodulator where it receives the least amplification. The relative amplitude of the R – Y and B – Y signals is adjusted by the component values in the demodulator plate circuits.

As we pointed out earlier, improvements are continually being made in phosphor efficiencies, particularly in improving the red phosphor. If you have to in-
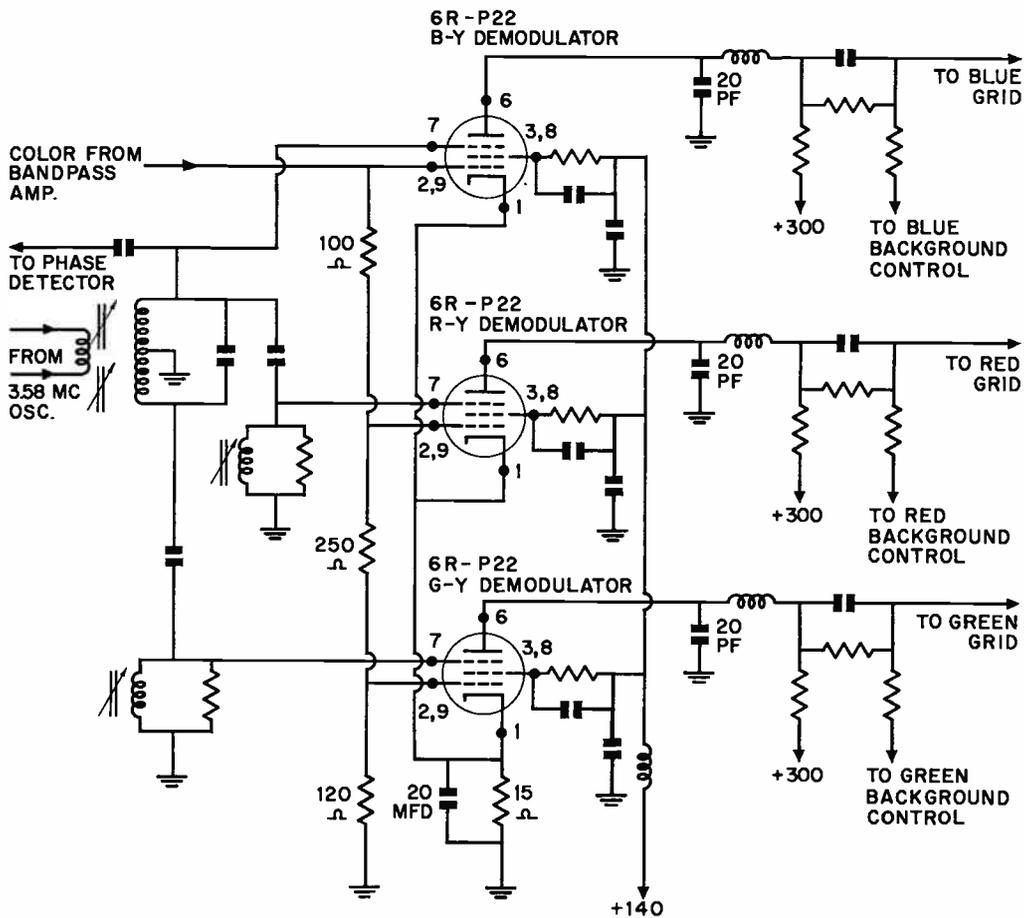
Fig. 25. Demodulator section of Sears 16-inch imported color TV.

stall a replacement tube in one of the sets, it's quite possible that the required bias settings of the different guns will be quite different from those shown. The exact settings will depend on the relative efficiencies of the three phosphors in the replacement picture tube.

HIGH-LEVEL B-Y, R-Y, G-Y DEMODULATOR

The schematic diagram in Fig. 25 shows the demodulator section of an imported 16 inch color TV receiver. In this circuit, three demodulator stages perform high-level demodulation on the three color difference axes. All three color difference signals are recovered by the demodulators without the use of matrixing circuits. The recovered color difference signals are filtered and applied directly to the grids of the picture tube without going through color difference amplifiers. Each demodulator stage uses a pentode vacuum tube with the tube type designation 6R-P22.

The 3.58-mc reinsertion signal is supplied to the demodulator suppressor grids. Each demodulator stage is supplied a reinsertion signal of the proper phase to demodulate on that color difference axis. The 3.58-mc reinsertion signal for the B - Y demodulator is taken from one end of the center tapped secondary of the 3.58-mc oscillator transformer. A tunable inductance in the suppressor grid circuit of the R - Y demodulator is used to set the correct phase of the

reinsertion signal to this demodulator. Likewise, a similar tunable inductance is used to adjust the phase of the reinsertion signal to the G - Y demodulator.

The chroma signal from the bandpass amplifier is applied to the control grids of all three demodulators. A voltage divider in the grid circuits proportions the relative amount of chroma signal applied to each demodulator. From the resistor network in Fig. 25, you can see that the B - Y demodulator receives the full chroma signal. The control grid of the R - Y demodulator is connected to the junction of the 100-ohm and the 250-ohm resistor in the network. Therefore the R - Y demodulator receives a smaller chroma signal than the B - Y demodulator.

The control grid of the G - Y demodulator is connected to the junction of the 250-ohm and the 120-ohm resistor in the network. Thus the G - Y demodulator receives the smallest chroma signal. The size of the chroma signal to each demodulator is selected to re-establish the correct relative amplitudes of the demodulated color difference signals. The cathodes of the demodulator stages are tied to a common cathode resistor. This will insure identical bias on all three demodulators. This cathode resistor is well bypassed so no signals appear across it and each demodulator stage operates independently.

The pentode demodulators operate as synchronous detectors and produce color difference signals in their plate circuits. The 3.58-mc reference signals on the suppressor grid switches the tube current from

the plate to the screen grid. Thus plate current flows on positive peaks of the reference signal and the plate is cut off for the remainder of the reference signal, cycle. The amount of tube current depends on the phase and amplitude of the color signal on the control grid during each current pulse. Therefore the stage demodulates the color signal in the axis determined by the phase of the reference signal to the suppressor grid.

The amplified color difference signals in the plate circuits are filtered and coupled to the grids of the color picture tube. The pentode demodulator stages amplify the color difference signals in addition to performing the demodulation. All three stages have identical filter circuits that remove the 3.58-mc component from the color difference signals. The filter circuits pass a range of color difference frequencies from 0 to about 500 kc. The color difference signals are dc coupled to the grids of the picture tubes so that no dc restoration circuits are needed.

"X" AND "Z" DEMODULATOR

More color receivers with "X" and "Z" demodulators have been marketed than receivers with any other demodulator type. The "X" and "Z" demodulator system was developed so that the demodulator stages and the color difference amplifiers could be made into uniform circuits. This arrangement has many advantages. The circuits are simple to adjust and tend to remain stable over long periods of time. The system takes full advantage of the different amplitude requirements of the three color difference signals. Also, it makes it possible to use a simple means of restoring the dc level of the color signals.

The axes of demodulation in the X and Z demodulators were selected to meet the matrixing requirements of the circuit. As often pointed out, demodulators can be made to operate on any desired axis. The demodulated signal can then be combined in the proper proportions (matrixed) to produce the color difference
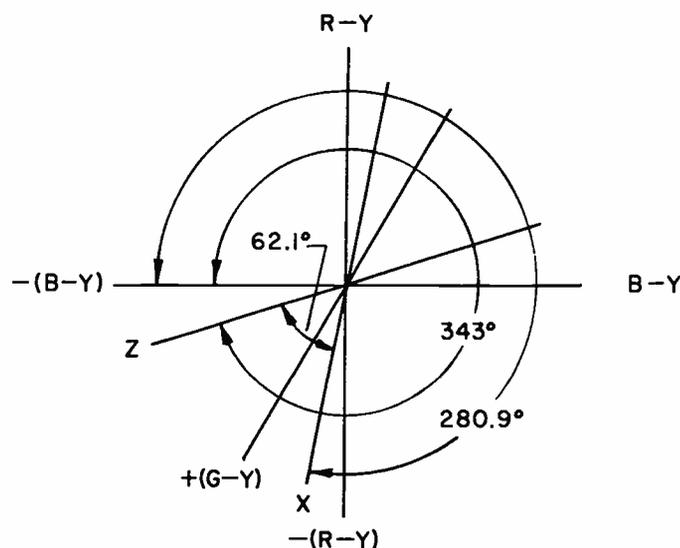
Fig. 26. Location of the "X" and "Z" axes in relation to the color difference axes.

signals that are required to properly drive the color picture tube. Fig. 26 shows the location of the X and Z axes in relation to the color difference axes. Since the X axis lies between the - (R - Y) axis and the + (G - Y) axis, the X demodulator output contains components of both of these signals. The Z axis lies between the - (B - Y) and the + (G - Y) axis so the Z demodulator output contains components of these two signals.

Notice that the X and Z axes are not in quadrature but are displaced by 62.1°. The exact angle between the axes is selected to meet the matrixing features of the adder-amplifier circuits.

The arrangement of the adder-amplifier circuits for the X and Z demodulators is shown in simplified form in Fig. 27. The output of the X demodulator is fed to the grid of the R - Y amplifier while the output of the Z demodulator is fed to the grid of the B - Y amplifier. Since the signals to these two grids are not color
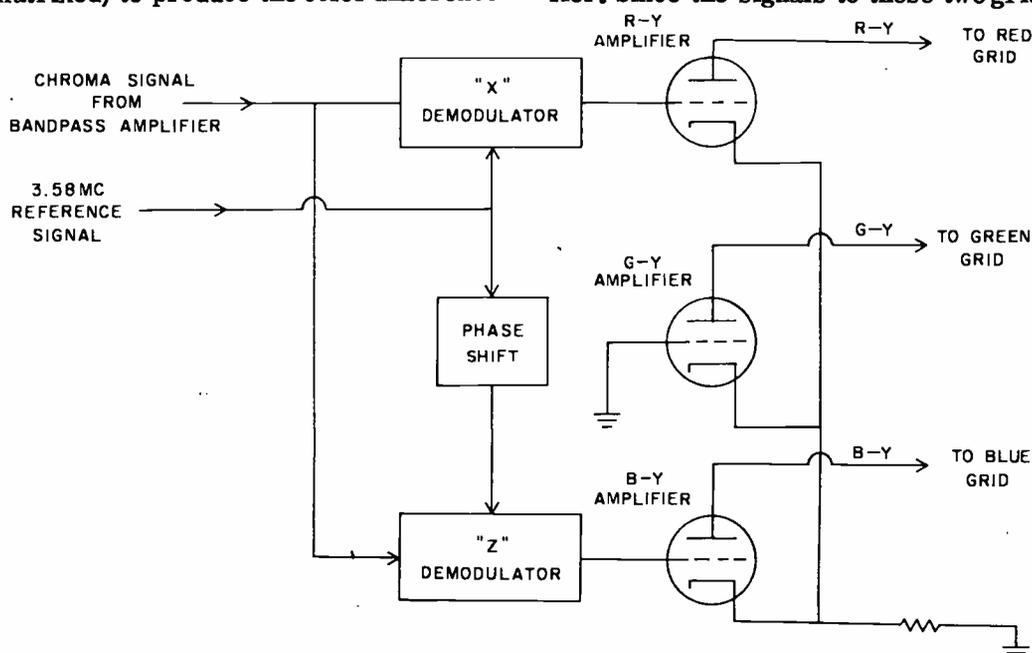
Fig. 27. The "X" and "Z" demodulator outputs are fed to color difference amplifiers that form an adder circuit.

difference signals, additional signals must be added in the amplifiers to produce color difference signals in the plate circuits. Notice that the cathodes of all three amplifier stages are returned to ground through a common, unbypassed cathode resistor. The demodulation axes were selected so that a + (G – Y) signal is developed across the common cathode resistor. This + (G – Y) signal is a combination of components from the outputs of the X and Z demodulators. Also from Fig. 26 you can see that the + (G – Y) signal can be expressed by components of the -(B – Y) and the -(R – Y) axes. Or we can say that the +(G – Y) signal contains - (R – Y) and - (B – Y) signal components.

The + (G – Y) signal across the common cathode resistor subtracts from the X signal applied to the R – Y amplifier. The size of the signal is just sufficient to cancel the - (B – Y) component that is present in the X signal so the resultant inverted signal at the plate is a + (R – Y) signal. Likewise, the + (G – Y) signal on the common cathode resistor subtracts from the Z signal applied to the B – Y amplifier so a B – Y signal is developed in the plate circuit.

The G – Y amplifier amplifies the signal that is across the common cathode resistor. The grid of the G – Y amplifier is grounded so the tube is driven by the + (G – Y) signal across the common cathode resistor. The cathode signal is not inverted by the stage so a + (G – Y) color difference signal is developed in the plate circuit.

Typical Circuit.

Fig. 28 is a schematic diagram of the X and Z demodulator circuit of a late model color TV receiver. The demodulator stages use 6GY6 pentodes while the color difference amplifiers use triodes. Notice that all three color difference amplifiers use identical components and therefore provide equal signal amplification. Any changes caused by component aging will tend to occur in equal amounts in all three stages. Therefore the changes will not upset color balance. The demodulator stages are also nearly identical. The relative amplitude of the demodulator outputs is set by the sizes of the unbypassed cathode resistors.

The 3.58-mc reinsertion subcarrier signal to the demodulator stages are taken from the 3.58-mc oscillator transformer, T703. One 3.58-mc signal is fed directly from the transformer secondary to the suppressor grid of V704. A phase shift network consisting of L703 and C728 shifts the phase of the 3.58-mc reference signal to the suppressor grid of V709. In this way the two demodulator stages are fed reference signals in the correct phase so that they demodulate on the X and Z axes.

The chroma signal from the bandpass transformer is developed across the color control potentiometer. The potentiometer slider picks off the desired amplitude color signal and couples it through a peaking coil, L111, to the control grids of V704 and V709. The demodulators operate as synchronous detectors and produce amplified X and Z signals in the demodulator plate circuits. The X signal is filtered and coupled through C731 to the grid of the R – Y amplifier. The Z signal is filtered and coupled through C726 to the grid of the B – Y amplifier. Both demodulator filters

are identical and pass signals having frequencies from zero to about 700 kc.

The G – Y signal is developed across resistor R728 which is common to all three cathodes of the color difference amplifier stages. As explained for the basic circuit, the G – Y signal subtracts from the X signal so an R – Y color difference signal is developed in the plate circuit of the R – Y amplifier. The G – Y signal subtracts from the Z signal producing a B – Y signal at the plate of the B – Y amplifier.

The G – Y amplifier responds to the G – Y signal across the common cathode resistor and produces a G – Y signal in the plate circuit. In the basic X and Z demodulator circuit the grid is grounded. The grid could be placed at signal ground (ac ground) by connecting it through a capacitor to B+. Observe the connections to the grid of the G – Y amplifier in Fig. 28. A .01 capacitor connects to a junction of R753 and R726. These resistors form a voltage divider network in the plate circuit of the R – Y amplifier. The voltage divider network supplies a very small part of the R – Y signal to the grid of the G – Y amplifier. The feedback arrangement corrects for a small error in the G – Y signal.

DC Restoration.

Coupling capacitors are used to couple the signal from the demodulators to the color difference amplifiers so the dc component of the color difference signals is lost. The proper dc level can be restored by referencing each line of color information to a fixed dc level. In the circuit in Fig. 28 this is accomplished by keyed dc restoration. At the end of each horizontal sweep, a large negative pulse is applied to the cathodes of the color difference amplifiers. All three stages conduct heavily and the plate voltages drop to a low level for the duration of the pulse. The negative pulse on the cathode makes the amplifier grid positive in respect to the cathode. The grid draws current and charges the grid coupling capacitor to a level determined by the amplitude of the keying pulse. Since the applied pulses are of uniform height, the capacitors are charged to the same value each time a pulse is applied. The signal voltage coupled to the grids simply adds-to and subtracts-from the fixed charge on the capacitor. The RC time constant of the grid circuit is long compared to the duration of one horizontal line. Therefore the dc component of the signal is not lost because the grid capacitor does not have time to discharge to the average level of the applied signal.

Direct coupling is used between the plates of the amplifiers and the grids of the picture tube. For example, resistor R751 in the plate circuit of the R – Y amplifier parallels coupling capacitor, C763. The high frequency components of the signal are coupled by the capacitor while the low frequency and dc signal components pass through the 100K-ohm resistor R751. Thus the reinserted dc level set by the keying pulses is maintained to the grids of the picture tube.

BEAM SWITCHING DEMODULATOR

Special beam-deflection tubes are used in the high-level demodulator circuit of Zenith color TV receivers.
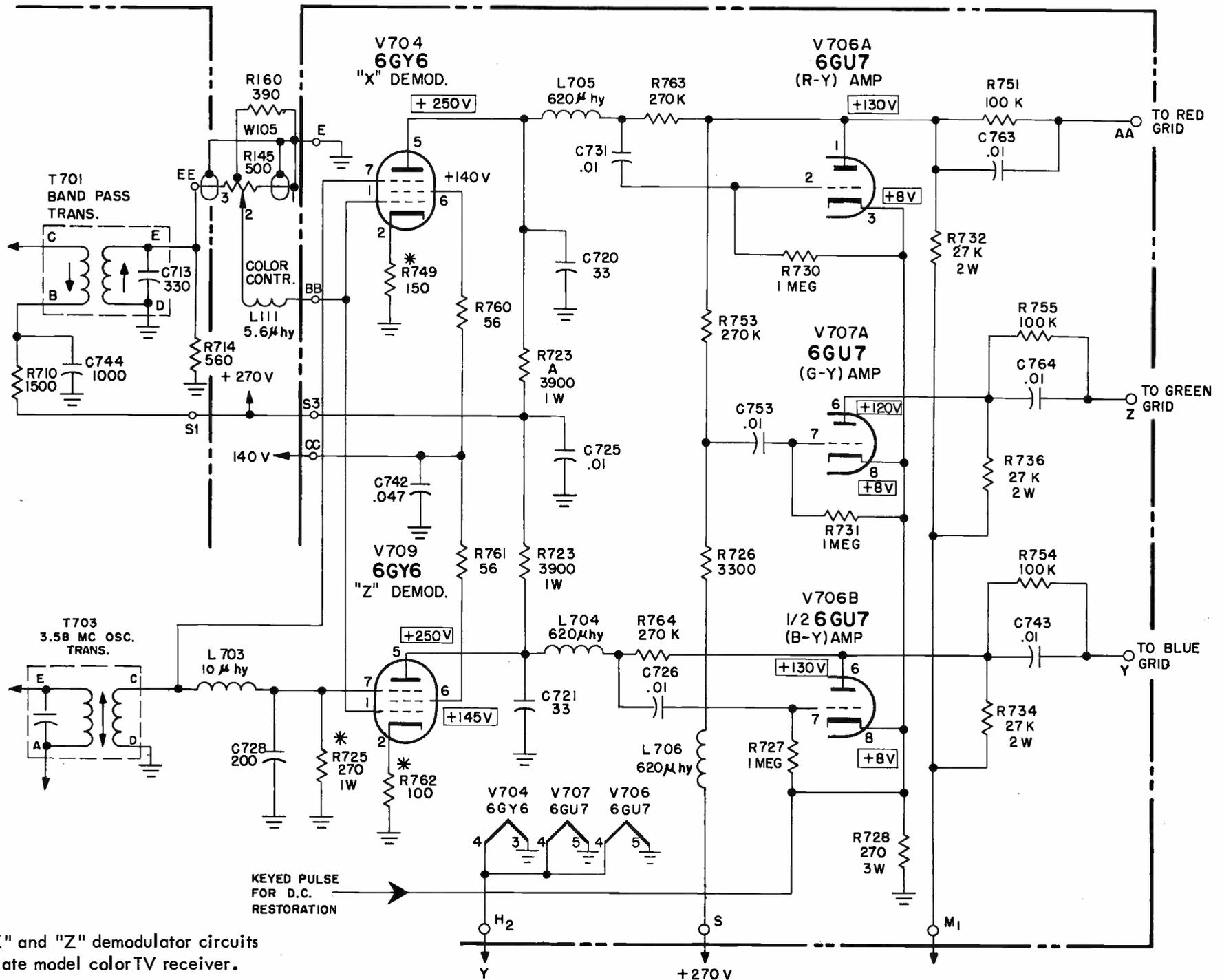
Fig. 28. "X" and "Z" demodulator circuits
used in a late model color TV receiver.

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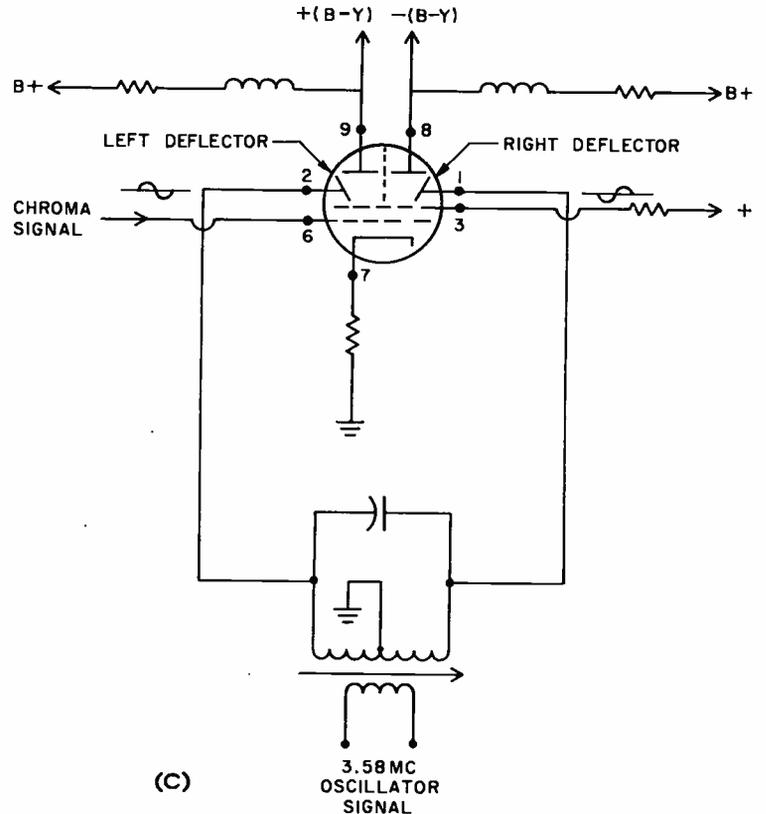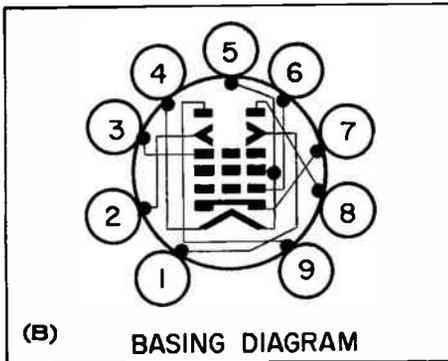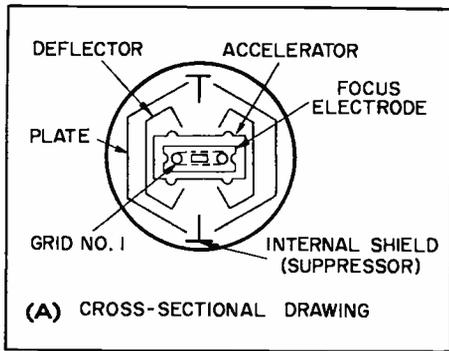
Fig. 29. Internal construction of beam switching tube (A), basing diagram (B), and basic beam switching demodulator circuit (C).

Fig. 29 shows the basic operation of a beam switching demodulator tube. The 6JH8 beam-deflection tube has a single cathode, a control grid, screen grid (accelerator electrode), two plates and two beam deflector elements. Except for the deflectors, the tube operates much like a pentode. The cathode current passes through the control grid and is accelerated toward the plates by a positive potential on the screen grid. The potential on the deflector determines to which plate the electrons will go. A positive potential on the deflector will attract the electrons toward its associated plate. Likewise, a negative potential on a deflector will repel the electrons away from its associated plate.

The deflectors are operated push-pull so that when the left deflector is positive, the right deflector is negative and the electrons go to the left plate. On the next half cycle, the right deflector is driven positive while the left deflector is driven negative and the tube current switches to the right plate.

Fig. 29A shows a cross section drawing of the internal construction of the tube. The tube basing diagram is shown in Fig. 29B. The indirectly heated cathode is located in the center of the tube. Grid No. 1, the control grid, surrounds the cathode. A focus electrode forms the tube current into a sheet beam of electrons. An acceleration electrode accelerates the sheet beam of electrons. This element is shown as the screen grid on the schematic diagram. The deflectors direct the beam to either of the tube plates. The internal shield suppresses any interchange of secondary emission between the two plates.

Fig. 29C illustrates the basic operation of the beam switching demodulator. A center tapped secondary winding on a 3.58-mc transformer applies a push-pull 3.58-mc reinsertion signal to the deflector plates. The chroma signal from the bandpass amplifier is applied to the control grid, pin 6. A cathode resistor sets the grid bias for the tube. A positive potential on the screen grid, pin 3, provides the acceleration potential. The two plate circuits are entirely separate and operate independently.

The circuit in Fig. 29C demodulates the color signal and produces a + (B - Y) color difference signal and a - (B - Y) color difference signal. The phase of the 3.58-mc reinsertion sine wave signal is such that the left deflector voltage is maximum positive in the - (B - Y) axis. The amount of current reaching the left plate, pin 9, during this time depends on the phase and amplitude of the color signal. Therefore the plate current is a sample of the color signal in the - (B - Y) axis. The tube inverts the signal because a decrease in plate current causes an increase in plate voltage. The plate current pulses are filtered and form a + (B - Y) color difference signal in the left plate circuit.

The reinsertion signal on the right deflector is 180° out-of-phase with the signal on the left deflector. Therefore, when the left deflector is positive, the right deflector is negative and no current reaches the right plate, pin 8. However, on the second half cycle, the polarities reverse and the tube current switches to the right plate. Since the + (B - Y) axis is 180° from the - (B - Y) axis, the right plate of the tube demodu-

lates the color signal in the + (B − Y) axis. The tube inverts the signal and produces a − (B − Y) color difference signal in the right plate, pin 8, circuit of the tube.

Fig. 30 shows a simplified schematic of the Zenith beam switching demodulator circuit. The 3.58-mc reinsertion signal is applied to the circuit through a quadrature transformer, T_{12}. The transformer has two center-tapped secondary windings. The tuned secondary windings are adjusted so that the reference signal to the B − Y demodulator lags the reference signal to the R − Y demodulator by 90°. In this way the reinsertion signal is phased so that the B − Y demodulator demodulates on the + (B − Y), − (B − Y) axis and the R − Y demodulator operates on the + (R − Y), − (R − Y) axis.

The chroma signal from the second color i-f amplifier, in Fig. 30, is fed to the grid of the B − Y detector through C_{72} and R_{114}. At the same time, the color signal is fed to L_{27} and part of the signal is taken from the tap on L_{27} and is fed to the control grid of the R − Y demodulator. This adjusts the relative amplitude of the color signal to the demodulators and brings the demodulated color difference signals up to the correct relative amplitudes.

The 3-volt positive horizontal pulse applied to capacitor C_{73} in the control grid circuit (Fig. 30) provides horizontal blanking for the picture tube. The positive pulse drives the demodulator grids positive during the horizontal retrace producing an amplified negative pulse in the demodulator plate circuits. These amplified negative pulses cut off the picture tube control grids and blank the picture tubes during horizontal retrace.

The + (B − Y) color difference signal in the left plate circuit of the B − Y demodulator is coupled to the blue grid of the color picture tube. The 3.58-mc series resonant circuit, consisting of C_{75} and L_{36}, removes
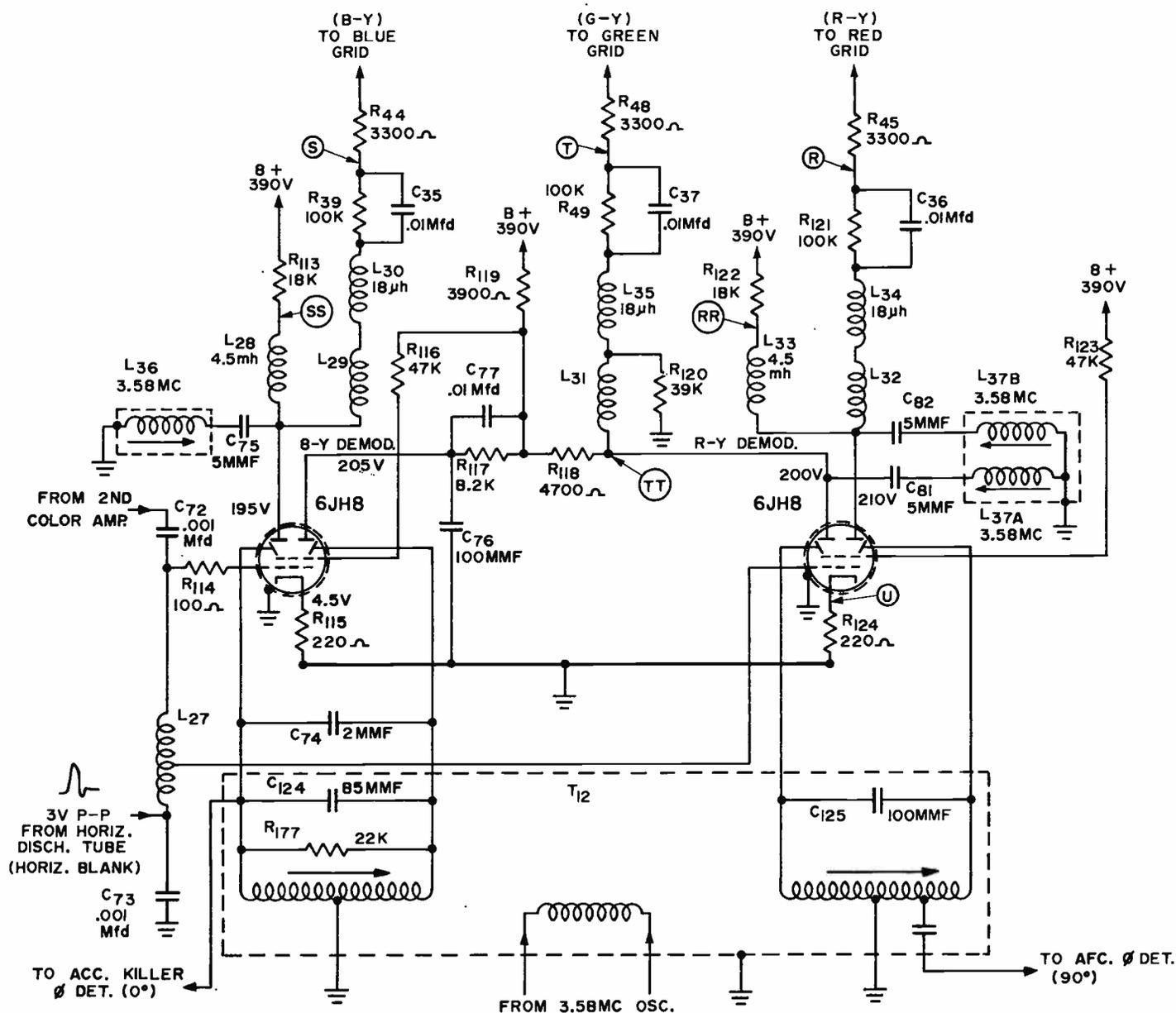
Fig. 30. Simplified circuit diagram of beam switching color demodulators.

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the 3.58-mc component from the B – Y color difference signal. Inductance L_{28} is a peaking coil to improve the high frequency response while L_{29} blocks the 3.58-mc components from reaching the picture tube. Inductance L_{30} is a peaking coil. Direct coupling is maintained from the demodulator output to the picture tube grid through R_{39}. Capacitor C_{35} provides ac coupling for the high frequency components of the signal.

The + (R – Y) color difference signal is developed in the right plate circuit of the R – Y demodulator. This circuit is identical to the left plate circuit of the B – Y demodulator. The R – Y color difference signal is applied to the red grid of the color picture tube.

G – Y Signal.

Portions of the – (B – Y) and – (R – Y) color difference signals are combined to produce the G – Y color difference signal. From Fig. 13 you can see that the + (G – Y) axis lies between the – (B – Y) and – (R – Y) axis. Therefore these two signals can be combined to produce the + (G – Y) color difference signal. The right plate of the B – Y demodulator and the left plate of the R – Y demodulator are returned to B+ through a common plate load resistor, R_{119}. Therefore, both negative color difference signals are present in the common circuit. The size of resistors R_{117} and R_{118} are selected to provide the correct proportions of the two signals. The resultant signal is filtered and applied to the grid of the green gun of the color picture tube.

SELF-TEST QUESTIONS

(j) What is the phase difference between the re-inserted subcarrier signal to the B – Y and R – Y demodulators in Fig. 14?

(k) In the circuit in Fig. 14 where is the G – Y color difference signal recovered?

(l) Why are the turns-ratios for the secondary windings different on the two secondary windings of the chroma transformer in Fig. 19?

(m) In the demodulators in Fig. 19, why are the demodulation axes shifted away from the color difference axes?

(n) Why aren't the demodulators in Fig. 22 operated in quadrature?

(o) How is the required amplification of the color difference signal attained in high-level demodulator systems?

(p) How is the 3.58-mc oscillator in Fig. 24 synchronized?

(q) What is the function of the red G1, blue G1, and green G1 controls in Fig. 24?

(r) In the demodulator circuit in Fig. 25, how are the correct relative amplitudes of the color difference signals re-established?

(s) What is the phase relation of the 3.58-mc re-insertion signals to the beam switching demodulators?

(t) Between what elements of the tube does the beam switching take place in the beam-deflection tube?

Color Amplifiers

The demodulated color signals produced by low-level demodulators and the matrix section of a color receiver must be amplified to a level that will drive the grids of the color picture tube. The amplitude of the signal applied to the picture tube is determined by the characteristics of the picture tube. Some picture tube types require larger color drive signals than others. Also, the relative amplitude of the three grid signals to the picture tube varies with tube types. As previously explained, this has to do with the relative light emitting efficiency of the three phosphors used on the face of the tube. In general, the red phosphor requires the greatest amount of excitation, the blue requires less than the red, and the green less than either the blue or red. These relative efficiencies not only vary with tube types but can vary for individual tubes within a tube type. Also, the relative efficiencies may vary over the life of a tube. For these reasons you will find adjustable controls in the picture tube circuits. These controls may adjust the amplitude of the signals or the operating characteristics of the individual guns of the picture tube.

The kind of amplification placed in the circuit between the demodulators and the grids of the picture tube depends on the types of demodulators and the requirements of the picture tube. You've studied high-level demodulators that produce outputs large enough to drive the picture tube directly. These high-level demodulators often provide considerable amplification of the color difference signal as well as performing the demodulation function. Also high-level demodulators are often preceded by two chroma amplifier stages. Thus some of the required amplification is produced before the signals are demodulated.

Low-level demodulators always have amplifiers between the demodulators and the picture tube. These amplifiers are usually combined with a matrix circuit. They combine the correct proportions of the demodulated color signals to produce the color difference signals that drive the grids of the picture tube. The gain of the amplifiers are selected to correct for the unequal attenuation of the color difference signal that was necessary at the transmitter to prevent overmodulation of the transmitted signal. Where the demodulators provide some of the signal amplification, the requirements for unequal amplification may be met in the demodulator. Or part of the unequal amplification may be taken care of in the demodulators and part in the amplifiers.

The design of the demodulator and amplifier circuits are influenced by other factors. Component aging often causes loss of color balance that requires readjustment of the color section of the receiver. For example, when it is possible to use identical components for all three color difference amplifiers, the circuits are less sensitive to component aging. Likewise the circuit design is often influenced by the ease with which the dc component of the color signal can be restored. High-level demodulators are usually dc coupled and require no dc restoration. Direct coupled amplifier stages are often troubled with unequal drift problems. Therefore, some color receivers use keyed dc restoration. While the design features are of no great practical importance to the TV repair technician, some design information is helpful in understanding circuit variations.

COLOR AMPLIFIERS WITH MATRIX

Matrixing functions are often performed in the color amplifier sections of a color TV receiver. Two types of matrixing are involved. In some receivers, the outputs of the demodulators are matrixed to form the color difference signals. This may be done in the grid circuits, cathode circuits, or plate circuits of the color amplifiers. The other type of matrixing has the function of combining the brightness signal and the color difference signals. When these signals are combined in the amplifiers, the stages are often called adders.

You studied an example in which both types of matrixing are performed in adder circuits. Fig. 11 showed the matrix and output circuits of an I and Q demodulator. The I, Q, and Y signals are matrixed in the grid circuits of the three adder stages. The adders produce green, blue and red output signals that drive the grids of the three color output stages. Notice that ac coupling is used throughout the stages. Therefore dc restorers are necessary to reference the level of the color signals before they are applied to the grids of the color picture tube.

Two color controls in Fig. 11 adjust the relative amplitude of the color signals. A green gain control in the grid circuit of the green adder stage, V135A, adjusts the amplitude of the green color signal. Likewise, the blue gain control adjusts the amplitude of the blue signal. The red adder stage is operated at full gain. These gain controls are setup adjustments that are used to get the proper proportions of each color in the displayed picture. They are adjusted to produce white and all shades of gray when the receiver is operated at various contrast levels. In the receiver that this circuit was taken from, ganged controls are used in the contrast and chrominance circuits. Thus when contrast is changed, the amplitude of the chrominance signal to the bandpass amplifier is also changed. This tends to maintain a constant relationship between the amplitude of the I, Q, and Y signals into the matrix.

The color difference amplifiers in Fig. 14 illustrate matrixing of two color difference signals to produce the third color difference signal. Signals are taken from the plate circuits of the B - Y and R - Y amplifiers. Portions of these signals are combined (matrixed) in the grid circuit of the G - Y amplifier. Correct proportions of B - Y and R - Y signals combine to produce a - (G - Y) signal. The G - Y amplifier inverts and amplifies the signal producing a + (G - Y) color difference signal in the plate circuit.

Other circuits in this lesson show matrixing in the cathode circuit and in the plate circuits to produce the third color difference signal. The circuits in Fig. 11 and Fig. 16 are the only ones that combine the color signal with the Y signal before they are fed to the picture tube. In Fig. 11, the color signals are fed to the grids of the picture tube. In the circuit associated with Fig. 16, the color signals are fed to the cathode of the picture tube; you'll study the rest of this circuit in this section of the lesson.

When color difference signals are used to drive the grids of the picture tube, the brightness (Y) signal is applied to the cathode of the picture tube.

THE PICTURE TUBE AS A MATRIX

You recall that the red, green, and blue color signals are a combination of the color difference signals and the brightness signal. It was shown that at the transmitter the color difference signal could be produced by subtracting the Y signal from the color camera signals. First the output of the three color cameras were combined to produce the Y or brightness signal. This signal had to be transmitted so black-and-white receivers could produce pictures from a color transmission. The brightness signal was then subtracted from two color signals to produce color difference signals. This was done to keep at a minimum the amount of additional signals that had to be transmitted to produce full color pictures. At the receiver, these signals must be combined to reconstruct the red, blue, and green signals needed to control the three guns of the picture tube.

The color picture tube can be used to matrix the color difference signals with the brightness signal to recover the color signal. The brightness signal is applied to all three cathodes of the picture tube while each color difference signal is applied to its respective control grid. Each gun combines the signals to produce the color signal.

To better understand how the color tube itself can matrix the brightness signal and the color difference signals to produce the original color signal, let us review how the brightness signal was formed. Remember

Fig. 31. Video signal fed to the grid is shown at A, signal fed to the cathode is shown at B.

that the brightness or Y signal is made up as follows:

$$Y = .59G + .30R + .11B$$

From the formula for the brightness signal you can see that the brighter the individual colors or scene may be, the higher the amplitude of the Y signal. Actually, a fully illuminated white scene will provide a maximum amplitude Y signal.

In defining the Y signal we have been assuming that the color signals represent positive voltages. Therefore the maximum brightness signal must represent the maximum positive video signal.

Now let us review what kind of signal we have to feed to the grid and the cathode of the picture tube. If we feed the signal to the grid of the picture tube we want the sync pulses pointing in a negative direction as shown in Fig. 31A. This is to insure that the tube will be blanked at the blanking level and driven into the blacker than black region by the synchronizing pulses. The lowest amplitude negative voltage, or in other words the most positive part of the signal voltage represents the video signal producing the brightest scene. In the dark scene, we'll have a fairly high amplitude negative signal which limits the amplitude of the electron beam in the tube. If we feed the signal to the cathode of the picture tube then we want to drive the cathode in a positive direction with the synchronizing pulses. This is the same as driving the grid in a negative direction, it will cut off the tube. However, if the maximum positive signal excursion drives the cathode into the cut-off region, then the maximum excursion in the negative direction will represent the brightest scene. Therefore, in order to drive the cathode of the picture tube to produce the brightest scenes, we need a signal with the maximum negative amplitude, or in the case of a signal such as shown in Fig. 31B the signal has the least positive amplitude. This represents a -Y signal. Therefore the brightness signal that we feed to the cathode of the picture tube is actually a -Y signal.

In Fig. 32 we have shown what the R – Y signal that is fed to the grid of the picture tube and the -Y signal that is fed to the cathode of the picture tube look like for a number of different colors. In Fig. 32A we have shown the R – Y signal and in Fig. 32B, the -Y signal.

Let's see how we get the value of 70 for the R – Y signal when we're transmitting a red color. When the color is red, the amplitude of the Y signal will be:

$$Y = OG + .30R + OB$$

In other words, if we receive a signal with an amplitude of 100 volts for each camera, then the amplitude of the Y signal when we're transmitting a red color would be 30 volts. Therefore the amplitude of the R – Y signal would be 100 - 30 = 70 volts.

Now notice that the R – Y signal drives the grid of the CRT to 70 volts in a positive direction and the -Y signal drives the cathode 30 volts in a negative direction. Thus the total voltage between the grid and cathode of the picture tube is 100 volts as shown in Fig. 32C. Thus the tube matrixes the R – Y signals to produce a total difference voltage of 100 volts between
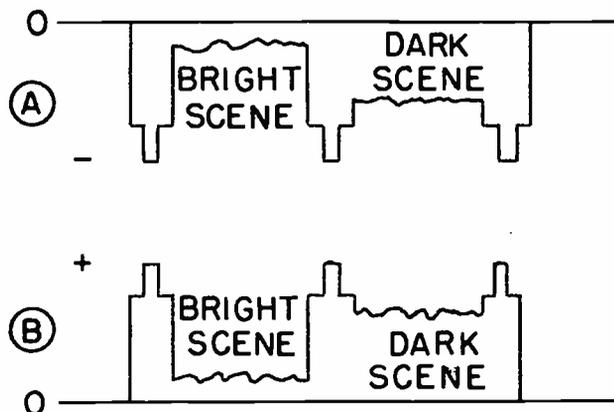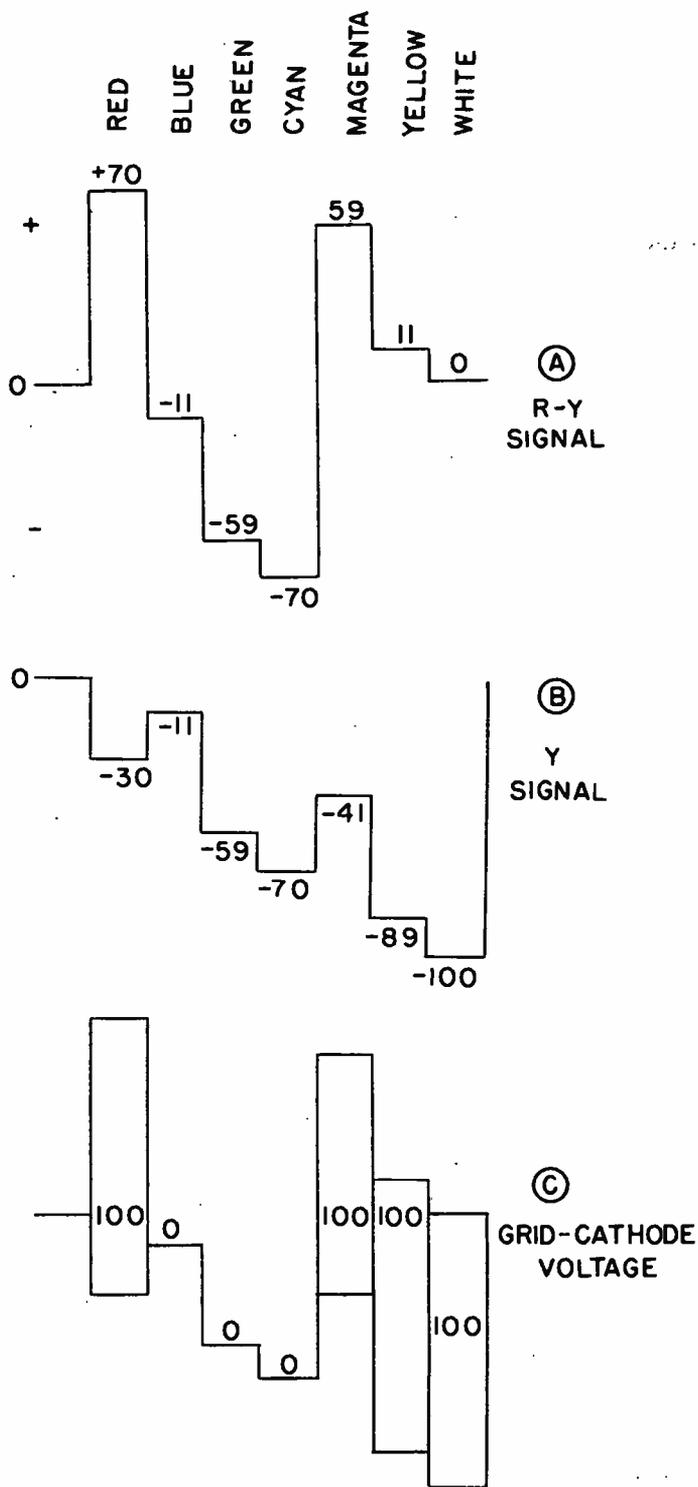
Fig. 32. R-Y and Y signals fed to the grid and cathode
of the red gun for various colors.

the grid and cathode and turns on the red gun at
maximum amplitude while the red is being transmitted.

Now let us look at Fig. 33 and see what signal is
fed to the blue gun when we are transmitting the color
red. As before, the Y signal will be equal to 30 volts
and therefore the -Y signal fed to the cathode will be
-30 volts. This is as it should be because if you will
remember the cathodes of the tri-color tube are tied
together and are all fed the same signal. Now, when
we are transmitting red, the output from the blue

camera is zero. Therefore the amplitude of the B - Y
signal will be 0 - 30 or - 30 volts. The B - Y signal
when we are transmitting red is shown in the first
bar in Fig. 33A and the -Y signal is shown in Fig. 33B.
The net difference in potential between the grid and
cathode is shown in Fig. 33C. Thus when red is being
transmitted the net difference in signal voltage between
the grid and cathode of the blue gun is zero.

Fig. 33. B-Y and Y signals fed to the grid and cathode
of the blue gun for various colors.

Fig. 34. G-Y and Y signals fed to the grid and cathode of the green gun for various colors.

age is 100 volts and we get maximum green output from the picture tube.

When we're transmitting colors that are made up of two or more of the primary colors we have two or more guns turned on so that we get light from each. For example, notice that when we are transmitting yellow, which is made up of red and green, that the red and green guns are turned on for maximum intensity. The R - Y signal which is fed to the grid of the red gun is 11 volts and the -Y signal fed to the cathode will be -89 volts so that the net grid-to-cathode voltage is 100 volts. At the same time, the G - Y signal fed to the grid of the green gun is 11 volts and we have -89 volts fed to the cathode so that the total grid-to-cathode voltage in this gun will be 100 volts and it will operate with maximum intensity. At the same time the B - Y signal fed to the grid of the blue gun is -89 volts. The -Y signal fed to the cathode of this gun is also -89 volts so that the net grid-to-cathode voltage is zero and that gun does not contribute anything to the color or brightness of the scene.

It is also interesting to notice that in the case of a white scene the R - Y, B - Y and G - Y signals all drop to zero. The -Y signal is -100 volts and this signal is fed to all three cathodes to produce white light. This is essentially as it should be because in our color TV system we have compatability with black-and-white television. Therefore if we are going to transmit a black-and-white picture we are going to do so by varying the amplitude of the Y signal. However, the three guns should operate at the same ratio in order to keep a white balance. Meanwhile there is no color signal fed to the grid of the tube because we are not transmitting color; we are simply transmitting a black-and-white scene. Notice that even when we are transmitting a color program, if the scene is black-and-white, the color signals drop to zero and all the information will be contained in the brightness signal.

DC RESTORATION OF COLOR SIGNALS

In color receivers it is essential to maintain the dc component of both the brightness signal and the color signal. You are aware that the loss of the dc component in a black-and-white receiver often goes unnoticed. The eye tends to adjust to the average brightness level of the picture. A picture with a high average brightness level may never completely cut off the electron beam. Thus even though no completely black areas appear in the picture, the eye accepts the darkest gray area as black. The viewer tends to set the brightness control toward the high side and the shades of gray are compressed. A black-and-white receiver must be carefully adjusted to take full advantage of dc restoration.

On some televised scenes a black-and-white picture may look much better on a receiver without dc restoration than it appears on a carelessly adjusted receiver with dc restoration. These considerations are not true on a color receiver. Loss of the dc component of either the brightness or the color signals can seriously upset color rendition.

We have already given one example, in Fig. 12, on

In Fig. 34 we have shown the signals fed to the green guns when we are transmitting the red color. This is represented by the first color bar shown. As before, the G - Y signal will be -30 volts and the Y signal also -30 volts; therefore, the net grid-to-cathode voltage will be zero and there will be no output from the green gun.

The various signals produced as the different colors are transmitted are shown in Figs. 32, 33 and 34. By noting the signals fed to the grid and cathode of each gun, you can see how the primary colors are transmitted. In the case of the red signal the red gun is turned on to maximum brilliancy and the blue and green guns are turned off. When we are transmitting blue, the voltage fed to the grid of the blue gun is 89 volts and the voltage fed to the cathode is -11 volts so we have 100 volts between the grid and cathode and the blue gun operates at maximum intensity. When we are transmitting green, the signals fed to the blue and red guns cancel. At the same time we feed a voltage of 41 volts to the grid of the green gun and a voltage of -59 volts to the cathode so that the net grid-cathode volt-

Fig. 35. Color signals that are correctly referenced (A) and the same signals after passing through a coupling capacitor (B).

the effect of the loss of the dc component on the video color signal. Fig. 35 illustrates the effect of the dc component of the color signal at the grids of the picture tube. The waveforms in Fig. 35A represent the signals required to produce a blue screen with a single white vertical bar down the center. The signals represent one horizontal line of color signal for each gun of the tube. The blue gun grid is driven positive for the entire horizontal line because we have a blue background. The red and green guns are driven positive only at the center of the horizontal line for the width of the white bar. The red, green and blue combine to produce the white bar. In Fig. 35B the signals are shown as they appear after passing through a coupling capacitor. Each signal has been averaged above and below zero so the dc component has been lost. The signals will not drive the picture tube correctly. The blue area will appear washed out because the blue grid will not be driven hard enough in a positive direction. The white bar area will appear yellowish because not enough blue signal is present when the red and green grids are driven positive. The inaccuracies of the color content of the picture would vary with changes in the color signal.

Examine the waveforms with the dc component in Fig. 35A. The blanking level of the signal extends to the cutoff level for each gun of the picture tube. The positive excursion of each signal drives that gun into full conduction and the blanking level drives the gun to cutoff. Thus the signal to the blue gun holds the beam in full conduction, producing a saturated blue field. The positive signals to the red and green guns during the white bar area also drive the red and green guns into full conduction. Therefore, the light from the red, blue and green phosphors add in the correct proportion to produce white light in the signal area representing the white bar. However in Fig. 35B, we see the amplitude of the blue signal, in particular, is reduced; therefore the blue gun will not be driven to full conduction.

Loss of the dc component of the brightness signal also upsets the proper renditions of color in a color picture. The brightness signal affects all three guns equally so a loss of the dc component does not nec-

essarily upset the color balance in the picture. However, it does affect the saturation of the displayed colors. Depending on the picture content, it can give the appearance of loss of color balance.

Direct coupling is usually used in the color receiver video amplifiers to preserve the dc component of the brightness signal. In your study of video detectors and video amplifiers, you studied various circuit arrangements that are used to maintain the dc component of the brightness signal.

Direct Coupling.

The dc level of the color signals are correctly established when the chroma signals are demodulated. You recall that the color signal at the output of the bandpass amplifier is modulated sidebands of the 3.58-mc subcarrier. Or you can think of it simply as a sine wave at a frequency of about 3.58 mc. The chrominance information, including the dc signal component, is contained in the signal in the form of amplitude and phase modulation. This signal can be amplified and ac coupled without losing the information. In passing through the demodulator, the color signal changes form. It becomes a video type signal with frequencies ranging all the way from zero (dc level) to about 600 kc. This is the type of signal required to properly drive the grids of the picture tube. The dc levels of the signal will be lost, if the signals are coupled through capacitors.

One way to maintain the dc level of the color signal is to use direct coupling from the demodulators to the grids of the picture tube. This is usually done in receivers using high-level demodulators. In this lesson you studied several examples of direct coupled high-level demodulators. The demodulator circuits in Figs. 19, 20, 22, 23, 24 and 25 are all high-level demodulators that couple the color difference signals directly from the demodulators to the grids of the picture tube. This eliminates the problems often associated with direct coupled amplifiers.

Direct coupled amplifier circuits usually have a tendency to drift. Any small change in a circuit component or operating characteristic of a tube or transistor results in a change in the no-signal dc potential at the output of the amplifier. This is the equivalent

of the amplifier producing a change in its output signal without a corresponding change in the input signal. In a color receiver, three channels supply signals to the picture tube. The colors displayed depend on the relative amplitude of the signals through the three channels. Therefore if the three channels drift, and particularly if they drift unequal amounts, the displayed colors become unbalanced.

Some color receivers use direct coupled color difference amplifiers. You studied several in this lesson. The color difference amplifiers in Figs. 14, 22 and 28 have one or more direct coupled amplifiers. In Fig. 28, capacity coupling is used between the demodulator and the amplifiers, but direct coupling is used between the amplifiers and the picture tube.

Circuits having only one color difference amplifier are less troubled by drift problems than those having three. When three color difference amplifiers are used, steps are taken to minimize the effect of drift and the circuits often use dc restorer circuits. The amplifiers in the X and Z demodulator circuit in Fig. 28 are constructed with identical components to minimize drift problems due to the dc coupling between them and the picture tube. The problem of ac coupling between the amplifier and the demodulator is overcome by the use of dc restoration in the amplifier circuits.

Diode DC Restorer.

The dc restoration circuit used with the I and Q demodulators in Fig. 11 restores the dc level of the color signal with diodes. In this circuit, the Y signal is matrixed with the color difference signals before they are amplified. This produces R, B, and G signals to drive the three color output amplifier stages. Since these color signals contain the Y or brightness signal, the horizontal sync pulse is available in the color signal.

We have already explained how the sync pulses are used in this circuit for dc restoration so we will not go into it again. The important thing to notice is that three dc restorers are used, one for each color amplifier. While this type of circuit was quite widely used at one time, it has not been used in late model color receivers.

Keyed DC Restorer.

The diode restorer circuit cannot be used with color difference amplifiers. The color difference signals do not contain the horizontal sync pulses so no constant-level reference is available in the signal. DC restoration can be accomplished by use of a separate keying pulse. A constant amplitude pulse at the horizontal rate is used to charge the grid coupling capacitors. The pulse is sometimes referred to as the "set" pulse because it sets the charge level of the capacitor.

Keyed dc restoration is used in the demodulator circuit shown in Fig. 28. Negative horizontal pulses are applied to the common cathode connection of the color difference amplifiers. These negative pulses cause the grids to become positive with respect to the cathode. The grid draws current, charging the grid coupling capacitor to a level determined by the amplitude of the keying pulse. Since the horizontal pulses are of uniform amplitude, the coupling capacitors are charged to the same level at the start of each horizontal line.

The grid time-constant is long compared to the time between horizontal pulses so the charge on the capacitor is maintained at the set level. The coupled signals add-to and subtract-from the charge level. In this way the color difference signals are referenced to a fixed level and the dc component of the demodulated signals is restored. Direct coupling is used between the plate circuits of the color difference amplifiers and the control grid of the picture tube so the dc component will be maintained.

AUTOMATIC BRIGHTNESS LIMITER

The video color amplifier used with the color demodulator shown in Fig. 15 is shown in Fig. 36. Notice that in each channel we have a two-stage direct-coupled amplifier. The signal from the red demodulator is fed to Q_1 where it is amplified and inverted in polarity. The signal is then directly coupled to the base of Q_2 where it is once more amplified and inverted and then fed to the cathode of the picture tube through R_8 and C_4.

You will remember that the red color signal is a positive signal and the higher the amplitude the brighter the red gun should be turned on. Since the color signal is fed to the cathode we know that the higher the negative signal fed to the cathode, the greater the amplitude of the color. Therefore, the signal fed to the cathode must be a -R signal. This means that the output from the color demodulator must be a -R signal since it is inverted twice in the color amplifier. In other words, a -R signal is fed to Q_1 and is amplified by it and in the output we'll have a +R signal. A +R signal is amplified and inverted by Q_2 so we have a -R signal in the output of this stage.

Each of the color channels is identical so let's continue looking at some of the features of the red channel. Notice the spark gap connected at the junction of C_4 and R_{20}. The purpose of this spark gap is to prevent damage to the output transistors in the event there is an internal arc inside the tube. The spark gap is spaced so that if the voltage exceeds a certain value it will arc and prevent an excessively high voltage from reaching the collector of Q_2 and destroying the transistor.

Notice that Q_1 is a PNP transistor. This means that electrons will flow out of the emitter and through R_3 to the emitter of Q_9. They will flow through Q_9 to the collector and then through R_{40} back to B+.

Notice that the base of Q_9 is connected to the potentiometer R_{36} in the emitter circuit of Q_8. R_{36} is the brightness control. The higher this control is turned, the higher the positive bias applied to Q_9 and hence the lower the resistance of the transistor. This will allow a higher collector current to flow; therefore, the current through the first color stage in each channel will increase. The increased current flow through the PNP transistor will mean that the voltage at the base of each of the output color stages will become more positive. This will cause a higher current to flow through these transistors causing a greater voltage drop in the collector circuit. Notice if there is no voltage drop in the collector circuit, due to the
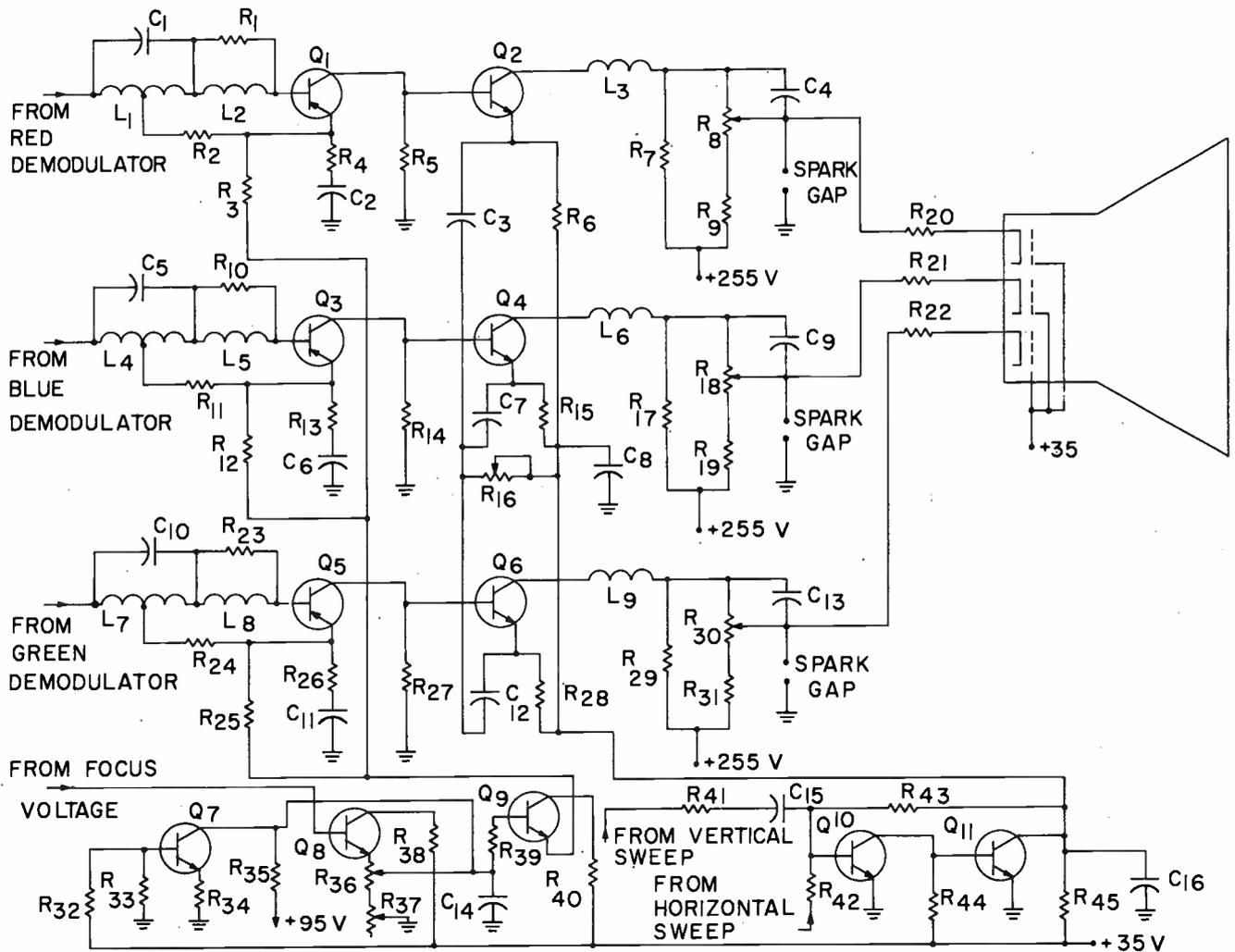
Fig. 36. Color amplifiers with automatic brightness control circuit and horizontal and vertical retrace blanking.

fact that the output transistors are cut off, the voltage applied to each of the cathodes of the tri-gun color tube will be +255 volts. With such a high voltage each gun would be cut off. However, the greater the voltage drop in the collector resistors then the lower the positive voltage of the cathodes of the picture tube will be. This means that the current will increase through the picture tube as the current through the output color-amplifier stages increases.

The three-stage amplifier consisting of Q_7, Q_8 and Q_9 functions as an automatic brightness limiter. A signal from the picture tube focus voltage is fed to Q_8. This voltage places a forward bias on this transistor which causes it to conduct. If the brightness of a scene is very high, the anode current through the picture tube will increase. The beam current is limited in order to protect the picture tube, and at the same time prevent a high anode current from loading the high-voltage power supply and reducing the voltage. When the high anode current begins to load the power supply, the focus voltage which is derived from the high-voltage supply goes down. This causes the base voltage on Q_8 to decrease, hence the forward bias across the emitter-base junction decreases and the current flow through Q_8 goes down. When this happens, the voltage across R_{36} decreases and this in turn reduces the voltage applied to the base of Q_9. Hence the

forward bias across the emitter-base junction decreases and the resistance of Q_9 increases. This causes the current flow through Q_1, Q_3 and Q_5 to go down. If the current flow through any of these transistors decreases, then the positive voltage applied to the base of the output color amplifiers goes down. This in turn will cause the current flow through the output transistors to decrease reducing the voltage drop across the resistors in the collector circuit. This causes the voltage on the cathodes of the tri-gun tube to swing in a positive direction which will reduce the current flow in each gun. Transistor, Q_7, is used to prevent brightness changes resulting from B+ changes. If the B-supply voltage changes, for example, if it increases, the current flow through R_8 might have a tendency to increase. However, the increased B-supply voltage is also felt in the base of Q_7. This causes the current flow through it to increase and hence the voltage drop across R_5 will tend to increase. This will counteract any increase in voltage at the slider terminal of the potentiometer due to an increase in current through Q_8.

In addition to the automatic brightness limiting circuit, this circuit also has horizontal and vertical retrace blanking. Notice that the emitter circuit of the output color amplifiers Q_2, Q_4 and Q_6 is completed through the transistor Q_{11}. Normally, this transistor

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is biased so that the transistor is saturated and there is very little resistance to current flow through the transistor. However, during the horizontal sweep retrace interval a positive pulse from the horizontal sweep circuit is fed through R_{42} to the base of Q_{10}. This causes this transistor to conduct very heavily and this in turn causes a large voltage drop across R_{44}. When this happens, the forward bias across Q_{11} drops and the transistor stops conducting which, in effect, opens the emitter circuit of the transistors Q_2, Q_4 and Q_6. This causes the voltage on the three cathodes of the picture tube to rise to a high positive value and cut off the picture tube during the horizontal retrace interval.

The same thing happens during the vertical retrace interval except that the vertical pulse is fed through R_{41} and C_{15} to the base of Q_{10}.

The circuit shown in Fig. 36 is quite interesting not only because it contains the three direct-coupled color amplifiers, but also because the circuit limits the brightness of the picture automatically in order to control the beam current of the picture tube and to help regulate the high voltage applied. It is also interesting because it includes the retrace blanking circuit.

SELF-TEST QUESTIONS

(u) What determines the amount of amplification that the color amplifiers must provide?

(v) Why is the amplitude different for each of the color difference signals?

(w) What are the two types of matrixing functions usually performed in the color section of the receiver?

(x) What three signals are required to control the intensity of the three electron beams of the picture tube to produce a full color picture?

(y) In what circuit of the color section of a receiver is the dc component of the color signal established?

(z) What type of coupling causes loss of the dc component of a color signal?

(aa) In keyed dc restoration, what important characteristic of the keying pulses must be maintained?

(ab) How is the dc path in the emitter of Q_4 in Fig. 36 completed?

(ac) What effect on the cathode voltage of the picture tube in Fig. 36 does increasing the setting of the brightness control have?

ANSWERS TO SELF-TEST QUESTIONS

(a) $57°$; $147°$.

(b) To compensate for the longer narrow bandpass delay experienced by the signal in the Q channel.

(c) Color signal from bandpass amplifier.

(d) To produce positive and negative I and Q signals.

(e) The brightness signal is the Y signal that is introduced into the matrix in the grid circuits of the color adder stages.

(f) Produces a flat response across the band of video frequencies handled by the circuits.

(g) To adjust the relative amplitude of the color signals to the three guns of the color picture tube.

(h) Since the red phosphor requires the greatest excitation, the red gun gets the full color signal. The green and blue gun signals are adjusted to be proportionately smaller.

(i) The sync pulse tips.

(j) $90°$.

(k) Grid circuit of the G – Y amplifier.

(l) To adjust the size of the chroma signals to the two demodulators.

(m) To correct for the effect of the G – Y signal across the common cathode resistor.

(n) Because the demodulators are operated on the R – Y and G – Y axis which are not $90°$ apart.

(o) They usually have two-stage chroma amplifiers and the demodulators provide some amplification.

(p) By a reference signal to the control grid of the tube.

(q) These controls set the operating bias on the control grids of the picture tube.

(r) By a voltage divider network that controls the relative amplitude of the chroma signals to the demodulator grids.

(s) $180°$ phase difference between the reference signals to the two deflectors of a demodulator stage. The reference signals to the R – Y stage are in quadrature, or displaced $90°$ from the reference signals to the B – Y demodulator stage.

(t) Tube current is switched to either of the two plates.

(u) Size of demodulated signals and drive requirements of the picture tube.

(v) Because the three phosphors used in the color picture tube have different efficiencies.

(w) Matrix two color difference signals to produce the third color difference signal and matrix each color difference signal with the brightness signal to produce the three color signals.

(x) Red, green, and blue color signals produced by combining the color difference signals and the brightness signal.

(y) Demodulator circuit.

(z) Capacitive coupling (also transformer coupling but this is not used.)

(aa) Uniform amplitude.

(ab) Through Q_{11}.

(ac) Causes the positive voltage on the cathode to decrease.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. What is the phase difference between a color signal on the I axis and a color signal on the Q axis?

2. What is the bandpass of the Q demodulator? Of the I demodulator?

3. What determines the amplitude and polarity of the color difference signals produced by a double-diode demodulator?

4. Why isn't dc restoration of the color difference signals required in the circuit in Fig. 19?

5. Why does one triode section of the B - Y demodulator in Fig. 23 produce a positive color difference signal while the other triode section produces a negative color difference signal?

6. In the demodulator circuit in Fig. 24, where are the B - Y and R - Y color difference signals matrixed to produce the G - Y signal?

7. In Fig. 25, why isn't a matrix circuit needed in the demodulator circuit to recover the third color difference signal?

8. Where is the G - Y color difference signal produced in the X and Z demodulator circuit?

9. What outputs are produced by the R - Y demodulator stage of the beam switching demodulator?

10. How does the loss of the dc component of the color signal affect the displayed color picture?

TV ANTENNAS

●

STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

☐ **1. Introduction** . . . . **Page 1**
    A general discussion of why the TV antenna is an important part of the TV receiving system.

☐ **2. Behavior of TV Signals** . . . . **Pages 2-4**
    You study the characteristics of the rf radiated television signals, and the differences between VHF and UHF signals.

☐ **3. Basic TV Antennas** . . . . **Pages 5-11**
    A discussion of a simple dipole and a folded dipole is given here.

☐ **4. Choosing the Proper Antenna** . . . . **Pages 12-19**
    You learn the important considerations for choosing antennas for use in primary signal areas, secondary signal areas and fringe areas.

☐ **5. Transmission Lines** . . . . **Pages 20-23**
    You study the different types of lines and the problems of matching lines to the receiver and to the antenna.

☐ **6. Installation of TV Antennas** . . . . **Pages 24-30**
    General instructions for making a normal rooftop antenna installation are given. Various types of mounting hardware are discussed. Safety precautions for yourself, the receiver, and the building are discussed. You are shown how to orient an antenna for best reception on all available channels.

☐ **7. Answer Lesson Questions.**

☐ **8. Start Studying the Next Lesson.**

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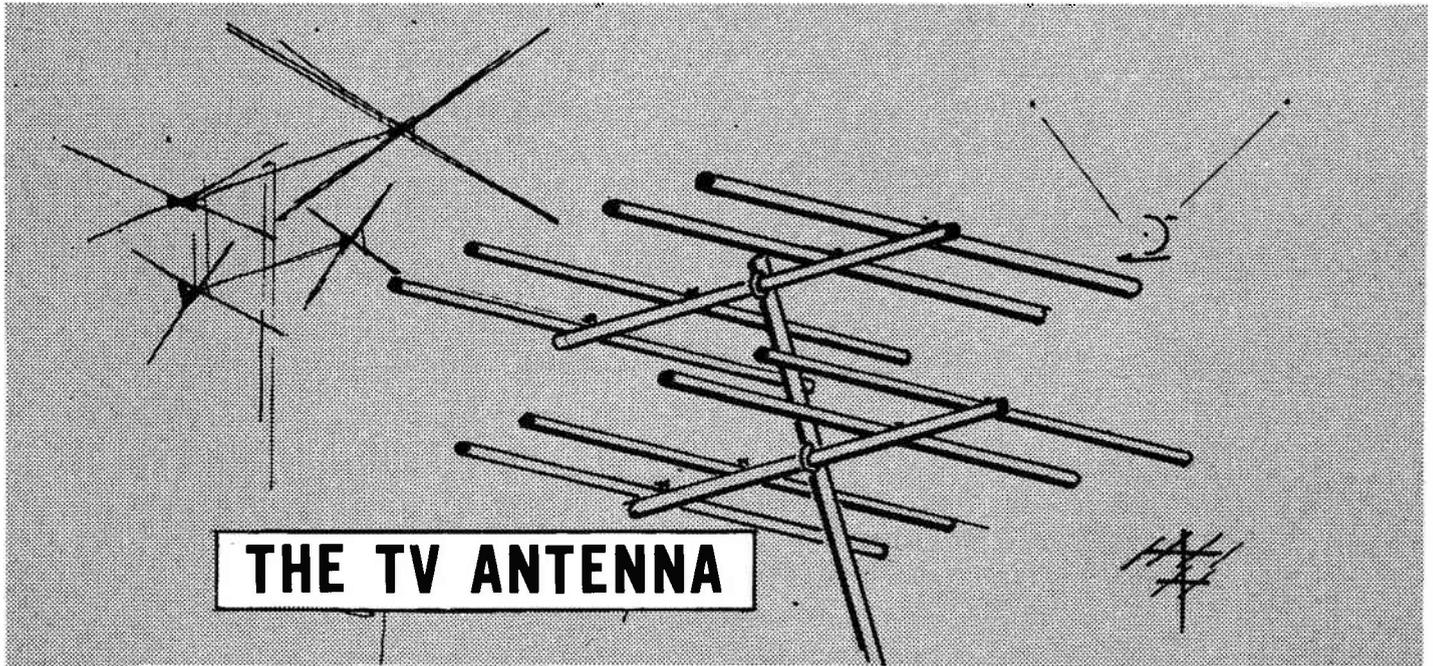
THE TV ANTENNA

The TV antenna system is a very important part of the complete TV installation. No matter how good the set may be, it cannot produce a satisfactory picture unless the signal fed to it by the antenna is sufficiently strong and free from undesired interference. The picture carrier is located at one end of the TV channel, the color subcarrier and the sound carrier are at the other end of the channel. The picture detail is contained in sidebands that are located throughout the channel from the video carrier frequency almost up to the color subcarrier frequency. Therefore it is important that the TV antenna system be able to accept the entire band of frequencies that make up the television signal without destroying or distorting the characteristics of any part of that signal.

Furthermore, it is important for the TV antenna to have sufficient directivity to pick up the desired signal but reject any undesired signals coming from other directions. This is particularly important in large cities where nearby buildings may reflect the signal and possibly cause ghosts or multiple images in the picture.

To obtain maximum signal transfer between the antenna system and the receiver, the antenna must be matched to the transmission line, and the transmission line must be matched to the receiver input circuit.

Therefore, an antenna with the proper impedance must be chosen, and the transmission line must be chosen to match both the antenna and the receiver input circuit, or some means of obtaining these matches must be provided.

Three bands of frequencies are used for television: two in the VHF range, and an extremely wide one in the UHF range. The lower frequency VHF band extends from 54 to 88 mc; the higher from 174 to 216 mc. The UHF band extends from 470 to 890 mc. In some areas, it is possible to pick up signals in each of these bands if the proper antenna system is used. Naturally, the owner of a TV receiver wants to receive as many stations as possible, and wants an antenna system with a frequency response broad enough to cover all the channels used in his immediate area.

Knowledge of TV antennas is important to the practicing serviceman so that he can choose the proper kind of antenna for a particular reception area, and so that he can install the antenna properly for maximum signal at the receiver input.

Before studying characteristics of various TV antennas, it is important for you to have a thorough understanding of the behavior of the TV signal. That understanding makes it easier to see how the antenna responds to the signal.

Behavior of TV Signals

The signals in the frequency range used in the standard radio broadcast-band travel along the ground or bounce back and forth between the earth and the Kennelly-Heaviside layer. Signals at the frequency range used for television, however, behave differently. They act more like light waves, the resemblance becoming more pronounced as the frequency is increased. These high-frequency signals travel in relatively straight lines from the transmitting antenna to the receiving antenna. They do not bend appreciably around hills or other obstructions as lower-frequency radio signals do, nor are they normally reflected by the Kennelly-Heaviside layer. Therefore, television reception directly from the transmitter to the receiver is not generally possible over extremely great distances.

As a result of this "line of sight" characteristic, the distance over which a television signal can be received is very limited. Also, the distance generally depends upon the height of the transmitting antenna and the height of the receiving antenna. The best results are generally obtained when each is as high as possible.

An illustration of a true line of sight signal is shown in Fig. 1A. As you can see, the signals from the transmitting antenna travel in a straight line (P_1) to the receiving antenna.

Those that pass the receiving antenna continue on out into space and never return to earth. Notice that if either the transmitter or the receiving antenna were slightly less elevated, the curvature of the earth would interrupt the line of sight between them and thus prevent reception.

As it happens, however, there is a certain amount of refraction (bending) of VHF signals. As a result of this bending, VHF television signals can travel slightly farther than they could if they were strictly line of sight. This is illustrated in Fig. 1B, where P_2 is a curved path actually taken by the signal. Comparing the length of P_2 with that of P_1, you can readily see that the curved path permits signals to be received over a greater distance. The actual increase of receiving distance is not proportionately as great as shown here, because the curve of the earth has been greatly exaggerated in these drawings. The increase in receiving distance caused by the refraction of the VHF signals, however, is appreciable.

Fig. 1. The slight refraction of TV signals in air permits reception over distances that are longer than the line of sight path.

Refraction does not greatly affect UHF signals, and the distance over which these signals can be received is even more severely limited. However, reflection does affect the UHF signal, often allowing reception where there is no line of sight between the transmitting antenna and the receiving antenna.

REFLECTIONS

Waves used to transmit television signals can be reflected from conductive material. If they strike a building, for example, they will be reflected from the metal structure of the building just as a light beam would be reflected from a mirror. (Some prefer to consider that the metallic structure of the building in such a case acts as an antenna that absorbs the signal and then re-radiates it. Whichever explanation you prefer, the effect is the same; the radio waves take on a new direction after striking the building.)

The reflection of the television signal is sometimes helpful and sometimes extremely annoying for the man attempting to erect a receiving antenna. It is helpful in those cases in which it permits television reception at points where it would be impossible to receive signals without the reflection. Suppose, for example, there is a large building between the transmitter and the location at which you are attempting to install a television antenna. If you cannot get the receiving antenna above the obstructing building, direct reception of the television signal will be impossible. You may, however, be able to pick up the signal by pointing the antenna toward some building or other object that will reflect the signal. In fact, this is a very common occurrence in installations made in large cities.
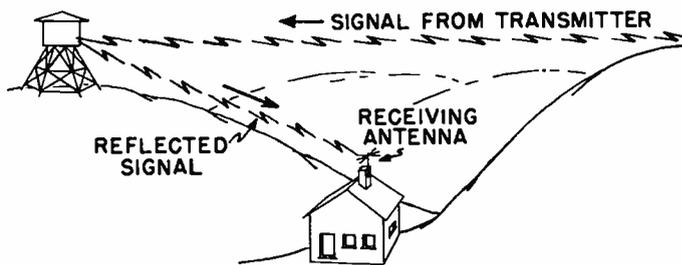
Fig. 2. How a reflected signal may give reception at a location not reached by the direct signal.

An example of another location in which a reflected signal is very helpful is shown in Fig. 2. Here the receiving antenna is located in a deep valley. The direct signal from the transmitter cannot reach the receiving antenna that is down in the valley. However, the water tower on the hill at the left in this figure is in the line of direct signal, and since it is metallic, it reflects the signal down into the valley to the receiving antenna.

In such cases, reflected signals are certainly helpful. Suppose, however, that the location at which you are installing a receiving antenna is such that you get
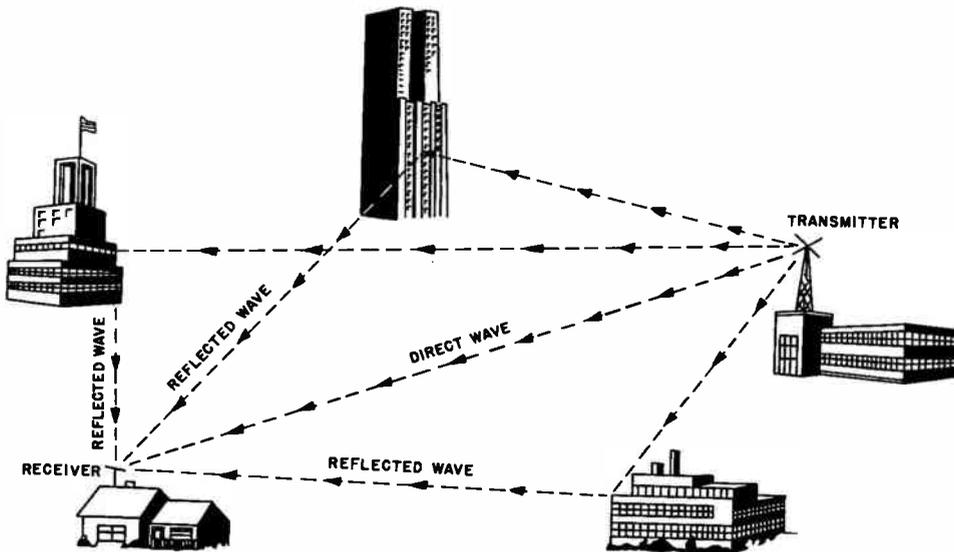
Fig. 3. How reflected signals can cause multi-path reception, which may produce ghosts.

a perfectly good signal directly from the transmitter, but that you also get one or more reflected signals from the same station that have traveled over different paths to reach the receiving antenna. Such a state of affairs is illustrated in Fig. 3. As you can see by examining this figure, the direct wave from the transmitter to the receiver travels over a considerably shorter distance than any of the waves reflected from the various buildings. Radio waves, even though they travel at the speed of light (186,000 miles per second), require a measurable length of time to get from one point to another. Therefore, the reflected waves will arrive at the receiving antenna a short time later than the direct wave, the time difference depending on the relative length of the paths. A radio wave traveling at the speed of light moves at the rate of 985 feet per microsecond (a microsecond is a millionth of a second), so a wave that travels over a path that is approximately a thousand feet longer than the direct path will arrive at the receiving antenna a microsecond later than the direct wave does.

This sounds like a very small interval of time, but its effect on a television receiver is appreciable. The scanning beam of a 20-inch picture tube travels across the face of the tube at the rate of .266 inch per microsecond. Therefore, a reflected wave that reaches the receiving antenna one microsecond later than the direct wave produces a picture on the tube that is .266 inch (or a little more than 1/4 inch) to the right of the picture produced by the direct wave. If you are looking at the picture, you will see the basic picture—the one produced by the direct wave—and a superimposed image of the same picture shifted 1/4 inch to the right. This effect is noticeable and rather distressing.

A multiple image of this sort, shown in Fig. 4, is called a ghost. It is possible for several ghosts to appear if there are several reflecting paths. The time difference between the direct and the reflected signal

need not be as great as a microsecond to produce a noticeable ghost. If the reflected wave arrives .19 microsecond later than the direct wave, the effect will be quite apparent. This time difference of .19 microsecond means that the reflected wave has traveled approximately 187 feet farther than the direct wave. A path difference of as little as 70 feet will produce a blurring in the right-hand edge of the picture, although a distinct ghost will not be produced.

Ghosts are always injurious to the quality of the received picture. The distortion may be only slight if the strength of the reflected signal is low. If many ghosts are received, the effect will produce gray outlines of the picture rather than distinctly separate images. A ghost condition is more noticeable on color programs because the hues are affected. Severe ghosts may break up the color sync.

Ghosts caused by multiple-path reception can usually be eliminated by orienting the antenna so that only the direct wave is received, if the antenna has sufficient directivity. If the antenna does not have sufficient
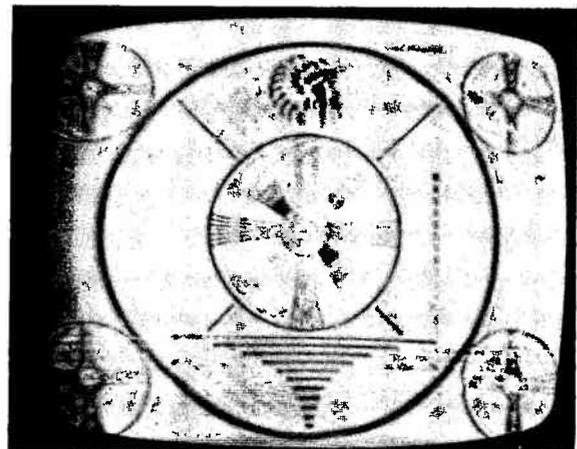
Fig. 4. Ghosts.

directivity, however, it may be impossible to clear up the problem by reorienting the antenna. In this case, the only solution is to use a more directional antenna.

Highly directional antennas are particularly important for UHF reception, because UHF signals are more likely to bounce off metallic objects and cause multiple-path reception.

Improper matching between the antenna and the receiver can also produce ghosts because of reflections within the transmission line that connects the antenna to the receiver. Suppose that a 100-ft. transmission line connects the antenna to the receiver. Suppose, too, that all of the signal sent down the transmission line to the receiver does not enter the receiver, but that part of it is reflected back up the transmission line to the antenna and then reflected down the line again to the receiver. If this happens, the part of the signal that was reflected up and down the line will have traveled 200 feet farther than did the signal that went straight down the line to the receiver. A path difference of this length will produce a ghost in the picture.

UHF SIGNALS

Though UHF TV signals behave in basically the same way as the VHF signals, there are certain differences that must be considered in installing TV antennas. A knowledge of these differences is particularly important in obtaining the best possible UHF reception.

All television signals decrease in strength rather rapidly as they move out from the transmitting antenna. The UHF signals, however, decrease more rapidly than the VHF ones because of the higher frequencies involved. That is, the UHF signals are absorbed by the atmosphere and by surrounding objects more readily than the VHF signals.

Also, reflection is more of a problem in UHF reception because the amount of reflection depends upon the size of the reflecting object in proportion to the signal wavelength, and a small object that would not reflect a VHF signal will often reflect a UHF signal.

Signal absorption by grounded objects is also a problem in the UHF range. For example, the UHF lead-in must be kept as far as possible from grounded objects to prevent excessive signal loss, and special types of lead-in must be used in some installations.

POLARIZATION OF TV SIGNALS

A radio wave consists of an electric field and a magnetic field that are at right angles to one another.

In radio and television work, we usually consider only the electric field when we are discussing the direction of a wave. Furthermore, we generally deal with a "plane polarized" form of this field--that is, one that lies all in one plane, which may be at any angle to the earth's surface.

From earlier lessons, you know that a voltage is induced in an antenna when it is in an electric field. If the antenna is in the same plane as the field, the voltage induced in it is a maximum; if it is at some angle with respect to the plane of the field, less voltage is induced in the antenna. Therefore, maximum efficiency is obtained when the antenna is mounted in the same plane as the electric field of the radio wave.

Television signals are transmitted so that the electric lines of the wave are horizontal with respect to the earth's surface. For this reason, television signals are said to be "horizontally polarized." There are several reasons for using horizontal polarization, chief of which is that most noise signals are vertically polarized.

Therefore, a horizontal antenna will pick up television signals most efficiently, and, at the same time, pick up vertically polarized noise signals poorly. For this reason, television antennas are usually mounted horizontally.

SELF-TEST QUESTIONS

(a) What is meant by "line of sight" transmission of television signals?

(b) Why are high frequency signals such as those in the UHF range more susceptible to reflections than lower frequency signals?

(c) What is the indication on the TV receiver when a receiving antenna picks up two or more signals that have traveled over different paths from the transmitter to the receiver?

(d) How can a reflected TV signal be used to an advantage?

(e) Why are directional antennas often necessary to get good TV reception in a city?

(f) What type of polarization is used for TV signals?

(g) What are the two types of fields present in a transmitted radio wave?

(h) Which field in the transmitted signal induces the signal into a TV antenna?

(i) Why are TV antennas usually mounted horizontally (elements of the antenna in a plane parallel to the earth's surface)?

Basic TV Antennas

Now that you have some basic information on TV signals and some of the reception problems, you are ready to study the actual TV antennas used to receive signals, beginning with the simple dipole. The simple dipole is seldom used today as a TV antenna, but it is the basic antenna and the performance of other antennas is compared to that of a dipole. In addition, many of the more complex antennas in use today were derived from the basic dipole.

DIPOLES

The dipole antenna shown in Fig. 5A consists of two cylindrical metal rods mounted so that they are in line with one another but not in contact. This is the basic antenna used in the study of all more elaborate types, in predicting the behavior of more elaborate antennas, and--in many cases--as part of more elaborate antennas.

An exact mathematical analysis of the behavior of a dipole is both difficult and complicated. Fortunately, it is not necessary to make such an analysis for our purposes. As a practical matter, we can consider a dipole (or any other receiving antenna for that matter) to be a generator having an impedance Z_A, as shown in Fig. 5B. Of course, the energy furnished by this "generator" is actually induced in it by the television signal so it has the characteristics of the received signal.

The impedance Z_A of the antenna depends on the length of the antenna with respect to the wavelength (λ) of the signal being received. If the antenna is exactly half a wavelength, its impedance is approximately 72 ohms; if it is a full wavelength, its impedance is approximately 2000 ohms; and if it is 3/2 wavelengths, its impedance is approximately 90 ohms. In each of these cases, the impedance is pure resistance. When we speak of the impedance of an antenna such as the dipole, we are referring to the impedance at the center of the antenna which is where the transmission line is connected to the antenna.

If the wavelength of the received signal is such that the length of the antenna is between one-half and one
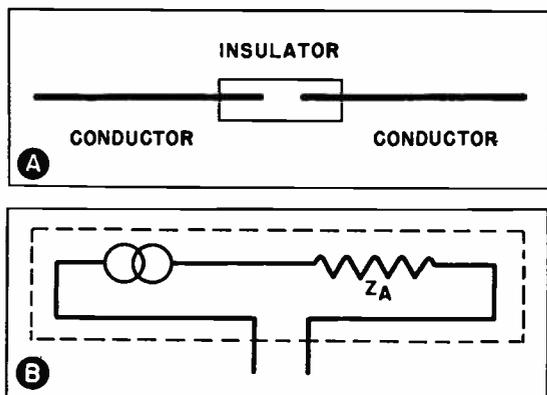
full wavelength, its impedance is a combination of inductance and resistance, and the value is between 72 and 2000 ohms; if it is between one wavelength and 3/2 wavelengths, its impedance is a combination of capacity and resistance and has a value between 2000 and 90 ohms.

Notice that the impedance of the antenna varies with the physical length of the antenna in proportion to the wavelength of the signal being received.

The impedance of a simple dipole like that shown in Fig. 5A varies rather quickly as the frequency of the received signal is varied. Therefore, reception of a signal only slightly separated from the design frequency of the antenna will prevent proper matching between the antenna and the feed line.
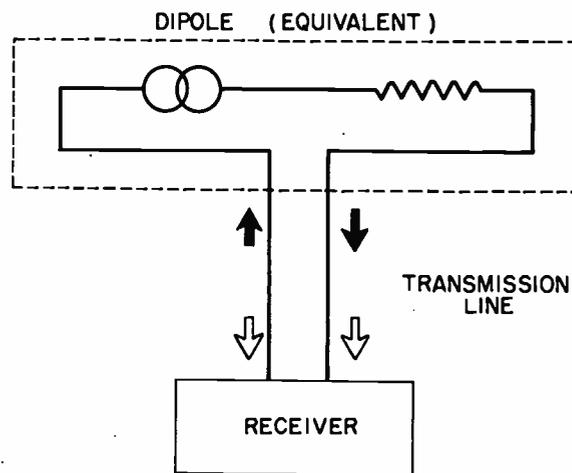
Fig. 6. A two-conductor transmission line passes signal currents (black arrows) from the dipole to the receiver, but tends to cancel signals picked up by the line itself (white arrows).

The dipole antenna is connected to a receiver through a two-conductor transmission line as shown in Fig. 6. As the black arrows show, the flow of signal current in the two conductors of the transmission line is in opposite directions at any instant.

Because the two conductors are closely spaced, however, any currents that flow in them, because of direct pickup by the line, are in the same direction in each line at any instant, as shown by the white arrows. These latter currents flow through the antenna transformer in the receiver in opposite directions and cancel. Therefore, they produce no effect at the input of the set. In theory the television signal delivered to the set is picked up only by the dipole. Also, noise signals picked up by the line will cancel. In practice, the line can contribute noise to the signal and its length affects the strength of the signal delivered to the set. These considerations will be covered in more detail later in this lesson.

Radiation Patterns.

The radiation pattern of an antenna shows the distribution of the field strength of an antenna if it were

Fig. 5. A dipole antenna and its electrical equivalent.

used for transmitting. At the same time, it shows how well the antenna will receive from each direction.

Fig. 7 shows the radiation pattern of the dipole when it is operating as a half-wave, as a full-wave, and as a three-half-wave antenna. In each case, the dipole remains the same physical length, but the frequency of the incoming signal changes.

Fig. 7A shows the radiation pattern of a half-wave dipole. Notice that there is no pickup off the ends of the dipole and there is maximum pickup at right angles to it. Also, notice that both halves of the pattern are the same size; this shows that the antenna picks up equally well from the front and the back.

A half-wave dipole is used as a standard reference antenna in determining the relative worth of more complicated types of antennas. Notice that each lobe of the half-wave dipole has been assigned the value 1.0. The dotted lobes in Fig. 7A show how the radiation pattern starts to change for signals of shorter wavelength.

Engineers measure the pickup of any antenna by comparing it with a simple dipole like that shown in Fig. 5A.

If the frequency of the received signal is twice that for which the dipole was cut (that is, if the dipole is one wavelength long for the received signal), the antenna has a radiation pattern like that shown in Fig. 7B. This pattern has four elongated lobes, which are at the angles shown with respect to the dipole. Again, there is no pickup at the ends of the antenna. There is, however, a major change. Notice that there is no pickup directly in front of or directly in back of the dipole as far as the signals of this wavelength are concerned.

The two small dotted lobes at right angles to the dipole show how the radiation pattern begins to change for signals at still shorter wavelengths. As the wavelength of the received signal becomes shorter, with the dipole remaining the same physical length, lobes begin to appear at right angles to the dipole. When the wavelength of the received signal becomes so short that the dipole is three half wavelengths long, the radiation pattern has the shape shown in Fig. 7C. Although the reception at right angles to the dipole is as good as it is for a half-wave dipole, the signal reception at angles of 42° from the dipole is even better: the center line of each of these side lobes has a value of 1.4, meaning that the pickup in these directions is 1.4 times as great as the maximum pickup of a half-wave dipole in its best direction. In other words, the
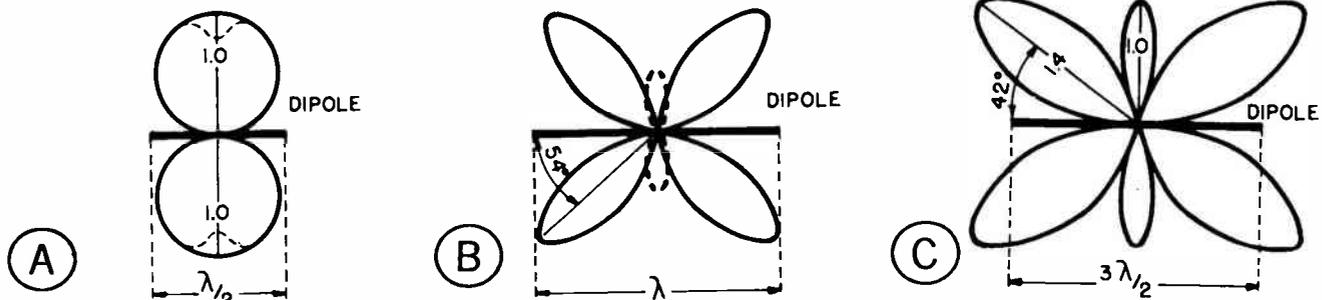
pickup in the directions of the side lobes is about 2 db greater than the pickup at right angles to a half-wave dipole.

Remember, each dipole shown in Fig. 7 is the same length in terms of inches. Its length in terms of wavelength increases only because the wavelength of the received signal decreases.

If the wavelength of the received signal becomes even shorter, more lobes will appear in the radiation pattern; each time the dipole becomes a half wavelength longer, one more pair of lobes will be produced on each side of the antenna.

In the early days of television, simple dipoles were frequently used. In fact, most of the early sets were designed with 72-ohm impedance input circuits that would match coaxial cable and a simple dipole. Modern TV antennas, however, are more complex, even in strong signal areas. However, the study of the basic dipole is important in understanding the theory of antennas.

The simple dipole is often used in UHF antennas. A somewhat more complex matching system, called a T-match, is used to provide satisfactory signal transfer between the simple dipole and the 300-ohm transmission line.
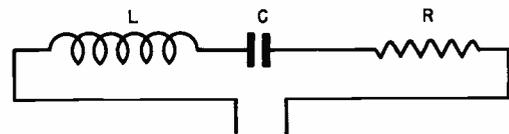
Fig. 8. A dipole can be considered to be a resonant circuit.

Now that you are familiar with the basic television antenna, the simple dipole, you can study more complex types. Before you do, however, there is one further point to be considered. As mentioned earlier, the dipole can be considered as a generator with an internal impedance Z_A. It is also possible, and sometimes more convenient, to consider the antenna as a series-resonant circuit with an inductance L, a capacity C, and a resistance R, as shown in Fig. 8. The values of L and C are such that the circuit is resonant at the frequency for which the antenna is half a wavelength long.

FOLDED DIPOLES

A common form of television antenna, known as the "folded dipole" is shown in Fig. 9. It consists of a single rod or tube that is bent into the shape shown.

Fig. 7. In these illustrations of the radiation patterns of a dipole as a half-wave, full-wave and three-half-wave antenna, the dipole remains the same physical length, but the frequency of the signal it is receiving changes.

LENGTH BETWEEN THESE POINTS SAME AS
OVERALL LENGTH OF SIMPLE DIPOLE.
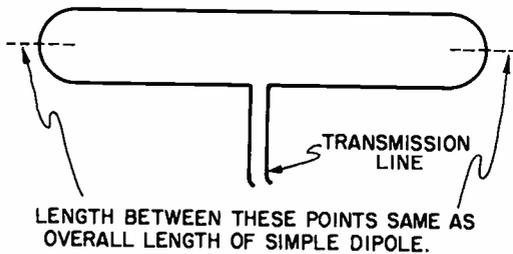
Fig. 9. A folded dipole antenna.

In use, the antenna is mounted with the long side parallel to the earth and the unbroken long side on top. The transmission line is connected to the two ends of the antenna as shown.

Such an antenna has the same radiation pattern as a simple dipole that is half as long as the perimeter of the folded dipole. For example, a dipole cut for channel 2 (54 to 60 mc) is about 8.2 feet long. A folded dipole made by bending a rod 16.4 feet long will have the same radiation pattern at the channel 2 frequency; in fact, as far as the radiation pattern is concerned, we could consider the two to be the same at all frequencies. In other words, the two will resonate to the same frequency and have identical radiation patterns.

We can, therefore, find out all we want to know about the radiation pattern of any folded dipole by studying the pattern of a simple dipole that is resonant to the same frequency, meaning one that is half as long as the perimeter of the folded dipole. Or, if we wish to make a folded dipole that will have the same radiation pattern as a particular simple dipole, we can do this by making it out of a rod that is twice as long as the simple dipole.

There are two reasons for using a folded dipole instead of a simple dipole that is the same as far as radiation pattern is concerned. First, the folded dipole has a higher impedance than a simple dipole at resonance; second, the folded dipole has a somewhat broader frequency response than the equivalent simple dipole.

The impedance of a folded dipole depends upon the spacing between the two long sides. The usual kind is made with a spacing of 1/64 of a wavelength, which gives an impedance of approximately 300 ohms at resonance—four times as great as that of a simple dipole. This spacing is used for most folded dipoles, and the 300-ohm transmission line designed to match the folded dipole is available.

It is important to remember that a proper impedance match between the antenna and the line permits maximum transfer of power from the antenna to the line.

As mentioned earlier, the impedance of a simple dipole depends upon the frequency of the incoming signal, since it is this frequency that determines whether the lengths of the antenna will be equal to half a wavelength, one wavelength, three half wavelengths or some other length. For frequencies above resonance, the impedance of a dipole increases rather rapidly. The impedance of a folded dipole also depends upon the frequency of the incoming signal; over a fairly wide range of frequencies above resonance, however, its impedance does not change as rapidly as that of a simple dipole. In other words, the impedance of a folded dipole is more nearly constant than that of a simple dipole over a range of frequencies off resonance.

Suppose that we have a simple dipole and a folded dipole, each of which is perfectly matched to its own transmission line. With respect to the amount of signal power delivered to a receiver, these two antennas will be the same at their resonant frequency. At frequencies above resonance, the impedances of each will change; consequently, neither will be perfectly matched to its transmission line, and the amount of power each will deliver to a receiver will therefore decrease. Since the relative impedance changes in the simple dipole will be greater than in the folded dipole, however, the mismatch between the simple dipole and its transmission line will be greater. For this reason, the power that the simple dipole will deliver to a receiver will decrease faster at off-resonance frequencies. Over ranges of frequencies above resonance, therefore, a folded dipole will furnish more power to a receiver than a simple dipole. This is an important consideration when an antenna is used for reception on more than one channel.

For this reason, engineers say that a folded dipole has a wider frequency response than a simple dipole. This does not mean that a folded dipole picks up over a wider range than a simple dipole; their pickup is the same at all frequencies, since they have the same radiation patterns. It does mean, however, that a folded dipole and its transmission line will furnish more power to a receiver than a simple dipole and its transmission line over a range of above-resonance frequencies.

This effect does not hold at all frequencies, because the impedance of a folded dipole rises very sharply at frequencies near twice its resonant frequency—that is, at frequencies where its length is approximately equal to one wavelength. This is not too important, however, because the frequency for which a low-band antenna is one wavelength long occurs in the frequency range between the two VHF television bands.

At three times its resonant frequency, that is, at a frequency for which the folded dipole is the equivalent of three half wavelengths, the folded dipole has an impedance of about 100 ohms. It has a somewhat wider response than a simple dipole at frequencies greater than this, though the effect is not as marked as it is at frequencies close to resonance.

Because of its relatively wide frequency response, the folded dipole is one of the most popular types for use in complex multi-element arrays for VHF use. As mentioned previously, the simple dipole is the preferred type for use in UHF arrays. Also, a folded dipole made of 300-ohm line is frequently used for local reception of a TV signal.

PARASITIC ELEMENTS

A parasitic element is a metal rod or wire that is mounted near an antenna for the purpose of changing the radiation pattern. Such a parasitic element is not connected to the transmission line or to the antenna. It produces an effect on the radiation pattern of the
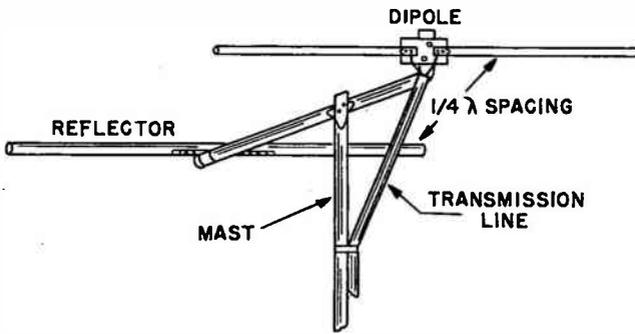
Fig. 10. An antenna using a parasitic element, called a reflector.

antenna because it picks up the signal and re-radiates it, changing the phase. This re-radiated signal is then picked up by the antenna. The antenna therefore has two signals induced in it: the original signal and the one re-radiated from the parasitic. These two may add to produce a stronger combined signal, or they may partially cancel each other to produce a weaker signal, depending upon the phase relationship between the two. As a result, the radiation pattern of an antenna that has a parasitic element mounted near it is different from that of the antenna alone.

The effect of a parasitic element on the radiation pattern of a dipole depends upon the length of the parasitic element, on the spacing between the parasitic and the dipole, and on the frequency of the incoming signal. It is possible to get almost any desired pattern by choosing the proper element length and the proper spacing.

An example of an antenna using a parasitic element is shown in Fig. 10. Here an element called a "reflector" is placed parallel to the dipole in the horizontal plane. The reflector is about 5% longer than the dipole. The spacing between the dipole and the reflector is usually one-quarter wavelength at the frequency for which the dipole is resonant, though spacings as close as .15 wavelength are used in special cases. The radiation pattern at the resonant frequency for a folded dipole and reflector spaced one-quarter wavelength apart is shown in Fig. 11. As you can see, the addition
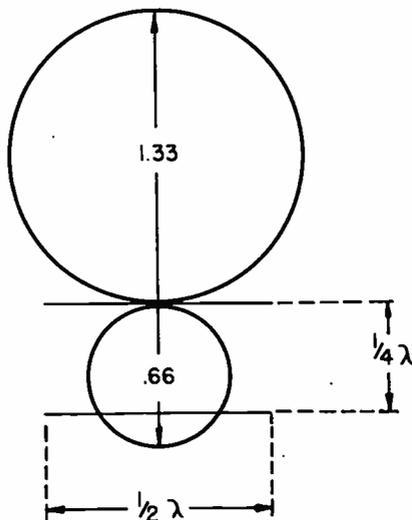
of the reflector increases the pickup considerably on one side and decreases it considerably on the other, the decrease being on the reflector side of the combination.

When a reflector is added to a half-wave dipole antenna, we say that the antenna has gain. That is, the pickup of a dipole and reflector is greater than the pickup of the simple dipole. This is illustrated by the forward lobe of the radiation pattern shown in Fig. 11. Notice that this forward lobe has a value of 1.33 as compared with the forward lobe having a value of 1.0 for the simple half-wave dipole.

Fig. 12 shows the radiation pattern for the combination when it is operated at three times the resonant frequency. Notice that the spacing between the antenna and the reflector is now three-fourths wavelength. This is explained by the fact that the spacing between them is fixed at one-fourth wavelength when the antenna is erected; since the wavelength of the incoming signal is only one-third the original wavelength when the antenna is operating at three times the resonant frequency, the spacing, which is fixed in terms of inches, becomes three times as great in terms of wavelength. You can see, the center forward lobe is considerably larger, and the center backward lobe is considerably smaller than they are in the radiation pattern of the dipole alone.
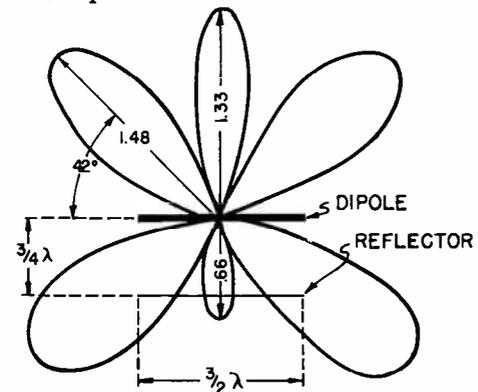
Fig. 12. The radiation pattern of a dipole and reflector operating as a three-half-wave antenna.

Since the combination of a dipole and a reflector picks up better in one direction than in another, particularly at the resonant frequency, it is said to be a directional antenna, or it is said to have directivity. Because the major lobe has a value greater than 1.0, the antenna is said to have gain in that particular direction. This indicates that the antenna would pick up more of the signal than a dipole cut for that frequency would.

The combination can be made even more directional by adding another parasitic element on the opposite side of the dipole from the reflector and parallel to both of them (see Fig. 13). This element, called a "director," is about 4% shorter than the dipole and is spaced one-fourth wavelength or less from it. The radiation pattern for a director-dipole-reflector combination at the resonant frequency is shown in Fig. 14. Notice that the addition of the director lengthens and narrows the forward lobe and further shortens the backward lobe.

Fig. 11. Radiation pattern for a dipole and reflector.
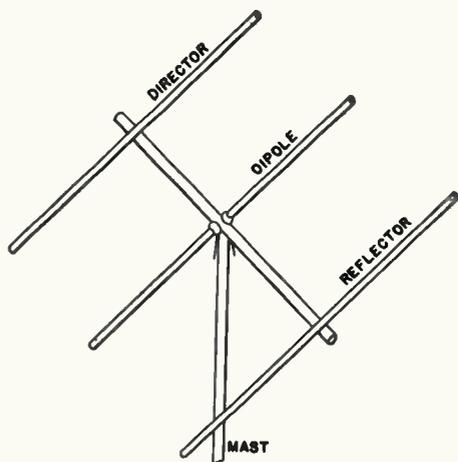
Fig. 13. A dipole with director and reflector.

The impedance of a dipole is decreased to about 60 ohms by the addition of a parasitic element spaced one-fourth wavelength from it. Its impedance can be brought back to about 72 ohms by reducing the spacing to something less than one-fourth wavelength. Notice that this applies in the case of a simple dipole used as a basic receiving element in the parasitic array. If a folded dipole is used as a basic antenna, there is a corresponding impedance reduction when parasitic elements are added.
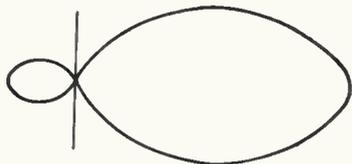
Fig. 14. Radiation pattern of dipole with reflector and director shown in Fig. 13.

The increased forward pickup caused by adding parasitic elements to a dipole makes the combination very useful in areas that are some distance from a television station. Such antennas, however, are also very frequently used when the signal strength is high; here their decreased backward pickup is the characteristic that makes them desirable. In a location

where there are strong reflected signals that can cause ghosts in a picture, a properly oriented parasitic array may be able to pick out the desired signal and ignore the reflected ones, thus eliminating the ghosts.

All parasitic arrays consisting of a dipole connected to the transmission line plus three or more parasitic elements--usually one reflector and a number of directors--are called "Yagis."

Unfortunately, the increased directivity and antenna gain produced by the use of parasitic elements are accompanied by a decreased broadness in response. This is generally true of many highly directional antenna arrays, although some are worse than others in this respect. Some directional antennas have frequency responses so narrow that they will not pick up equally all frequencies in a 6-megacycle television signal. This fact, of course, rules such antennas out for television use, no matter what their other characteristics may be, since uneven response over the frequency range of a single channel would cause distortion of some portion of the TV signal.

THE LOG PERIODIC ANTENNA

So far all the antennas we have discussed, even the simple dipole and folded dipole, are quite frequency sensitive. By that we mean they operate much better at one or two frequencies than they do over the entire band of frequencies used for TV. In many locations where there is only one or two TV stations operating and the signal from the station is strong, this may be no problem. However, in some locations it can be a problem; you may not be able to get a satisfactory signal from one of the stations due to a frequency sensitive antenna.

Probably the best antenna for a wide frequency coverage is the log periodic antenna, often called the log periodic V because of its shape. The basic configuration of the log periodic antenna is shown in Fig. 15. Notice that the dipole a-a_1 is the shortest element and that each element toward the right is slightly longer than the one on the left. The longest element is the i-i_1.
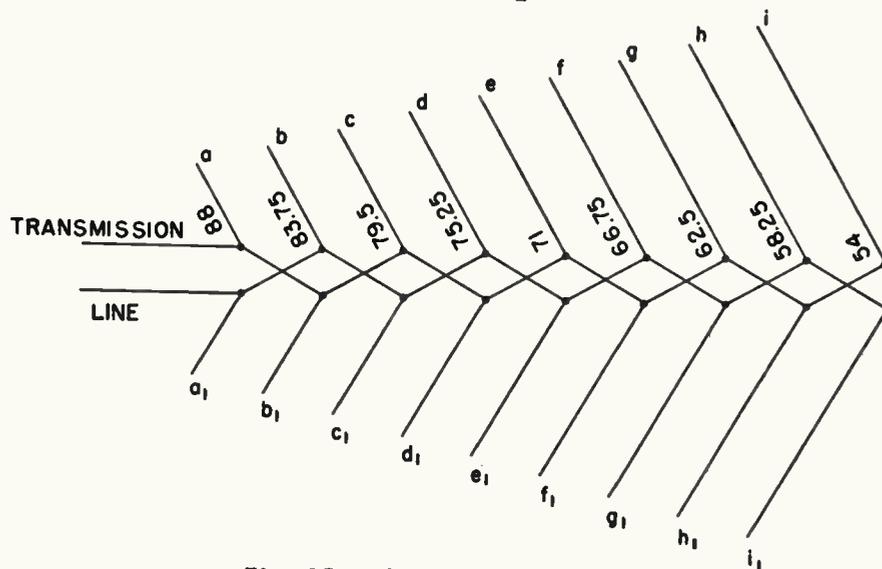
Fig. 15. A log periodic antenna.

The idea in back of this antenna is that each dipole element is resonant at a certain part of the frequency band to be covered by the antenna. For example, the element a-a_1 may be resonant near the high end of the low VHF channels (channel 6) and the element i-i_1 is resonant near the low end (channel 2). Thus the elements between a and i will be resonant at frequencies in between so we get complete coverage of the low VHF channels.

How well the antenna covers the frequency spectrum and the output from the antenna depends on how many elements the antenna has. For example, if the element a-a_1 is resonant at 88 mc and i-i_1 at 54 mc, we have 34 mc between these two antennas. There are 7 elements between a and i so they could be spaced at 4.25 mc intervals as shown in Fig. 15. Thus in receiving each TV channel, we have several elements active and contributing to signal pickup. If we had only three or four elements between a and i, we would not get as high a pickup or as even a coverage over the frequency spectrum.

In receiving the high VHF channels (7-13), the elements of the antenna act as 3/2 wavelengths. A 3/2 wavelengths antenna has a pattern like that shown in Fig. 16A, but when it is bent into a V shape, we get a pattern like that in Fig. 16B. Thus the one antenna gives us good broadband coverage of all VHF TV channels. The VHF log periodic antenna can be combined with UHF antennas to give both VHF and UHF coverage. For example, in an area where there are several VHF stations and one UHF station, you might combine a log periodic VHF antenna with a UHF Yagi to cover the area TV stations.

The VHF log periodic antenna can also be combined with a UHF log periodic antenna for all channel cover-

Fig. 16. Waveforms of 3/2 wavelengths antennas. A straight dipole is shown at (A), a V-shaped dipole at (B).

Fig. 17. A VHF-UHF log periodic antenna.

age as shown in Fig. 17. Here, the long elements at the right form the VHF antenna and the short ones at the left the UHF antenna. The UHF antenna is designed so that its longest element is a 3/2 wavelengths at the low end of the UHF band, channel 14-470 mc. The shortest is a 3/2 wavelengths at the high end of the UHF band, channel 83 - 890 mc. The elements between are 3/2 wavelengths at various frequencies in between. Notice that the angle between the UHF elements is different from the angle between the VHF elements. Not all all-band log periodic antennas are made this way; on some the angle is essentially the same on both UHF and VHF.

With the advent of color, log periodic antennas, because of their wide frequency response, are probably the most ideally suited TV antenna available. By varying the number of elements, both the gain and directivity of the antenna can be changed. Generally speaking, the more elements, the higher the gain and the more directive the antenna is.

SELF-TEST QUESTIONS

(j) What determines the impedance of a dipole antenna?

(k) If the impedance of a basic dipole antenna is 72 ohms, what is the length of the antenna in wavelengths?

(l) What is the antenna pattern called that is used to evaluate the ability of the antenna to receive signals from different directions and distances from the antenna?

(m) What directions from a half-wave dipole antenna exhibit minimum signal pickup?

(n) How long is the piece of metal rod used to make a folded dipole antenna that is designed for channel 2?

(o) How does the frequency response of a folded dipole antenna compare with a simple dipole?

(p) What physical dimension determines the impedance of a folded dipole?

(q) Why will a folded dipole antenna furnish more received signal power to the TV receiver at frequencies above resonance than a similar simple dipole antenna?

(r) What is the parasitic element called that is about 5% longer than the dipole and mounted one-quarter wavelength behind the dipole?

(s) What is the parasitic element called that is about 4% shorter than the dipole and mounted about one-quarter wavelength in front of it?

(t) What characteristic does an antenna have when that antenna receives a signal better than a simple dipole?

(u) From which direction of an array consisting of a reflector, dipole, and director, will the antenna receive signals best?

(v) What does the addition of parasitic elements do to the impedance of a dipole?

(w) What disadvantage does the use of parasitic elements produce in antennas such as Yagis?

Choosing the Proper Antenna

The antennas you have studied so far are the basic ones. There are many other types in general use, but the great majority of installations consist of one of the types described in the preceding section.

How complex an antenna must be depends upon many things. The following factors play a part in determining what antenna will be satisfactory: the signal strength in the area where the set is used; the direction of the station or stations from the receiver location; whether or not reflected signals are present at the location; the sensitivity of the set; and how much electrical noise there is at the installation location. You will study all these factors and several others.

Generally, television reception areas can be divided into three classes: 1. primary service areas; 2. secondary service areas (up to fifty miles from the station); 3. fringe areas (more than fifty miles from the station). Because the reception problems are likely to be different for each area, it is generally necessary to discuss these reception areas in terms of the type of antenna required to give satisfactory results in each. Of course, it is virtually impossible to give exact information on the type of antenna that will be required in each particular case, but a knowledge of the various types of antennas that are used, plus an understanding of why different types are used is sure to help you in choosing the proper antenna for use in a particular situation.

The problem of choosing the proper antenna is further complicated where both VHF and UHF are used in a single area. In the following portion of the text, general specifications on the type of antenna for use in the service area--both VHF and UHF--will be given.

PRIMARY SERVICE AREAS

Reception areas within ten or fifteen miles of the transmitting station are called primary service areas. In these areas the type of antenna used is not usually a very great problem insofar as picking up a strong enough signal is concerned. However, ghosts may be a problem, particularly in an area where there is a large number of tall buildings.

Indoor Antennas.

Many television receiver manufacturers include built-in antennas with the receiver. These antennas vary in complexity from folded dipoles made of 300-ohm twin lead mounted inside the cabinet to rather elaborate antennas with a separate tuning control on the front panel.

These antennas usually give satisfactory results in residential areas where the receiver is not too far from the transmitter. However, ghosts are often a problem with the simple built-in antennas particularly in large apartment buildings and in locations near tall buildings or other objects that can cause multi-path reception.

The primary disadvantage of a built-in antenna is the lack of room inside the cabinet to install an an-

tenna long enough to resonate at the frequency of the incoming signal. Furthermore, it is often difficult to place the antenna where the best signal is received simply because the receiver would not satisfactorily blend with the rest of the furniture if it were placed in the desired location. Also, it may be difficult or impossible to eliminate reflections with a built-in antenna.

Portable receivers and some table model receivers are often equipped with a telescoping built-in antenna. These consist of monopole or dipole sections that can be extended to change the effective antenna length. Since they are attached to the set, their position can be changed only a small amount.

A separate indoor antenna that will often give good results in an area where the signal strength is high is shown in Fig. 18. This antenna consists of two telescoped metal rods secured to a base through a pivot. These rods are electrically insulated from each other and are connected to the two leads of the transmission line. The angle between the two rods can be changed at will, and the length of the rods can easily be changed by pulling out the telescoped sections. The whole antenna can be rotated simply by picking it up and turning it.

The effective length of this antenna depends on the distance between the tips of the two rods. Thus, lengthening the rods or increasing the angle between them makes the antenna resonant at a lower frequency, and shortening the rods or decreasing the angle between them makes it resonant at a higher frequency. Often you must adjust either the length or the angle when the set is turned from one channel to another.

One of the most important advantages of these antennas (which are usually called rabbit ears) is the possibility of moving the antenna away from the receiver if desired.

Fig. 18. A widely used form of indoor antenna.

The antenna can be set on a nearby table if the set owner finds that more satisfactory results are obtained. This is not, of course, possible with a built-in antenna.

More elaborate "rabbit ears" with tuning controls and special sections for UHF reception are available. The switches and tuning controls enable the operator to change the electrical length of the antenna and adjust the impedance match. These antennas often prove satisfactory in strong signal areas where reflected signals are a problem. The ability to orient the antenna, and change the electrical characteristics gives the set owner an almost infinite number of combinations that he can try for the different stations in his area.

Window Antennas.

A window antenna that is on the same side of the building as the transmitter usually gives better results than an indoor antenna. A typical window antenna is shown in Fig. 19. As you can see, it is a folded dipole that is mounted on a very short mast. At the other end of the mast is a cross bar that can be secured to the window frame, usually by extending the ends of the bar to wedge it across the frame.
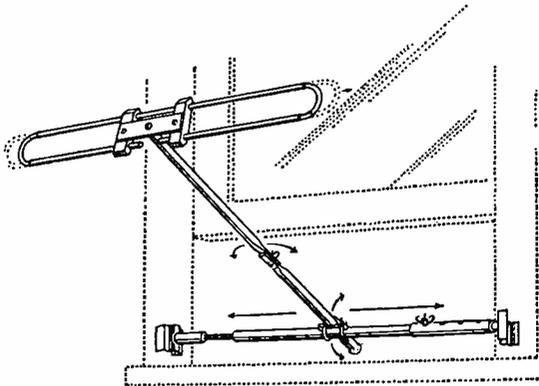
Courtesy Insuline Corp. of America

Fig. 19. An adjustable window antenna.

This antenna has a response like that of any other folded dipole. The ends of the one shown in Fig. 19 can be extended to make the antenna resonant to a lower frequency if desired. The length is adjusted when the antenna is first installed, since it is inconvenient to change the length thereafter.

As mentioned previously, it is usually better to install a window antenna on the side of the building that faces the transmitter. However, it is sometimes possible to pick up an adequate signal on the other side of the building if buildings or other objects reflect the signal toward that side.

Many other forms of indoor and window antennas have been developed. Generally speaking, there is little to recommend one kind over another. The only way to tell whether a particular type will be satisfactory in a particular location is to try it there.

Indoor antennas are not as satisfactory for UHF reception as for VHF reception because the signal is greatly attenuated in passing through the building and because there are so many reflections inside the building.
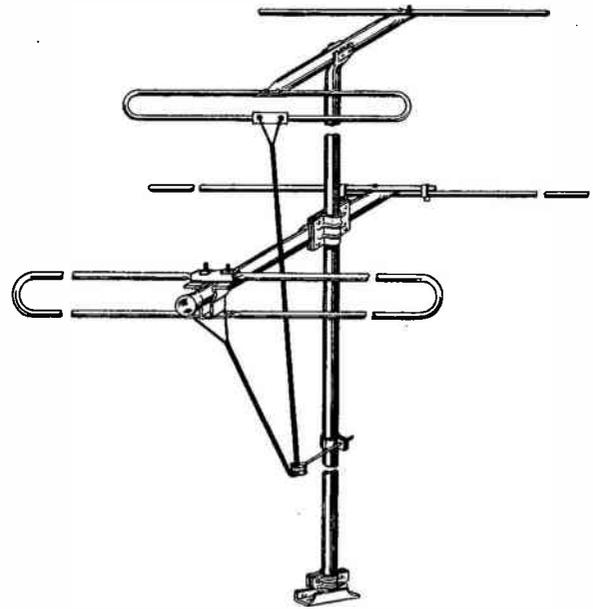
Fig. 20. A two-bay folded dipole and reflector combination. The larger section is used for low-band (channels 2 through 6) reception, and the smaller section for high-band (channels 7 through 13) reception. The two sections can be individually oriented.

Outside Antennas.

An antenna that has been widely used in VHF primary service areas where more than one station is to be received is shown in Fig. 20. This is called a "two-bay" folded dipole or a "Hi-Lo" folded dipole.

Notice that the lower section of this antenna is much larger than the upper part. The larger section is designed to have maximum response on the low channels of the VHF range, 2 through 6; the upper section is designed to have maximum response on the high channels, 7 through 13. The two sections, or bays, are connected together with a length of transmission line, and then connected to a single lead-in. The transmission line used between the two sections should be about 36 inches long, and the transmission line connecting the antennas to the receiver must be connected to the larger section. No special matching section is needed between the two bays.

The high-channel section of the antenna is generally mounted at the top of the mast to take advantage of the additional height. As mentioned previously, the signal reduction becomes greater as the frequency is increased; therefore, it is important for the high-frequency antenna to be mounted as high as possible.

In some particular cases, however, it is advantageous to put the low-channel section of the antenna at the top of the mast, particularly when the low-channel stations are at a greater distance from the receiving location than the high-channel ones.

Also notice that the individual sections or bays of the antenna can be individually oriented for best response. This feature is very important when the high-channel stations and the low-channel stations are in different directions from the receiving location.

A slightly different version of the two-band VHF
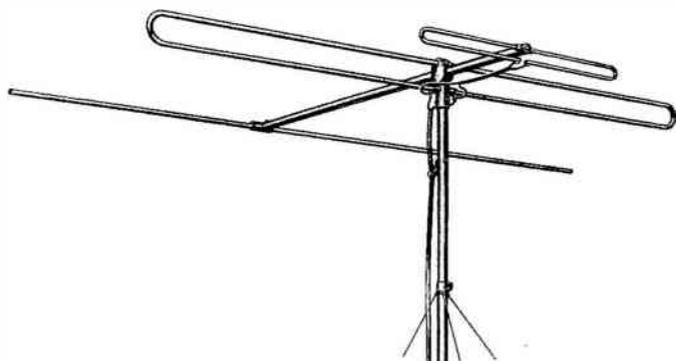
Courtesy *American Phenolic Corp.*

Fig. 21. Another form of two-band antenna.

folded dipole and reflector is shown in Fig. 21. The major lobes of both the high-band and low-band antenna point in the same direction. For this reason, this antenna is best suited for areas where all the TV stations are located in the same general direction from the receiver.

UHF Reception in Primary Areas.

A UHF antenna must have extremely wide frequency response, because the UHF band itself is so wide. Furthermore, good directivity is necessary to prevent the appearance of ghosts in the picture, and the antenna and its lead-in must be properly installed to maintain the losses at the lowest possible level.

To obtain the broad response necessary for UHF reception, the simple dipole is modified by making it "thicker". That is, the effective size of the dipole is increased by using a tapered construction like that shown in Fig. 22. Because of the shape, this type of antenna is called a "bow-tie". One lead of the transmission line connects to each triangle.
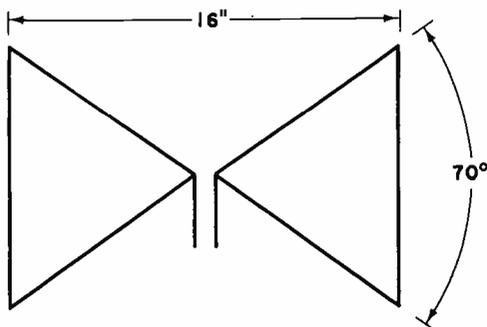
Fig. 22. Typical dimensions for a UHF bow-tie or fan antenna.

Although the individual sections of such an antenna can be made from solid pieces of metal, perforated sheets or screen wire are usually used to decrease the wind resistance.

The increased width of this type of dipole in comparison with one made from a single rod reduces the Q of the antenna so that the resonant peak is broader. This reduces the output at resonance, but it also provides a better impedance match to the transmission line over a wide band of frequencies.

Because multiple-path reception is such a problem on the UHF channels, a bow-tie antenna is almost never used alone. Instead, it is used as a basic element

in a more elaborate array. The extra directivity and gain provided by parastic elements is very important on the UHF channels.

One type of UHF antenna, a bow-tie with a corner reflector, is shown in Fig. 23. Although the gain of this antenna is very high in comparison with the gain of VHF antennas commonly used in primary service areas, the directivity and the extra gain are very im-
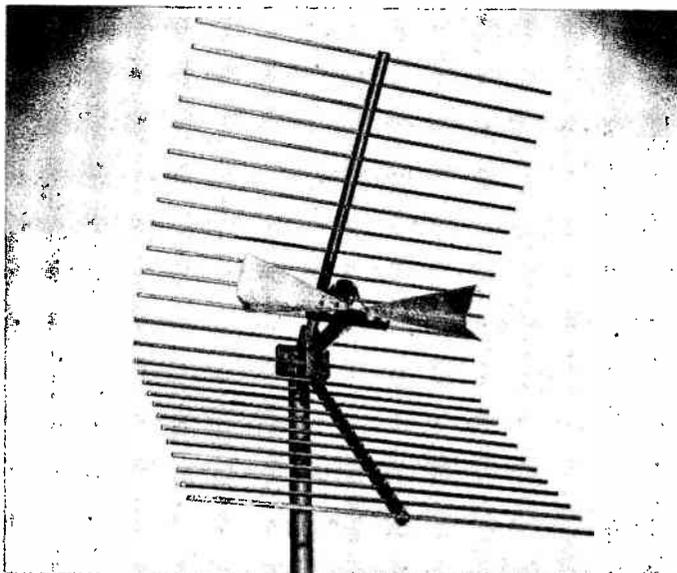
Courtesy *RCA*

Fig. 23. A corner reflector and bow-tie antenna.

portant. Fig. 24 shows the directivity patterns of the bow-tie with a corner reflector. Notice the extremely small back lobe. Although the forward lobe is somewhat broader than is generally desirable, satisfactory results can be obtained if the antenna is properly oriented. Its directivity in the vertical direction is very good so that ground reflections are no problem.

The bow-tie and reflector UHF antenna is excellent for use in primary service areas where there are no VHF stations because it has good directivity, high gain, and is easy to mount. If the bow-tie and reflector antenna is used in an area where there are VHF stations as well as UHF stations, a separate VHF antenna will be required.

Combination VHF-UHF antennas for primary signal areas are also available. These antennas are combinations of different types of antennas or two similar types. For example, some all-channel antennas use a
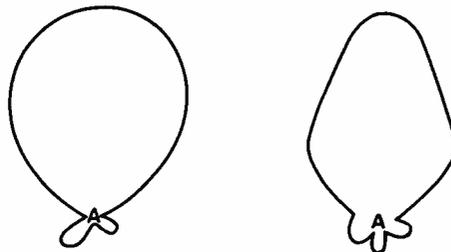
Fig. 24. Reception patterns for a corner reflector and bow-tie antenna at 500 mc (left) and 850 mc (right).
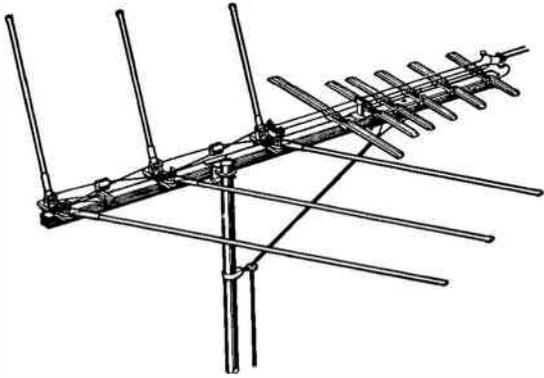
Fig. 25. A combination VHF-UHF antenna for primary signal areas.

Fig. 26. A conical antenna.

log periodic type of VHF antenna along with a broadband Yagi type for UHF. Neither antenna contains more than three or four elements since a great deal of gain is not needed in a primary signal area. Other antennas may consist of two log periodic antennas; one for the VHF channels and the other for the UHF channels in an arrangement such as shown in Fig. 17. In primary signal areas, there will be fewer elements than shown in Fig. 17. A typical VHF-UHF antenna designed for use in strong signal areas is shown in Fig. 25. This antenna has wide frequency response and good directivity and is an excellent antenna for use in primary signal areas having both VHF and UHF stations.

SECONDARY SERVICE AREAS

Reception areas between 15 and 50 miles from a VHF station or between 10 and 30 miles from a UHF station are generally considered secondary service areas. This term is not too well defined, however, and the real definition of a secondary service area depends in part on the surrounding terrain. For example, in mountainous sections, the secondary service area may begin 5 miles or less from the station.

The television signal, although originally transmitted with horizontal polarization, will become partially vertically polarized traveling through space because of reflections and other effects. In other words, the television signal at a remote location will have both a horizontal and a vertical component.

To take advantage of all the signal reaching the particular location, conical antennas were widely used in secondary service areas at one time. There are many of these antennas still in use today. A stacked conical is shown in Fig. 26. The stacking of the two bays results in a greater signal pickup than a single bay would have. This is still a good antenna for use in secondary service areas where there are only VHF stations.

In many cases, the noise level at the particular location will affect the choice of antenna. Since most noise signals are vertically polarized, if the noise level is high, a horizontal antenna must be used to prevent excessive noise pickup. Therefore, a single
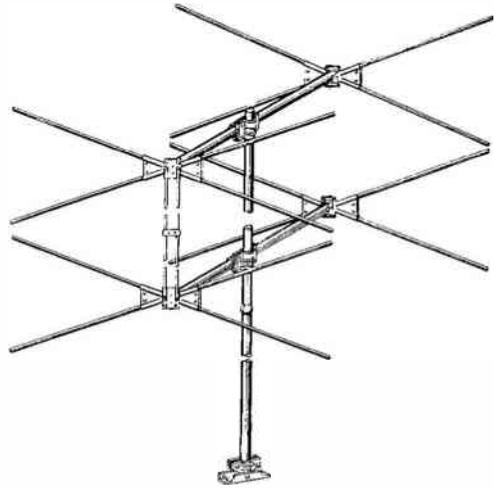
bay conical should not be used in areas where the noise level is high. However, a stacked conical will often work satisfactorily because the two bays are arranged so that the pickup of a signal having only a vertical component is low, while at the same time the pickup of signals that are not completely horizontally polarized is maximum.

In secondary VHF service areas where noise is a problem, antennas like the one shown in Fig. 27 were widely used at one time. There are still many in use and in most cases giving satisfactory performance. Notice that this is simply a stacked version of the two-bay folded dipole and reflector mentioned previously. Stacking the two antennas and maintaining the proper spacing between them, however, increases the
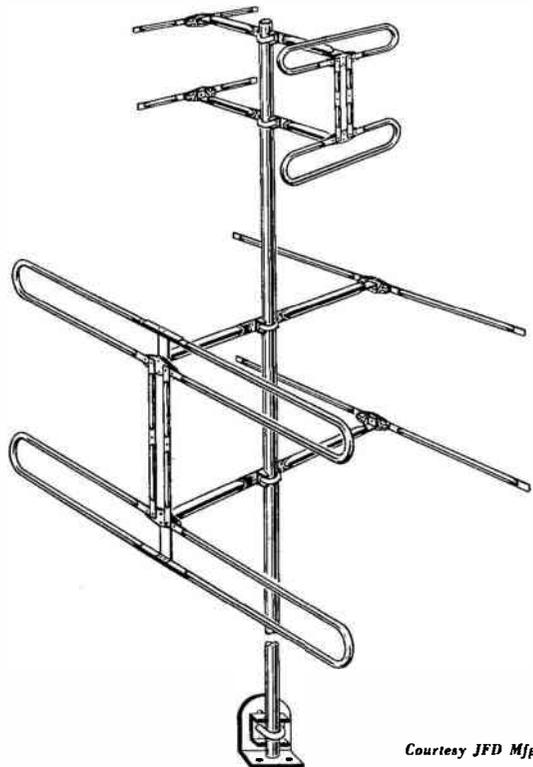
Fig. 27. Low-band and high-band stacked arrays mounted on the same mast.

gain and sharpens the forward response of the antenna. Again notice that the high-band section and the low-band section can be individually oriented for best response from the particular stations.

The most important characteristics of an antenna for use in the secondary service area are medium gain and wideband response. The antennas shown in Figs. 26 and 27 meet these requirements to a great extent, but not as well as the log periodic antenna. A VHF log periodic antenna with about five active elements makes an excellent antenna for use in VHF secondary service areas. They are particularly suitable for areas where there are several VHF stations operating. However, if the stations are located in different directions, it may be necessary to use a rotator to turn the antenna for best signal pickup from each station.

UHF Reception in Secondary Areas.

In secondary service areas, the bow-tie and corner reflector mentioned for the primary service area is generally satisfactory for UHF reception, provided it is properly installed. In fact, the care exercised in installing the antenna is the most important single factor in secondary service area UHF reception.

In some instances you will find that a parabolic reflector will give greater signal pickup and better results at greater distances from the UHF station than the corner reflector. A dipole with a parabolic reflector is shown in Fig. 28. If the antenna is mounted high enough, it will give satisfactory results.

Also, UHF Yagi antennas are often used. Special Yagis designed to give satisfactory response over the entire UHF band are available. These antennas are designed for use with the common 300-ohm transmission line. Further information on the proper lead-in for UHF use will be given in a later section of this lesson.

A typical UHF Yagi antenna is shown in Fig. 29. This antenna is highly directional so if you have UHF sig-

nals coming from several directions, you'll have to use a rotator with the antenna so it can be turned for best pickup on the station to which the receiver is tuned.

Log periodic UHF antennas are also available and they make an excellent choice for UHF reception in secondary areas. They have probably the best frequency response of all wide-band antennas; this is particularly important for color TV. In addition they are quite directional and therefore are good for eliminating pickup from reflectors.

Installation is seldom a problem with UHF arrays, because the entire antenna is extremely small. It is important, however, that the antenna be mounted securely so that it cannot move in the wind. Even slight movement of the antenna will often cause annoying changes in signal strength and consequent picture flicker.

When installing the UHF antenna, it may be necessary to try the antenna in several different positions on the customer's roof to obtain best results. There will undoubtedly be cases when the antenna will have to be carried all over a customer's roof before a satisfactory spot can be found where best reception with minimum interference is obtained.

In secondary service areas where there are both VHF and UHF stations, an all-channel log periodic antenna designed for a moderately strong VHF signal and a weak UHF signal is probably the best choice. The antenna shown in Fig. 30 should perform well in such an installation.

FRINGE AREAS

There is no definite technical definition of a fringe area, but it is generally considered to be any area that is more than 50 miles from a VHF station or more than 30 miles from a UHF station. Special precautions
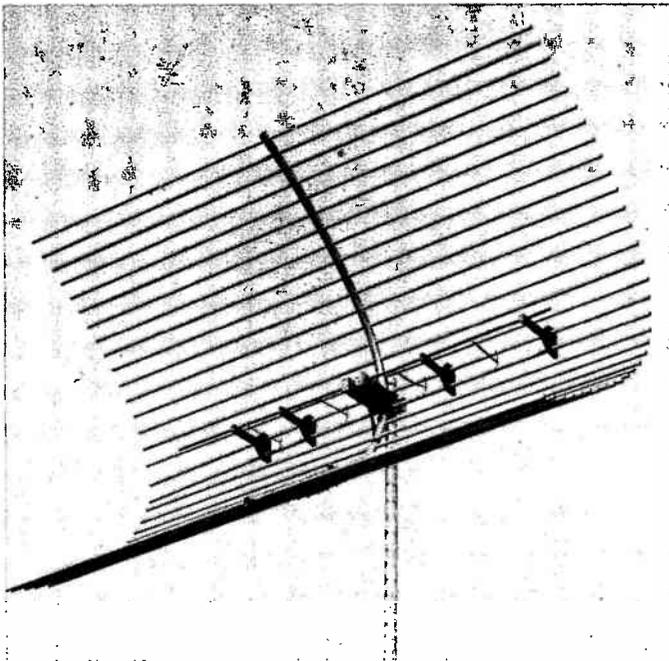
Courtesy Tele-Tech

Fig. 28. Antenna with parabolic reflector.
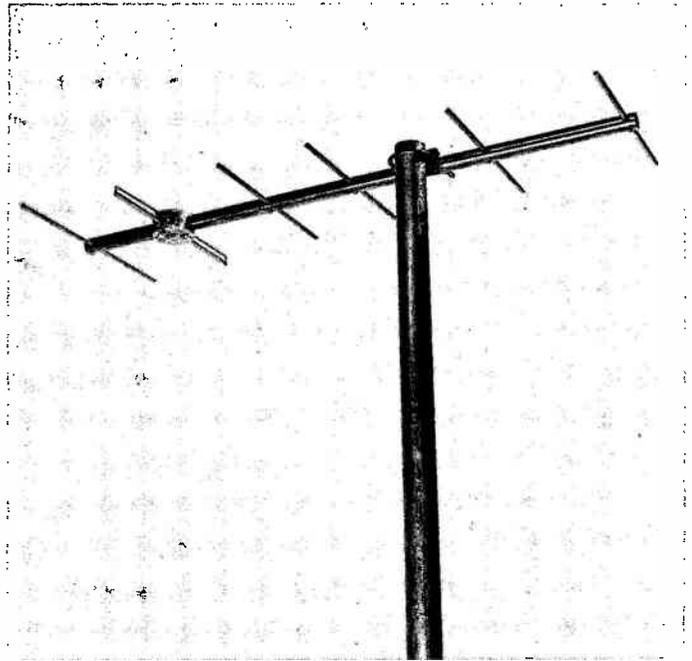
Courtesy RCA

Fig. 29. UHF Yagi antenna.
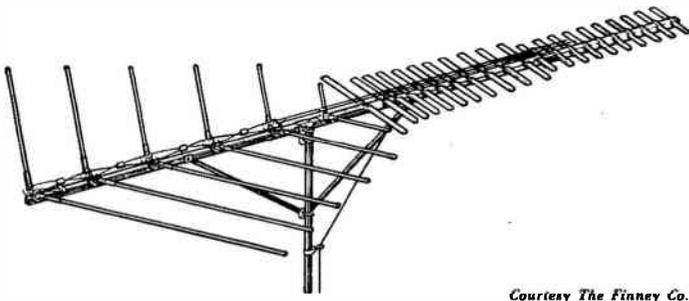
Fig. 30. All-band log periodic antenna for use in secondary service areas.

are necessary when installing antennas in such areas, both to pick up a satisfactory signal and to prevent local noise from interfering with reception. Installation techniques are very important.

A fringe area antenna must be mounted as high as possible. Masts and towers 50 feet high or more are often used to get the antenna high enough to pick up a reasonably strong signal. Of course, these masts or towers must be strongly supported by guy wires or they will probably come down in the first wind of any consequence.

If the receiving location is in a deep valley between two hills or mountains, it is often worthwhile to mount the antenna as high as possible on the mountain or hill and use a long transmission line. The loss in the long transmission line may be quite high, but this is usually offset by the stronger signal picked up by the antenna.

One system that was widely used advantageously in fringe areas is a high-gain antenna with a somewhat restricted bandwidth. The antenna is peaked for maximum gain at the video carrier frequency. This type of antenna gives a somewhat stronger signal at the carrier frequency than a broad-band antenna and also reduces response at higher video frequencies where most of the noise signal picked up in fringe areas is located. Of course, some of the higher video-frequency signal components may be lost when this type of antenna is used, but the reduction of picture interference usually more than compensates for the loss of picture detail. Many of the high-gain single-channel antennas designed for fringe area installations are peaked at the video carrier frequency. This type installation is unsatisfactory for receiving color because the response must be nearly flat across the 6 mc station bandpass. A restricted bandpass attenuates part of the color signal because it is located near one edge of the passband.

Therefore in fringe area installations, you may run into a situation where a person has purchased a new color receiver and when he tries to operate it from his antenna, he cannot get any color on the receiver even though he was getting satisfactory black-and-white reception. If the receiver will produce a color bar pattern when connected to a color bar generator, then it is likely that the failure to pick up color broadcasts in color is due to the narrow bandwidth of the antenna. The antenna is simply not picking up the color subcarrier and its sidebands.

The use of antenna rotators and preamplifiers (boosters) is common in VHF fringe areas. Weatherproof boosters are designed to mount on the mast at the antenna. A typical booster of this type is shown in Fig. 31. By amplifying the signal before any line noise is picked up, the signal-to-noise ratio can be improved, and satisfactory results can be obtained in areas where it would otherwise be impossible.

Modern boosters are made in two separate units; a small transistorized amplifier in a weatherproof case which you mount on the top of the antenna mast as close to the antenna as possible and a power supply. The power supply is mounted indoors where it is protected from the weather. Boosters are available only for the VHF channels; practical low cost UHF boosters are not available.

An antenna rotator allows the set owner to orient the antenna so that best possible reception is obtained from a particular channel. An antenna rotator is a low-speed reversible motor mechanically coupled to the mast, with a control box at the receiver. This allows the viewer to orient the antenna for best possible reception on each channel.

There have been many different VHF TV antennas manufactured for fringe area reception, but those available today are either the Yagi-type, or derived from the Yagi or a log periodic type of antenna. One of these types is the best choice for fringe areas. An
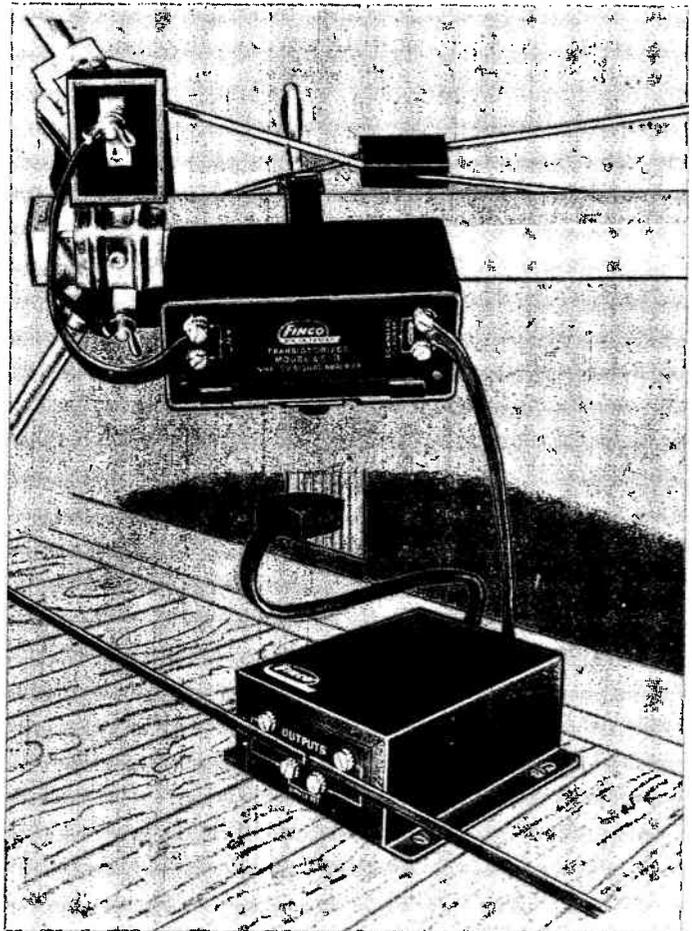
Fig. 31. A booster designed for installation at the top of the antenna mast.
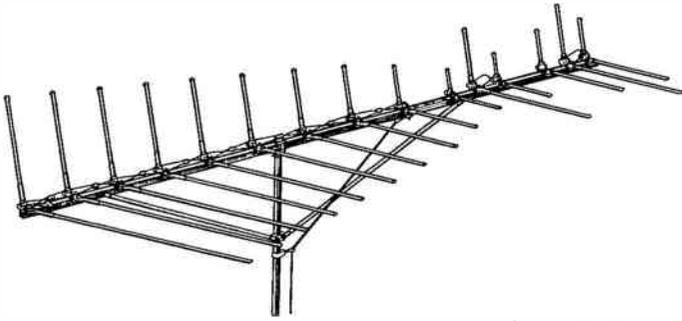
Fig. 32. A fringe area VHF antenna.

example of a VHF log periodic antenna is shown in Fig. 32.

UHF Reception In Fringe Areas.

UHF reception is generally impossible more than 75 miles from the station. The fringe area for UHF is usually considered to be the area from 30 to 75 miles from the station.

In UHF fringe areas, stacked arrays or multiple element Yagis have been widely used. A stacked array may consist of two or more Yagis with suitable matching bars. A stacked array consisting of two Yagis is shown in Fig. 33. Each Yagi consists of a folded dipole with a reflector and four directors. Stacked corner-reflector arrays can be used.

VHF-UHF Reception.

In most fringe area locations today, service is available from both VHF and UHF stations. Therefore it is advantageous to use a single antenna that will cover all the channels. A high gain log periodic antenna designed for VHF and UHF reception in fringe areas is shown in Fig. 34. This antenna has the advantage of earlier high gain antennas which have essentially a flat response on each of the TV channels. Thus the antenna is well suited

for color reception as well as monochrome. An added advantage of the antenna shown in Fig. 34 is that it provides coverage of the FM broadcast band as well as the VHF and UHF channels. Thus if the TV set owner also has an FM receiver, it is not necessary to provide a separate FM antenna.

As mentioned previously, in fringe area installations it is important to get the antenna as high as possible. Orienting the antenna for maximum signal pickup or using a rotator is equally important. Also, the best quality lead-in available should be used to keep the attenuation of the lead-in as low as possible. Keeping the lead-in away from grounded objects also helps to keep losses in the lead-in at a minimum.

Fig. 34. Example of a log periodic antenna that provides high gain flat response over the VHF, FM and UHF bands.

ANTENNA PROBLEMS

Most of the problems that occur with antennas have been covered in the discussion of types of antennas for each signal area. Four characteristics affect the performance of an antenna. These include bandwidth, gain, radiation pattern, and stray resonant conditions. When each of these characteristics meet the needs of the signal area, the antenna performance will be satisfactory.

The bandwidth of the antenna must be sufficient to give the needed gain to those frequencies that the TV set receives. The gain of the antenna may be different for different channels within the band of frequencies covered. However, the gain over the frequencies for a single channel should be reasonably flat. For monochrome TV reception, a variation of 2 to 3 db over the 6 mc occupied by a TV channel is usually tolerable. For color reception, a variation of no more than 1.5 db is desirable. Since the response of the transmission line and the tuner may not be perfectly flat, it is possible for the poor response points to accumulate and cause serious overall distortion of the signal.

The radiation pattern of the antenna affects not only the signal received but also it affects the amount of undesired signals rejected by the antenna. For ex-

Fig. 33. A stacked Yagi array.

ample, an antenna with a broad radiation pattern may have adequate gain to receive the desired signal. At the same time, the broad pattern may permit the antenna to pick up undesired signals such as reflections. We usually associate a narrow radiation pattern with increased gain. However, here is a case where the gain is not needed but the narrow pattern is still desirable. The signal areas where interfering signals are a problem, improved antenna directivity almost always helps. In worse cases, an antenna rotor and a highly directional antenna may be the only solution.

Stray resonant conditions in an antenna system can produce poor reception. Any metal surface near the antenna can produce a stray resonant condition. These include the antenna cross arms and tie rods. The metal acts as a parasitic element in the antenna field. The field around the metal may add-to, or subtract-from, the normal antenna pattern. This introduces bumps or dips in the antenna response curve and causes poor reception at certain frequencies. These conditions are more likely to occur at UHF frequencies where short pieces of metal become resonant frequency lengths. Also, the effects are more noticeable on color reception than on black-and-white pictures.

SELF-TEST QUESTIONS

(x) When two or more similar antenna sections are mounted one above the other on an antenna mast, what is the unit called?

(y) What are the three general classes of TV reception areas?

(z) In what service area will the received signal be strong enough to use an indoor antenna?

(aa) What kind of signal does a window antenna usually pick up if it is installed on the side of the building away from the TV transmitter?

(ab) What type of outdoor VHF antenna is usually satisfactory for primary signal areas?

(ac) How is a basic dipole modified to get a broad response UHF bow-tie antenna element?

(ad) What improvement is provided by adding a corner reflector to a basic UHF bow-tie dipole?

(ae) What antenna type is good in areas where the TV signal contains both horizontally and vertically polarized components?

(af) What is one serious disadvantage of a single bay conical antenna?

(ag) What reception fault results if a UHF antenna sways even slightly in the wind?

(ah) In what type of TV reception will an uneven antenna response across the 6 megacycle TV channel be most noticeable?

(ai) What device can be used with an antenna to increase the TV signal strength in fringe areas?

(aj) What type antenna is available that will give high gain response over the VHF, FM and UHF bands?

(ak) What important advantage does a directional antenna have besides providing gain for the desired signal?

Transmission Lines

The lead-in used to connect an antenna to a television set is called transmission line. Three types of these lines—coaxial, twin-lead, and shielded twin-lead—are in use. First we will learn the physical characteristics of these lines, then study their electrical operation as carriers of rf current.

Like any other conductors, transmission lines have distributed inductance and capacity. A line therefore has impedance when it is carrying rf current. In television, we are concerned with the "characteristic" or "surge" impedance of a line, which is the input impedance of an infinitely long section of that particular line. This characteristic impedance is determined by the physical construction of the line and by the electrical properties of the material used in it.

Other important properties of a transmission line are its attenuation, which is usually stated in db per 100 feet for signals of various frequencies, and its ability to reject interference. We discuss each of these factors in the following description of the three main types of television transmission lines.

TYPES OF LINE

Coaxial Line.

The coaxial line, shown in Fig. 35, consists of a wire surrounded coaxially by a tube of flexible metal braid that is spaced evenly from the wire by insulating material. The center wire and the outer braid (which is covered with waterproof insulation) are the two conductors in this line.
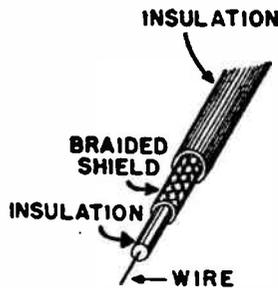
Fig. 35. A typical coaxial transmission line.

The diameter of the wire, the distance between the wire and the braid, and the dielectric constant of the insulating material determine the impedance of a coaxial line. The kind commonly used in television installations (sold under the code number RG59U) has an impedance of 72 ohms. Its attenuation is 2.2 db at 40 mc, 3.75 db at 100 mc, and 5.6 db at 200 mc per 100-ft. length.

When coaxial line is used, the metal braid is grounded at the receiver. It therefore acts as a shield around the central wire, reducing interference pickup considerably. Because of this ground connection, the line should be used only with a set having an unbalanced input.

The two most important advantages of coaxial cable, or "coax" as it is commonly called, are its relative freedom from interference pickup on the line and its

ability to serve as its own lightning arrester. (If the shield is properly grounded, lightning will jump through the insulator surrounding the center conductor and return to ground before it reaches the receiver input.) The greatest disadvantage of coax is the high attenuation of high frequency signals. This attenuation is so high at UHF that the use of coax in UHF installation is completely impractical.

Twin-Lead.

The twin-lead line, shown in Fig. 36, consists of two flexible wires molded into a flat ribbon of plastic insulating material. The impedance of the line depends upon the diameter of the wires, the spacing between them, and the dielectric constant of the insulation. The kind most commonly used in television installations has an impedance of 300 ohms, although 150-ohm and 72-ohm twin-lead can also be obtained.

Fig. 36. An unshielded twin-lead transmission line.

The 300-ohm type has an attenuation of 1.1 db at 40 mc, 2.1 db at 100 mc, and 3.6 db at 200 mc, per 100-foot length. As you can see, its attenuation is far less than that of coaxial cable, a factor that can be very important in an installation made where the signal strength is low. It does not reject noise pickup as well as coaxial line.

Twin-lead is very popular because it matches the most common receiver input impedance, 300 ohms, and it is easy to install. Also, the cost of twin-lead is quite low. The attenuation is quite low when the line is kept dry and free from soot. If the line becomes wet, the losses increase greatly, particularly at UHF frequencies. The wet loss jumps to about 20 db per 100 feet in the UHF band. This means that only one-tenth of the antenna signal voltage reaches the receiver. Therefore, this type of line cannot be used for outdoor installations at UHF.

Tubular Twin-Lead.

This special type of twin-lead was originally designed to prevent excessive "wet" loss in the line. The original type is shown in Fig. 37. Notice that the center space is hollow so that there is practically an air dielectric between the two wires.
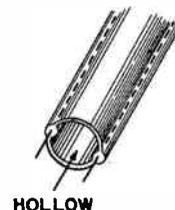
Fig. 37. Tubular twin-lead with center hollow center.

This type of twin-lead has a low attenuation figure whether wet or dry. It does, however, have a tendency to fill with water if the upper end of the line is not sealed. Even if it is, a certain amount of moisture collects inside the line due to condensation, and a drain hole must be provided at the bottom of the line.

Fig. 38. Tubular twin-lead with polystrene center.

Another type of tubular twin-lead is shown in Fig. 38; instead of having a hollow center, it is filled with a dielectric material that has characteristics similar to those of air.

This type of line has low loss, whether wet or dry, and has the added advantage of freedom from losses due to collection of moisture inside the line. Tubular twin-lead with the center insulator is generally preferred for UHF and for combination VHF-UHF installations where a single transmission line is used.

Shielded Twin-Lead.

If it were made in the conventional manner, a 300-ohm shielded twin-lead line would have to be extremely large in diameter, because the shield would have to be spaced far away from the conductors to reduce the capacity between them. However, the shielded twin-lead line, shown in Fig. 39, is reasonably small and yet has an impedance of 300 ohms.
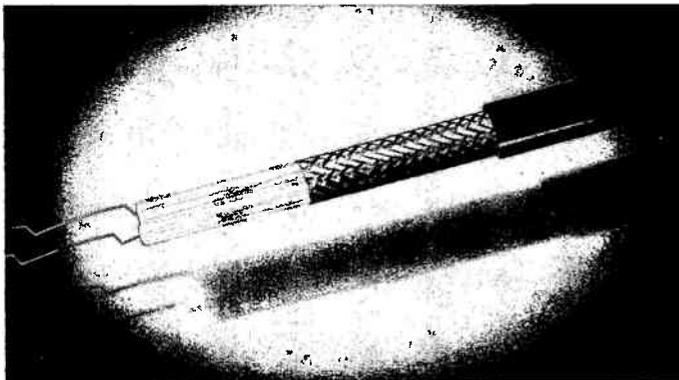
Courtesy Federal Tel. and Radio Corp.

Fig. 39. A shielded 300-ohm twin-lead transmission line.

The two conductors used in this line are crimped into a series of sawtooth sections. In manufacture, a tube of polyethylene (a plastic insulator) is extruded around each of these conductors. Each conductor touches the tube in which it is encased only at the points of the sawtooth; otherwise, the conductor is surrounded only by air. The effect of this construction is to reduce the capacity between the two conductors and the capacity between the conductors and the shield, because air has a lower dielectric constant than any other insulator. The line can therefore have a 300-ohm impedance and yet be reasonably small in cross-sectional diameter.

The two conductors in their polyethylene tubes are enclosed in a shield of flexible braid, which is in turn enclosed in a thermoplastic insulating jacket. This shield is grounded when the line is installed and therefore permits the line to have as good interference rejection as coaxial line.

The attenuation of this line is 2.4 db at 50 mc, 3.4 db at 100 mc, and 4.6 db at 200 mc, per 100-foot length --slightly less than that of 72-ohm coaxial cable. However, even though the attenuation or shielded twin-lead is less than coaxial cable, it is still too high to make it practical to use it for UHF or combination VHF-UHF installation.

Now that we have learned what practical transmission lines are like, let us learn how they operate when rf flows through them.

LINE REFLECTIONS

We mentioned earlier that the three important characteristics of a transmission line are its ability to reject interference, its attenuation, and its surge impedance. What effect the first two of these have on our choice of a transmission line can be stated simply. Generally speaking, we want as little attenuation in the transmission line as possible. All other factors being equal, therefore, unshielded twin-lead line is the best one to choose for an installation. If interference due to line pickup is a problem, however, a shielded line may be the only solution in VHF installations. In UHF installations, unless you can find the source of the noise and eliminate it, there is not much you can do.

Now, let us see why the impedance of a line is important.

The job of a transmission line is to deliver a signal to a load. It can do so efficiently only if the load is resistive and has an ohmic value equal to the surge impedance of the line. If the load has reactance, or if its resistance is not equal to the impedance of the line, a phenomenon known as "reflection" occurs; part of the signal that comes along the line to the load is returned, or reflected, back to the line, setting up a series of voltage loops and nodes along the line as the reflected signal adds-to or subtracts-from the original signal as the two are alternately in phase and out-of-phase. The series of loops and nodes are referred to as standing waves.

To see what effect such a reflection has in a practical case, let us suppose we have a 72-ohm line connected to the input of a set that has a 300-ohm input impedance. (Most TV receivers have a 300-ohm balanced input. A few have been made with an input impedance of 72 ohms, but these sets were made years ago and it is unlikely that you will run into any of them. Some modern receivers have been made with both 72 ohm and 300 ohm input impedances.) Suppose, too, that the line is connected to a folded dipole that has an impedance of 300 ohms.

A signal picked up by the antenna is fed into the line and travels down to the set. Because the line and the set have different impedances (that is, their impedances are not matched), only part of the signal reaches the set. The part of the signal that is not accepted by

the set is reflected back into the transmission line. This reflected signal travels back up the line to the antenna. Because of the mismatch between the antenna and line impedances, part of this reflected signal is reflected again; it travels back down the line and again appears at the input of the set.

If the line is 50 feet long, the part of the signal that has been reflected twice has traveled 100 feet farther than the original signal. Because of this difference in path length, the reflected signal will cause blurring of the picture. Line reflections caused by mismatches of impedance at the ends of the line produce exactly the same effect as that produced by multi-path reception. Severe ghosts can be produced by such mismatching, because it is perfectly possible for a strong signal to be reflected up and down the line several times, thus causing multiple signals to be applied to the input of the set.

Such reflections cannot occur if the impedance of the transmission line matches the input impedance of the set, because then all the signal that comes down the line will be absorbed by the set. If there is a proper impedance match at this end of the line, it does not matter whether there is a match between the antenna and the line as far as reflections are concerned. Therefore, one important thing to remember about a transmission line is that its impedance must match the input impedance of the set if ghosts are to be avoided.

ANTENNA MATCHING

Whether or not the antenna impedance is matched to that of the line is not important as far as reflections are concerned, as we have just pointed out. However, the lack of an impedance match will have an effect on the transfer of the signal from the antenna to the line.

We mentioned earlier that the antenna can be considered to be a generator and the transmission line its load. You know from previous studies that the greatest transfer of power between a generator and its load occurs when the two are matched in impedance. Therefore, an impedance mismatch between the antenna and the line will give less than a maximum transfer of signal power from the antenna to the line.

As far as the antenna is concerned, a line that is properly matched in impedance at the receiver end will be an infinite line--that is, its actual impedance will be equal to its surge impedance at all frequencies. Therefore, we could be sure of getting a maximum transfer of signal at all frequencies if we could match the impedance of the antenna to that of a properly terminated line at all frequencies.

Unfortunately, this cannot be done. As you learned earlier in this lesson, the impedance of an antenna depends upon the frequency of the received signal. An antenna can be made to have a fixed impedance for one frequency but not for all. Even a wide-band antenna will vary rather considerably in impedance over the television bands.

Fortunately, this fact seldom causes any problems in the metropolitan areas where most installations are made. There the signal strength is almost invariably high enough so that part of the received signal can be wasted without affecting reception. In such areas, usually the only impedance match of importance is that between the line and the set; as long as this match is made, it does not matter much whether the line and the antenna are matched. If they are not, part of the signal will be wasted, but there will still be enough to operate the set satisfactorily in most cases.

As a matter of fact, the antenna and the transmission line are often deliberately mismatched in areas of high signal strength where there are several stations. The purpose of doing so is to make reception fairly uniform over a wide band. If a 300-ohm line is used with a 72-ohm dipole, for example, there will be a 4-to-1 mismatch at the frequency for which the dipole is cut. This will cause a loss of signal for that station; since the signal strength is high, however, this loss is not serious. At higher frequencies, where the dipole does not pick up as well, its impedance will increase. The impedance match between the antenna and the line will therefore improve, and the consequent improvement in signal transfer will partially compensate for the reduced response of the antenna.

This effect can be produced, by the way, only if the impedance of the antenna at resonance is lower than that of the line. The reverse of this condition (having the impedance of the line lower than that of the antenna) will not produce any helpful effect, because the impedance of an antenna always rises at off-resonance frequencies; therefore, the mismatch between the line and the antenna will get worse as the frequency increases. In fringe areas, where every bit of signal is needed, the match between the antenna and the line becomes very important.

Most antennas designed today will match 300-ohm line directly. If the basic antenna has low impedance,
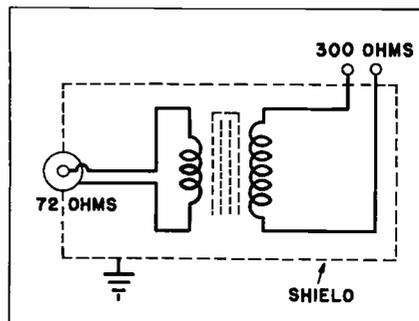
Fig. 40. A transformer for matching 72 ohms to 300 ohms.

a matching section that provides a 300-ohm antenna output is generally included as part of the antenna.

In general, you can use a 300-ohm antenna and 300-ohm transmission line in all installations. When this procedure is followed, there is no problem of matching.

If you use a 72-ohm transmission line and the receiver input impedance is 300 ohms, you should use a matching transformer between the transmission line and the receiver input. A suitable broadband matching transformer is shown in Fig. 40.

On some receivers, separate inputs are provided for connecting the UHF antenna and the VHF antenna. When this feature is provided, it is usually best to use separate lead-ins from the individual antennas. If only one pair of input terminals are provided on the receiver, however, and separate VHF and UHF antennas are used, the transmission lines from these antennas must be connected together. They cannot be connected directly, however, and a special matching network must be used to prevent excessive loss.
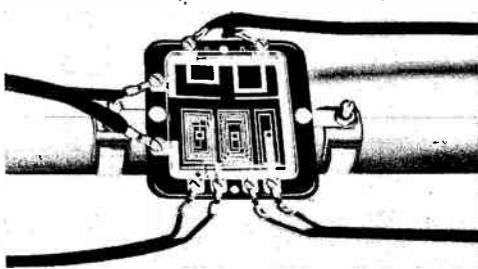
Fig. 41. Matching network for connecting a low-band VHF antenna, a high-band VHF antenna, and a UHF antenna to a single lead-in.

A complete matching network for connecting a low-band VHF antenna, a high-band VHF antenna, and a UHF antenna to a single lead-in is shown in Fig. 41. This network isolates the individual antennas and keeps losses at a minimum.

One way to eliminate the need for a matching network in VHF-UHF installations is to use an all-channel TV antenna that uses a single lead-in. With this type of antenna, the matching between the VHF part of the antenna and the UHF part will be taken care of in the design of the antenna.

As mentioned previously, most modern TV antennas have the necessary matching devices built in as part of the antenna itself. If special instructions for matching the antenna to a particular type of transmission line are necessary, those instructions will be included with the antenna.

SELF-TEST QUESTIONS

(al) Describe the construction of a coaxial transmission line.

(am) What two factors determine the characteristic impedance of a transmission line?

(an) How does the signal attenuation of coaxial cable compare with that of twin lead?

(ao) What type of transmission line is best for rejecting noise pickup in VHF installations?

(ap) What is the characteristic impedance of the most commonly used twin lead TV transmission line?

(aq) What type lead-in is most satisfactory for UHF reception?

(ar) Besides wasting the signal, what other effect can be caused by line reflections?

(as) Where is a transmission line mismatch more serious, between the antenna and the line or between the line and the receiver?

(at) What conditions must be met to get maximum transfer of signal power from the antenna to the receiver?

(au) Why is a deliberate mismatch sometimes used between the antenna and the transmission line?

(av) When a separate VHF antenna and a separate UHF antenna are connected to a single input terminal of a receiver, what is needed to prevent interaction between the antennas?

Installation of Antennas

Installing an indoor antenna is so simple that it hardly requires mention. However, there are a couple of precautions. Be sure to remove the connections to any built-in antenna before connecting the indoor antenna to the antenna terminals. Remove any frayed wires that may be left on the terminals from a previous installation. Bits of wire can short between the terminals or prevent proper connections of the lead-in wires. The lead-in wires of most indoor antennas are terminated in spade lugs for easy attachment to the antenna terminals. If you attach the bare wires, be sure to strip the insulation back far enough so you can get the wire around the terminal screw. Twist the wire so it does not spread out when the terminal screw is tightened. Wrap the bare wire around the terminal screw in the direction that the screw turns when it is tightened. Tighten the terminal screw firmly and make sure that no frayed wire ends can touch the other terminal. It is always best to use spade lugs on the antenna lead-in for an installation that will give long satisfactory service.

Where an outdoor antenna is required, antenna installation and orientation is somewhat more complicated and requires a crew of at least two men. The general procedure for installing an outdoor antenna is first to select a good location and mount the antenna so that it is held securely in place but the mast is not clamped down so tight that it cannot be rotated. The transmission line should be permanently connected to the antenna at this time, but not clamped to the mast; only a temporary connection to the receiver should be made.

The next step is to orient the antenna for optimum reception on all channels that are available in the area. At the same time this is done, the receiver should be tested for proper operation on each of the received channels. Make any needed adjustments to the receiver including the AGC adjustment. The customer will judge the antenna installation by the operation of the receiver, so be sure it is properly adjusted and operating correctly.

The final step is to clamp the antenna permanently in the best position found during orientation, secure the transmission lines with stand-off insulators, and make a permanent connection to the set.

ERECTING THE ANTENNA

The type of antenna that you put up will usually be a compromise between what the signal conditions demand and what the customer is willing to pay for. Recommend an antenna that you know will give good service. Even though the initial cost may be higher, the customer will get more for his money in the long run. For example, don't recommend a flimsy antenna structure in an area where high winds are prevalent. Also, your reputation is at stake. Do a sales job to get him to buy the installation he needs. Many of the new antennas have a gold anodize coating on the ele-

ments. These antennas are more expensive, they do not improve reception to any extent, but the gold coating does prevent corrosion of the elements so the antenna will last longer. Explain things like this to your customer so he will know what he is getting and what service he can expect. The service man who makes a good antenna installation that gives the customer years of service will be remembered long after the price has been forgotten.

You know the characteristics of the various types of antennas, and from that knowledge you should be able to select the most suitable antenna for a given signal condition. Probably the most common type of installation will consist of a mast mounted on some part of the roof or chimney with a suitable all-channel antenna for primary area reception. Of course, there are some instances where an expensive tower installation or a long mast with guy wires may be necessary with a high gain fringe area antenna.

The antennas used in primary signal areas are usually not too large; they are made of aluminum and are quite light in weight. The mast is also aluminum and not too heavy. Therefore the usual procedure in installing such an antenna is to assemble it and the mast and then pull them up to the roof for installation. The first step is to assemble the antenna and attach it to the mast.

Also permanently connect one end of a reel of transmission line to the antenna while it is still on the ground.

The next step is to raise the antenna to the roof. This usually requires two men. Tie two ropes to the antenna assembly; one at the top for a man on the roof to use to pull it up, and the other somewhere near the bottom for the man on the ground to use to hold it away from the wall of the house. Arrange the reel of transmission line so that it will reel off freely as the antenna is pulled up to the roof. Be careful not to damage or bend the antenna elements, which are made of much lighter tubing than the mast or the cross sections.

An alternative to assembling the antenna on the ground is to take all the various parts to the roof where the antenna is to be mounted, and assemble it there. This could be done by one man, but frequently the shape of the roof at the installation site is such that it is very inconvenient, if not impossible, to work on the roof with both hands free. The fewer tools the man on the roof has to handle, the fewer he will drop and have to climb back down for or have brought back up to him.

ANTENNA MOUNTS

Fig. 42 shows three common methods of mounting the antenna mast to a house. The chimney mount shown in Fig. 42A is popular with servicemen because it does not require drilling any holes. Two metal straps are placed around the chimney and tightened by means of
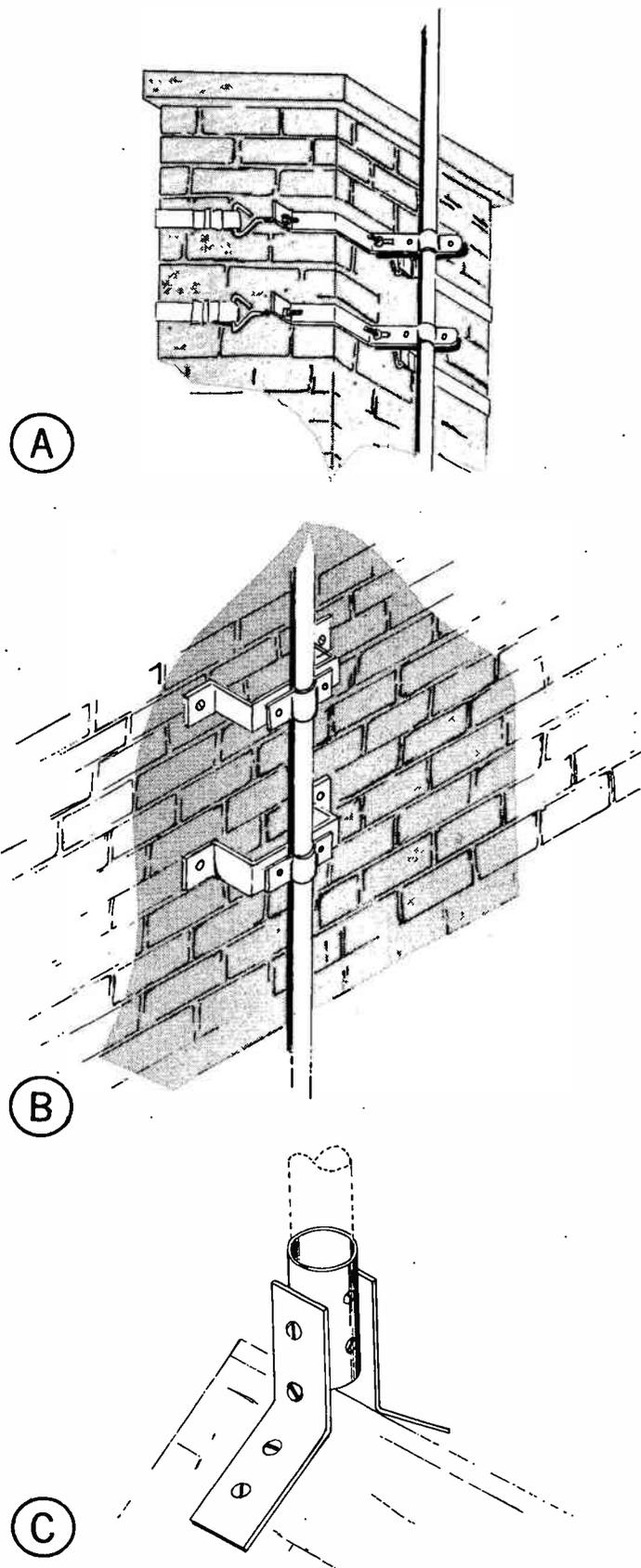
Fig. 42. Three examples of mounting fixtures for attaching the antenna mast to the house.

bolts or turnbuckles. The straps should be separated 12 to 18 inches apart. Adjust each strap so that it is level all around the chimney. The strap should rest on the bricks, not on the mortar between the bricks.

Bolts or turnbuckles on the strap are tightened to hold the straps securely to the chimney. Adjustable clamps hold the antenna mast to the straps.

Fig. 42B shows a wall mount. These mounting brackets are available in various sizes to extend the mast far enough away from the wall to clear the projecting eaves of the roof. Square-headed lug screws or large rustproof wood screws are used to secure the bracket to wooden walls. On masonry walls, the screws must be secured into the masonry. Drill the holes and insert soft lead anchor sleeves. When the screws are tightened into these sleeves, the soft material expands and anchors the screw to the masonry. In an installation of this type, the holes should be drilled in the brick, not in the mortar. The bricks are much harder to drill so there is a temptation to drill the holes in the mortar. If you put the holes in the mortar, the antenna will probably blow down in the first high wind.

Fig. 42C shows a popular roof mount for securing a mast to the peak of a roof. Holes should be drilled through the shingles to prevent the screws from cracking or splitting the shingles. Pick a location where firm wooden rafters or sheathing is available for securing the screws. Install roofing compound under the brackets to prevent the possibility of causing leaks around the screw holes. After the mounting bolts have been tightened, cover them with tar.

Once the antenna is mounted on the roof, tighten the mast clamp just enough to hold the antenna in place temporarily, because you will have to rotate the mast when orienting the antennas. After mounting the antenna temporarily, decide what route the transmission line will take to the receiver and measure off enough line to reach the receiver. Be generous; it is better to waste a few feet of transmission line when the line is finally clamped down and permanently installed than to have to make a splice in the line. When the antenna is temporarily installed and the transmission line is connected to the receiver, you are ready to orient the antenna.

SAFETY PRECAUTIONS

Antenna installations involve two areas of safety. The first is your personal safety when making the installation. The second, is the safety of the installation in relation to the house and its occupants after the antenna is installed. In most areas local regulations spell out certain safety features relating to antenna installations. These regulations have to do with lightning arrestors, ground connections, and clearances between power lines and the antenna. Most local regulations are patterned after the provisions of the National Electrical Code (NEC). These provisions can be used as a guide to safe installations. Your local electrical inspector should be consulted concerning what provisions are in effect in your area. If you make an installation that does not meet local regulations and a fire, for example, results, you may be held responsible.

Personal safety must be considered when installing outdoor antennas. Two dangers are present, the exposure to electrical shock and the danger of falling

from the roof or ladder. Make sure the ladder is placed on a secure footing before climbing it. Limit the amount of tools and parts you carry up the ladder at one time. Always leave one hand free so you can hold securely to the ladder. Metal ladders provide a conductor between you and the ground or exposed wires. Be especially careful not to touch a power line with a metal ladder. Know what is on the other side of a wall where you are drilling. If you drill through a wall and into the house wiring, your drill becomes hot. Metal ladders make a complete circuit from the drill, through you and the metal ladder to ground. This kind of electrical shock can be fatal.

The location of an antenna above the roof top makes it susceptible to being struck by lightning. The lightning can damage the receiver that is connected to the antenna or the lightning can set fire to the house. Excellent lightning protection is afforded by grounding the mast of the antenna. The receiver can be protected from electrical damage by installing a lightning arrestor. A lightning arrestor should be installed on the transmission line at the point that it enters the house. It is usually permissible to locate the arrestor inside the building but it should be as near as possible to the point that the line enters the building. The lightning arrestor must, of course, be connected to an approved ground.

An effective earth ground must be provided for the ground connection to the mast and exposed metal parts of the antenna. Whenever possible, the cold water pipe in the house should be used for the ground. This assumes that at least 10 feet of the water pipe is buried in the ground. If the ground connection is made on the house side of the water meter, a grounding wire must be connected to the pipe on each side of the meter to provide a mounting jumper around the meter. If a water pipe ground is not available you will have to make a ground. It should consist of an 8 foot 5/8th inch galvanized rod, one-half inch copper plated rod, or a 3/4 inch galvanized pipe. The ground rod should be driven into the earth at least 18 inches away from the building foundation.

The grounding wire connecting the exposed metal parts of the antenna to the ground must be one continuous wire without splices or connections. The ground wire should have as a minimum size either No. 10 copper or No. 8 aluminum wire. The ground wire should be secured to the mast and to the water pipe with suitable clamps. The ground wire must be run in as nearly a straight line as possible from the mast to the ground connection. Avoid sharp bends in the wire when it is routed around eaves and corners.

Minimum clearance must exist between the antenna and the electrical power lines. This includes the antenna elements, guy wires, and the transmission line from the antenna. The minimum clearance from a power line carrying 250 volts is 2 feet. For power lines carrying over 250 volts, the minumum clearance is 10 feet. Where the power line carries less than 150 volts a 4 inch clearance is permissible between the power line and the antenna lead-in wires if both wires are supported in a permanent position. These clearances are minimum permissible and in most installations it will be possible to easily provide greater, and therefore safer, clearances.

ORIENTING THE ANTENNA

The antenna must be oriented to produce the best possible reception from each of the stations in the vicinity. If the antenna is equipped with a rotator, of course, finding the right orientation is no problem; the customer will turn the antenna to bring in the best picture each time he tunes in a different station. If the antenna is to remain in one place, however, it must be carefully oriented before the installation is completed so that the reception on all stations will be equally good.

Orientation of the antenna is a two-man job. There must be one man on the roof to turn the antenna, and there must be another at the receiver to watch the effect of turning it. These two men must have some way of communicating with each other so that the man turning the antenna can learn what happens when he turns it. A telephone like that shown in Fig. 43 is frequently used for this purpose.

Courtesy Wheeler Insulated Wire Co., Inc.

Fig. 43. A sound-powered telephone handset.

This particular telephone is sound operated. A sound-operated telephone is equipped with a high-output magnetic microphone that is capable of operating a telephone receiver over a considerable distance without amplification. The chief advantage of such phones is that they require no external power source. Conventional battery-operated telephones are, of course, perfectly usable. Two-way "walkie-talkie" radios are also suitable for wireless communication between the man on the roof and the man at the set.

Some installation crews clip their sound-powered telephones across the ends of the transmission line, thus saving themselves the trouble of having an extra inter-connecting line between the antenna position and the set position. However, connecting the telephone across the line may affect the characteristics of the line and thus impair the quality of the picture, thereby making it difficult to judge how good the picture is. For this reason we recommend that you have a separate connecting line between the two telephones.

There are many possible systems you can use to

find the right orientation for the antenna. The one we are going to describe, however, is easy to follow and has proved to be very satisfactory.

There are several different types of installations that you will have to be concerned with, but the same basic principle can be used to find the right orientation for the antenna in each type of installation. For example, in one installation you might have an all-channel antenna that is designed to receive the VHF and UHF channels. In another installation you might have a VHF antenna for channels 2 through 13 and a separate UHF antenna for channels 14 through 83. There is still a third possibility where you might have three separate antennas; one for the low-band VHF channels (channels 2 through 6), one for high-VHF channels (channels 7 through 13) and a third antenna for the UHF channels. Actually the arrangement with the three separate antennas is the most flexible and usually the easiest to orient to get best possible reception from all local stations. The single antenna designed for both VHF and UHF reception is usually the most difficult to orient. However, fortunately in recent years there has been a trend toward locating all the TV stations in the same part of the city. In fact, in some areas all the local TV stations have their antenna on the same tower. This generally simplifies the job of orienting the antenna to pickup signals from all the locally operating stations.

The best procedure to follow is to first locate the direction from which you pick up a satisfactory signal from each station. Let us assume that you are the man turning the antenna. First, orient the antenna so it faces north (that is, points its rods east and west), and have your assistant at the receiver tune in the lowest frequency station that can be received in the area. Then have your assistant describe the quality of the picture to you as you rotate the antenna. For example, if the antenna is rotated, your assistant may make a report something like this: "faint picture getting better-better-good picture-getting worse-ghosts-no picture."

You must keep a record of picture quality versus antenna position as you rotate the antenna. A convenient way to do this is to use a chart like the one shown in Fig. 44. As you rotate the antenna, draw a
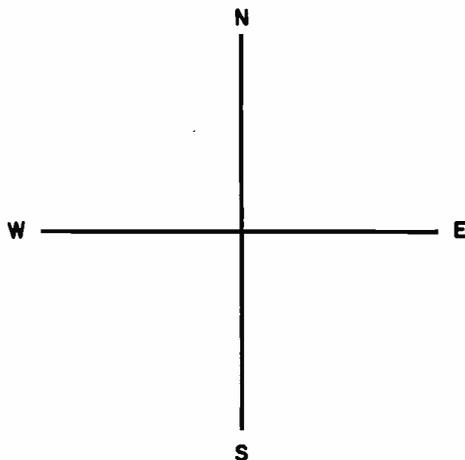
Fig. 44. Use a simple chart of this sort to help you determine the best orientation.
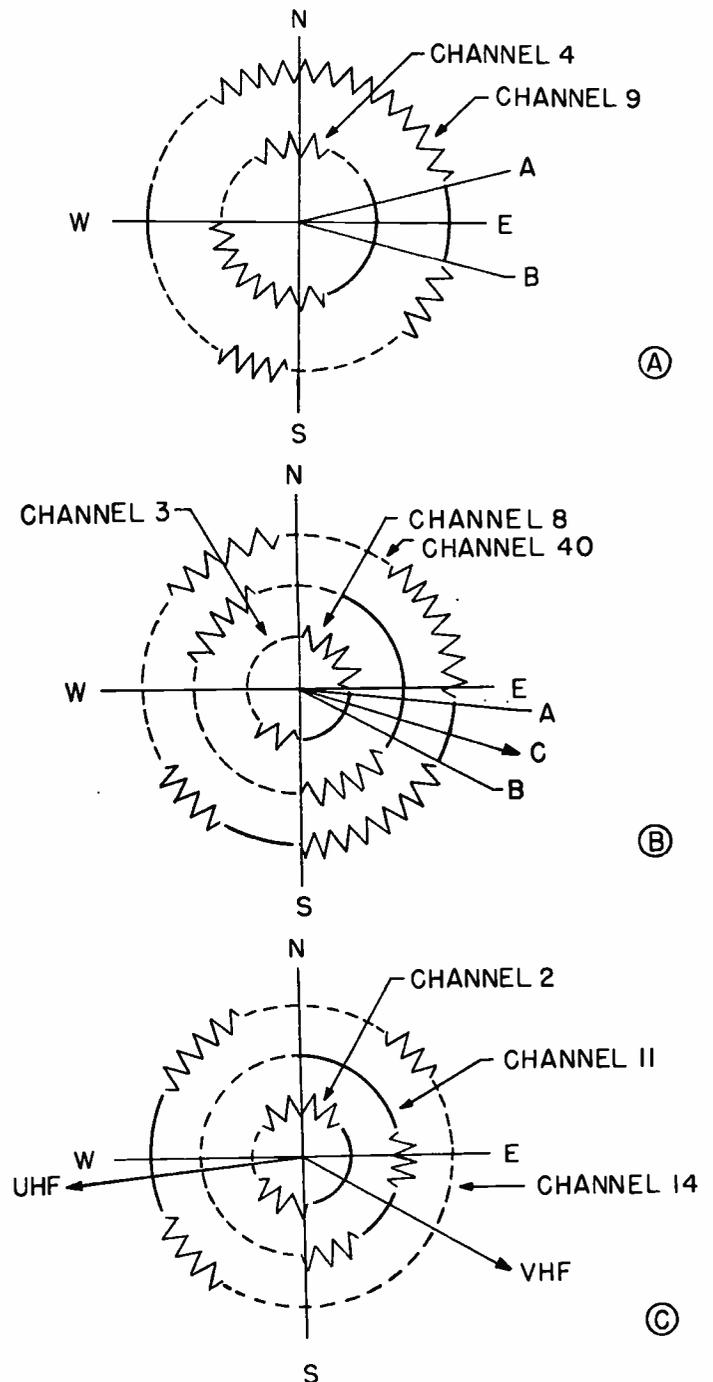
Fig. 45. Orientation charts for: (A) VHF channels; (B) VHF and UHF channels where setting of the antenna is possible; and (C) VHF and UHF channels where separate antennas or a rotator is needed.

circle on the chart using a heavy line on the circle to represent the direction the antenna is turned when reception is reported to be good and a broken line to show those directions in which the picture is reported to be poor or non-existent. If the picture is reported to have ghosts in it, draw a wiggly line to show the directions in which the ghosts appear.

In Fig. 45A we have shown the type of plot you might get in a location where you have two channels, channel 4 and channel 9. We have drawn the inner circle first and the solid line on this inner circle represents the direction from which we receive a good clean ghost-

free signal from channel 4. After you have made this chart for channel 4, you once again point the antenna due north and then rotate it through 360° as before and plot a second circular graph for channel 9. After you have done this you can see that good reception is possible from both stations in an angle formed by the lines from the center of the chart out to point A and point B. Approximately midway or in the center of this angle is due east and therefore probably the best thing to do would be to point the antenna due east since you are well inside the arc where you obtain satisfactory reception from both channels. If you have additional VHF channels you would simply go ahead and plot additional circles in the same way.

In Fig. 45B we have shown the type of graph you might get where there are three stations, two VHF stations and one UHF station. Notice that it is possible to get good reception on all three stations within the angle formed by A, the center of the chart, and B. The point C is approximately midway between A and B and therefore the antenna should be aimed in this direction. Since you can receive all stations satisfactorily from one direction, you can use an all-channel antenna and point it toward C and get satisfactory reception on the VHF and UHF channels. On the other hand, if you had separate antennas you would point them all in this general direction since this would probably make the easiest installation. Of course, if you wanted to, you could orient the separate antennas anywhere within the arc of each channel that provides satisfactory reception.

In Fig. 45C we have shown a different situation. Here we have two VHF channels and one UHF channel and we have shown that we cannot get satisfactory reception on all three channels from a single direction. In this case, you will have a choice of using a VHF antenna to pick up channels 2 and 11 and point it in the direction shown along with a separate UHF antenna and orient it in the direction shown. Two separate lead-ins should be brought down to the receiver and if the receiver has a single input you would have to use a matching transformer to connect the two lead-ins to the single input. If the receiver has separate UHF and VHF inputs, you simply connect the UHF input and the VHF lead-ins separately.

One other solution to the situation shown in Fig. 45B is to use an all-channel UHF and VHF antenna in conjunction with a rotator. In this situation you would point the antenna in one direction to pick up channels 2 and 11 and the direction shown for the UHF reception to pick up channel 14.

After you have made a few installations in your location and become somewhat familiar with the type of reception you can expect from the various stations in your location, you will know best what type of antenna to select for each installation. Needless to say, in a situation such as shown in Fig. 45C, an all-channel antenna is not particularly practical. Not only does the set owner have to continually rotate the antenna back and forth whenever he goes from a VHF to a UHF station, but also an installation with a rotator is more expensive than an installation using a VHF antenna and a separate UHF antenna.

In many installations you have far more stations than the three stations shown in the examples at B and C of Fig. 45. However, you follow the same procedure in orienting the antenna. In some cases where you are using separate VHF and UHF antennas it is more convenient to plot two charts, one for VHF stations and the other for the UHF stations. Then you can set the VHF antenna and after you have it pointed in the direction that will give satisfactory reception on the VHF channels, plot a chart of the UHF stations and then set the UHF antenna. In other situations you may have to have an antenna such as the two-band VHF folded dipoles shown earlier where you have one dipole for the low-band VHF channels and the other for the high-band VHF channels. In addition to this you might have the separate UHF antenna. In this case, it might be advantageous to plot the three charts, one for the low-band VHF stations which you can use in setting the orientation of the low-band VHF antenna. A separate chart is prepared for the high-band VHF stations and then you use this chart for setting the high-band VHF antenna. A third chart is prepared for the UHF stations and it is used to orient the UHF antenna.

SECURING THE TRANSMISSION LINE

Once the antenna itself is mounted permanently in its proper position, you are ready for the final step of the installation, securing the transmission line and permanently connecting it to the receiver. If unshielded transmission line is used, it should be spaced out from the mast with a stand-off insulator. Similar stand-off insulators, shown in Fig. 46, are available for running the line down the side of the house. The end of the metal stand-off is terminated in a wood screw for securing to a wooden wall. If the house has masonry walls, holes must be drilled in the masonry and plugs inserted for attaching the screws. Shielded lead-in can be secured directly to the side of the house without using stand-offs.

Courtesy Phoenix Electronics, Inc.

Fig. 46. Stand-off insulator for twin-lead line.

The transmission lines should be led as directly as possible from the antenna to the receiver. Unshielded twin-lead line should be twisted once every foot to reduce pickup of local interference; shielded line can be run straight.

Whenever possible, it is advisable to bring the line in through the basement and through the floor in back of the set. This will make it unnecessary to run long lengths of line through the house. To make an installation of this sort, the line may be brought down the side of the house to a basement window. You can then drill the casement of the window and bring the line in through it. Just before the line is brought into the house, a lightning arrester should be connected to it. You can

then bring the line over from the window to the point where the hole is drilled in the floor at the rear of the set.

The owner may prefer the transmission line to be brought directly into the room in which the set is located without going through the basement, or the installation may be made in a house that has no basement. If so, bring the line through a hole drilled in the casement of the window, mounting the lightning arrester outside the window. From the window, lead the line along the baseboard to the set. If it is a shielded line, secure it to the baseboard with staples; if it is unshielded twin lead, you can drive fiber-headed tacks through the center of the insulating ribbon to secure it.

Whenever you drill a hole through the casement of a window to bring a transmission line through, be sure to slant the line downward from the inside of the house. This will prevent rain from coming in along the line. Use caulking compound to fill up the hole around the lead-in after the lead is permanently in place.

It may be possible to bring unshielded twin lead-in between the two halves of the window. This will make it unnecessary for you to drill a hole through the casement.

The location of the transmission line with respect to its surroundings is often important. In addition to being run as directly as possible from the antenna to the set, the line should also be removed as much as possible from sources of interference. For example, a transmission line brought down the back of a house away from the street is much less likely to pick up ignition interference than one that is brought down the street side of the house. It is also wise to make sure that the transmission line is not in some location where it can be damaged easily -- in particular, it should be kept out of the reach of children. Also, in the case of twin lead transmission line, you should twist the line once each foot rather than run the line so the two conductors are parallel. Twisting the line will reduce noise pickup.

SELF-TEST QUESTIONS

(aw) What danger does a metal ladder have that is not present in a wooden ladder?

(ax) What is one disadvantage of assembling an antenna structure before taking it up to the roof?

(ay) What is one distinct advantage of a chimney mount for securing an antenna?

(az) Why should you drill holes through shingles before securing antenna mounting bracket screws into the solid wood behind the shingles?

(ba) What steps should be taken to prevent the antenna mounting screws from causing roof leaks?

(bb) What is the objective of orienting the antenna?

(bc) Why should stand-offs be used on antenna transmission lines?

(bd) What is the minimum distance that an antenna lead-in should be placed from a 240-volt power line?

(be) How deep should a ground rod be driven into the earth?

ANSWERS TO SELF-TEST QUESTIONS

(a) VHF and UHF signals normally do not produce skywaves so reception is limited to a direct path between the transmitter and receiver antennas.

(b) Higher frequencies have shorter wavelengths, therefore smaller objects provide good reflecting surfaces for the shorter wavelengths.

(c) Multiple images called "ghosts".

(d) When a direct path signal is unavailable, it may be possible to point a directional antenna at an object that is reflecting the TV signal and pick up enough signal for a good picture.

(e) The directional antenna is able to reject unwanted signals such as reflections.

(f) Horizontal.

(g) An electric field and a magnetic field.

(h) The electric field.

(i) So the antenna elements are in the same plane as the electric field of the horizontally polarized TV signal.

(j) Length of antenna in relation to the wavelength of the received signal.

(k) Exactly one-half wavelength.

(l) Radiation pattern. The distribution of the field strength of an antenna's transmitted radiation also indicates its ability to receive radiated signals.

(m) From the ends.

(n) 16.4 feet.

(o) Folded dipole has broader frequency response.

(p) Spacing between the two long sides.

(q) Because the impedance of the folded dipole does not change as rapidly as the impedance of the simple dipole.

(r) Reflector.

(s) Director.

(t) Gain. The ability of a simple dipole to receive a signal is given as a gain of 1.0. The performance of other antenna configurations is expressed in multiples of the gain figure of 1.0.

(u) From the direction on the side of the director element.

(v) Lowers the impedance.

(w) Narrow response.

(x) Stacked array.

(y) Primary, secondary, and fringe areas.

(z) Primary.

(aa) A reflected signal.

(ab) Hi-lo folded dipole.

(ac) By using tapered sections for each half of the dipole element.

(ad) Increased gain and directivity.

(ae) Conical antenna.

(af) Excessive noise pickup because it responds to vertically polarized signals.

(ag) Picture flicker.

(ah) Color reception.

(ai) Preamplifiers (boosters).

(aj) Log periodic antenna.

(ak) Rejects unwanted signals.

(al) A center conductor surrounded by an outside conductor, usually braid covered with insulation. The two conductors are separated by insulation.

(am) Physical construction and electrical characteristics of the material used.

(an) Coax has much higher attenuation.

(ao) Coax.

(ap) 300 ohms.

(aq) Tubular twin-lead.

(ar) Smearing or multiple images on the received picture.

(as) Between the line and the receiver.

(at) Match the antenna to the transmission line and match the receiver to the transmission line.

(au) To get more uniform reception over a wide band of frequencies in a strong signal area.

(av) An isolation network.

(aw) Electrical shock. The metal ladder can provide a conductive path from you to ground.

(ax) The antenna elements may get bent in handling.

(ay) It is not necessary to drill holes.

(az) To prevent the screws from splitting the shingles.

(ba) Apply roofing compound under the brackets and tar over the screw heads.

(bb) To get good reception with minimum interference on all available channels.

(bc) To prevent the line from blowing in the wind and damaging the line.

(bd) Two feet.

(be) 8 feet.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. How does refraction (bending) affect the distance at which a television signal can be received?

2. Assuming sufficient antenna directivity, how can ghosts caused by multiple-path reception be eliminated?

3. What is the impedance of a folded dipole operated at its resonant frequency?

4. What is the primary disadvantage of a built-in antenna?

5. What is the minimum wire size recommended when aluminum wire is used as a ground wire?

6. Why is it preferable to install a preamplifier (booster) at the antenna instead of at the input terminals of the receiver?

7. What is the most important factor to consider in choosing an antenna for color reception?

8. Which has the highest loss: coaxial line, twin-lead, or shielded twin-lead?

9. What is an antenna element called that receives a signal and re-radiates the signal to another part of the antenna?

10. Proper impedance matching between the antenna and the transmission line is important: (a) to obtain maximum signal transfer, (b) to prevent ghosts.

SHOULD YOU DEPEND ON LUCK?

Accident -- chance -- luck have very little bearing upon the production of any great result or true success in life. Of course, there have been many discoveries and accomplishments which may seem to be the result of "luck".

For instance: Newton "discovered" the law of gravity by watching an apple fall from a tree. Galileo "invented" the telescope after hearing of a toy constructed by a spectacle-maker. Brown "invented" the suspension bridge after watching a spider throw its web.

But these discoveries and inventions were made by men trained to take advantage of what they observed. Thousands of untrained men had seen the same things and paid no attention.

The new discoveries in Radio-Television-Electronics will be made by men trained to take advantage of what they observe.

J. M. Smith

COLOR TELEVISION SERVICING
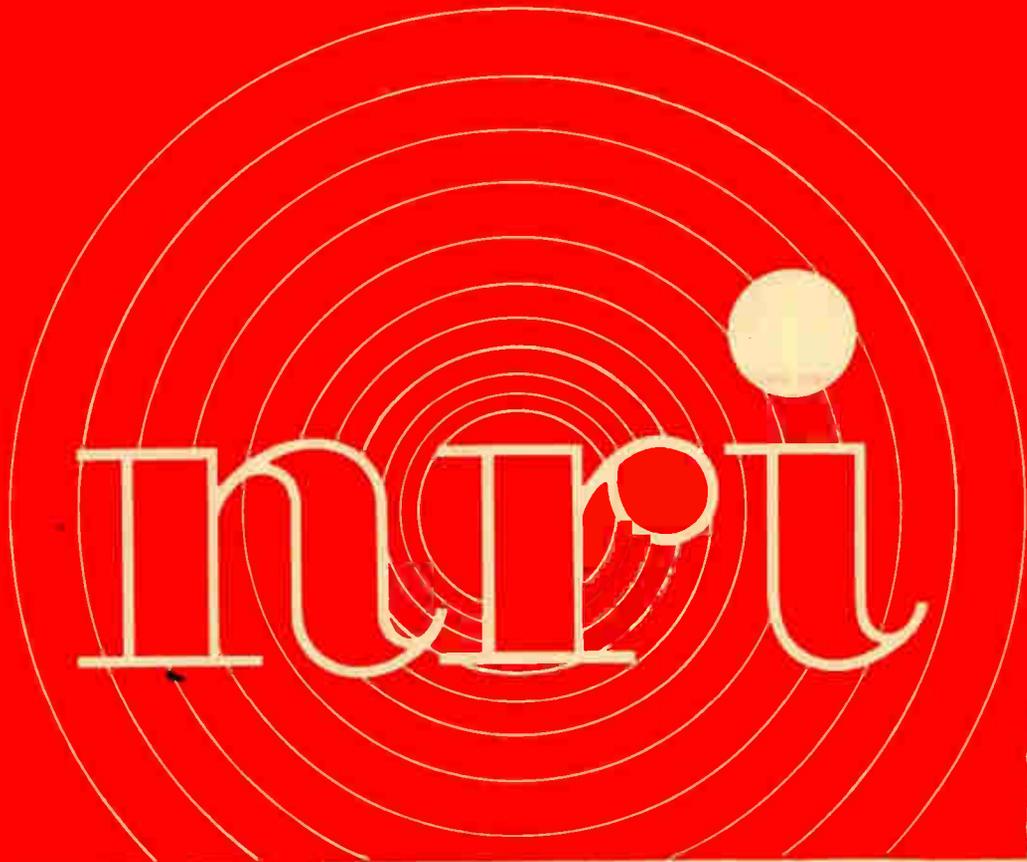
INSTALLATION AND ADJUSTMENTS
OF TV RECEIVERS

B516

USING THE TV RECEIVER
AS A SERVICING TOOL

B517

TV RECEIVER ALIGNMENT

B518

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INSTALLATION AND ADJUSTMENTS OF TV RECEIVERS

●

STUDY SCHEDULE

> For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

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INSTALLATION AND ADJUSTMENTS
OF TV RECEIVERS

Performing adjustments on TV receivers is a very important part of TV Servicing. While adjustments may appear to be incidental to repairing a receiver, this is not the case. Your first contact with a defective receiver is to see how the receiver responds to the controls and adjustments. Your last contact with the repaired receiver is to check the operation of the controls and make any needed adjustments. Thus you will find that making adjustments to TV receivers constitutes a very large percentage of the total servicing.

Developing your skill at making adjustments will do much to speed your servicing work. The ability to quickly run through the receiver adjustments enables you to judge the receiver operation. This is an important first step in locating the trouble in a defective receiver. Likewise when you give a repair estimate to a customer, your estimate may have to be based almost entirely on what you learn from operating the controls and making adjustments. The more information you get, the more accurate your estimate will be. Accurate estimates improve customer relations.

The customer tends to judge your technical competence by how you operate and adjust his receiver. While this may not be entirely fair, remember you are dealing with people. The customer reasons that if you are unable to operate his receiver, how could you possibly find a defect in the complicated circuitry. If you have never seen his particular model of a receiver before, you may have trouble locating some of the controls. However, once you get into the circuitry, you would probably find it very familiar and have no trouble locating and correcting the fault. For these reasons, you must learn to instill customer confidence by skillful manipulations of the receiver controls and adjustments.

Your success as a TV technician will depend as much on customer relations as it does on technical competence. When you install a new receiver or make a home service call, your every action is observed by the customer. This is probably your first contact with the customer and first impressions tend to be lasting. You must work out a standard routine that will show you up in a good light. While you are under the watchful eye of the customer, consider how each of your actions appears to the customer. Thus your routine will be guided more by how it appears to the customer than by the technical reasons for doing it. Several sections in this lesson deal with work in the customer's home. As you study these sections, try to develop attitudes that will induce good customer relations.

While this lesson covers the installation and adjustment of both monochrome and color receivers, special emphasis is placed on the color adjustments. Color receivers require more accurate adjustment than black-and-white receivers. Also, many of the adjustments interact and must be made in the correct sequence. In using the secondary controls for testing the color receiver, you must be careful not to upset adjustments that you are not equipped to properly readjust. For these reasons, you need to become very familiar with adjustments on color receivers.

A complete color setup procedure is given in this lesson. You will want to refer to this procedure the first few times that you set up a color receiver. The manufacturer's literature for each receiver gives the setup procedure and you should follow it. However, you will usually find these procedures quite abbreviated. They assume you know how the adjustments are made and the reasons for making them. The procedure they give enables you to locate the controls and perform the adjustments in the correct sequence. The information we give in this setup section will help you to interpret the manufacturer's instructions and enable you to better understand the reasons for each adjustment of the setup.

Mastering the skills of setting up and adjusting a TV receiver requires a good overall understanding of the receiver. An individual control or adjustment is located in some particular circuit in the receiver. However, when you are making the adjustment, you must think in terms of how it affects the overall operation and what other adjustments can cause a similar effect. For example, you know that the contrast control changes the amplitude of the video signal to the picture tube. However, insufficient contrast could also be caused by an improper setting of the agc control. You have already studied the overall receiver and the individual sections of the receiver. Use this knowledge when making adjustments. Learn to "shift gears" in your thinking. As you make an adjustment, you may want to think of the particular circuit where the adjustment is located. But then as you observe the picture, try to think in terms of the receiver block diagram. This is particularly helpful in deciding what adjustments to try next. As you develop your skill, you will do these things automatically. Never lose sight of the fact that the mechanics of turning controls to make adjustments is only a small part of the job. Your mental activity of comparing the performance, judging circuit interaction, and deciding what checks to make next are by far the most productive part of the job.

This lesson includes a section on installing picture tubes. The picture tube presents hazards that require special safety precautions. These are important to your own safety and to the customer because you may want to replace the picture tube in the customer's home. You learn how to test picture tubes to determine when replacement is necessary. The picture tube is the most expensive single part in a TV receiver. You may need a convincing test to prove to the customer that his picture tube is defective.

Home Service Calls

Any television service operation relies largely on the business centered around servicing TV receivers in the customer's home. Even if your shop is on a busy street, the only direct contact between your shop and many of your customers will be the home service call. Your reputation as a service technician will be formed mainly by what you do in making the service calls. It is your reputation among the customers that will generate new business by word of mouth recommendation. If your business is to grow and succeed you need this steady increase in new business. For these reasons, you must give much thought and effort to planning every phase of the home service calls you intend to undertake.

Plan your home service calls so they project a good image of your service operation. Whether you operate a full time service shop or are just starting in part time servicing, your service calls should reflect the kind of service you render. By this we mean that the customer should be able to judge your service operation by the way you handle the service call. This is a subtle form of communications. In everything you do, you are telling him things about your service operation. If you dress neatly, have a neatly arranged tool kit, and handle his receiver carefully, he will get the impression that you do neat, careful work. When you write a legible, itemized bill with your shop name imprinted on the top and a written warranty spelled out on the back, he recognizes that he is dealing with a responsible business man. Hundreds of little things tell him volumes about you. Make these indicators tell him the good things about you and he will feel he knows you and can trust your work.

This brings up the question of what kind of service operation you have or want to have. It is important that you know clearly in your own mind exactly what kind of operation you want. Then you can use this as a guide in planning everything you do. For example, are you going to service only radios and TV's? Or will you service Hi-Fi, car radios, mobile communications, and install sound systems?

The type of service operation you establish is influenced by many factors. Your personality, the economic status of the customers in your area, the competition you are faced with, and many other things. You can control some of these factors to a certain extent; others are beyond your control. In general, you may observe the need for a certain type of service in your area and you tailor your operation to fill that need profitably. Or you see service being performed in such a way that you can be competitive and get some of the business for yourself. You must remain alert to the service needs in your area. You may start out to build a certain type of operation but find that conditions are such that it is more profitable to change.

In any case, try to have in mind a clear picture of your operation and do everything you can to promote an accurate image of it.

THE SERVICE CALL ROUTINE

Normally a home service call starts with a phone call requesting your service. If it is a new customer, he has gotten your phone number from your advertising or by recommendation from one of your customers. In either case, this first contact with him is important. Use good telephone manners. He may have questions concerning your charges or other details of your service. Give him definite answers whenever possible. The customer may be a bit apprehensive about trusting a stranger to work on his TV receiver, which to him may be a treasured possession. Or he may be reluctant as to who comes into his house when his wife is home alone. Your telephone voice, both what you say and the manner in which you say it, must reassure him that you can be trusted. Your conversation should reflect a cheerful, friendly, impersonal, business attitude.

You should have a fixed minimum service charge that will actually cover your cost of making a service call. If the phone caller is just shopping for cheap service, be polite but firm. You can afford to pass up this type of customer. He may come back to you after he has been stung. The service operation that advertises ridiculously low service call charges must make it up somewhere. Inflated labor charges or other attempts to pad the bill will lead to arguments and hard feelings. If the customer is reasonable, he will not object to fair charges when he understands what the charges are for.

You must get a certain minimum amount of information from the phone call. Obviously you need his name, address, phone number and time of appointment. If possible, get the make and model of his receiver and a description of the complaint. Don't press for details of the complaint because he may not know the model of his receiver. If this information is available you can use it to advantage. Pull the service literature on his receiver and check what tubes or transistors are likely to cause his complaint. Look for anything unusual in the receiver circuitry so you'll be prepared for whatever you might encounter. If the receiver uses tubes, make sure you have the tubes with you that are likely to be causing the trouble.

Be prompt in arriving for the service call at the appointed time. When you make the appointment try to leave yourself a little leeway for time. For example, appointments such as "after 1 P. M." or "between 1 and 2 P. M." are easier to keep than at a fixed time. Take your tube caddy and tool kit with you when you step up to ring the door bell. Present a cheerful businesslike appearance as you state the purpose of your call.

The customer will probably turn the receiver on and demonstrate the trouble while he describes the complaint. Give him your full attention and listen carefully to the symptoms he describes. What he says

may provide an important clue to the trouble. If he does not volunteer any information, ask questions. When was the trouble first noticed? Does it do it all the time? Did the trouble develop gradually or did it start suddenly? Is this the only complaint or are there other troubles? These and similar questions can shorten the time required to complete a service call and assure that you have all the troubles fixed.

Turn the receiver on and observe its operation. See that the tube filaments light up, listen for sound -- even a hiss -- from the speaker. With a little practice you can "sense" when high voltage comes up, even when no raster is present on the screen. Operate the receiver controls and attempt to get a normal picture. Check the secondary controls since they may have been moved by the customer in attempting to get a picture. Don't spend too much time on this step -- usually two or three minutes should be enough to confirm the customer's complaint. Also, you have assured yourself that the trouble is not improper operation of the controls or a simple fault such as an unplugged line cord or broken antenna lead-in.

While confirming the complaint, you should have been able to localize the trouble to a section of the receiver. The isolation may be very broad such as: Low-voltage power supply, high-voltage power supply, sound section, sync, video signal path, etc.

If the receiver uses tubes, the most likely cause of trouble is a defective tube. Since tubes can be substituted easily, remove the back of the receiver; substitute the suspected tube and connect your "cheater" cord to the set. Observe the operation of the receiver with a substituted tube. Proceed with other tube substitutions in the suspected circuits until you find the fault or determine that the problem is not a defective tube.

If the receiver uses transistors, trying to replace transistors in the customer's home is not practical. For one thing, transistors are usually soldered into printed circuit boards. Therefore in order to try a new transistor you have to unsolder the old one and then solder the new one in place. This takes a good bit more time than it does to try to substitute a vacuum tube.

In addition, there is not the standardization between transistors of different manufacturers that there is between tubes. For example, you know that there are probably a half dozen different types of tubes being used as video amplifiers in modern TV receivers. It is within the realm of possibility to carry at least one each of these different tubes along with you. When you are going to call on a customer and do not have one of the tubes, it is economically feasible to purchase one of these tubes and take it along with you just in case that tube happens to be the one that is burned out. You know that if you do not use the tube in the set, you'll be able to use it in another receiver. However, in the case of transistors there are so many different types in use and the particular types used in one set may not be used in any other set. Therefore, it would be difficult to carry along a complete stock of transistors. Of course, there is a certain amount of substituting you can do in replacing tran-

sistors, but often this substituting must be done on an experimental basis. Therefore, it is better to do this experimenting in your own shop than it is in the customer's home. There is nothing that gives the customer a stronger feeling that he has called the wrong serviceman than if you try two or three different transistors in the one socket in the hopes of finding one that will work satisfactorily in place of one that you think might be defective.

Of course, even in transistor receivers there are certain obvious defects that you may consider worth repairing in the customer's home. Suppose, for example, you see a bypass capacitor and a series of resistors between it and B+ that are charred or burned. It is quite possible that that particular bypass capacitor broke down and if you replace it and the charred resistor the receiver will operate satisfactorily. Under these circumstances you may consider it worthwhile to perform this repair job in the customer's house rather than move the set to the shop.

One thing that you should always keep in mind in working on a customer's set in the house is that in most cases you do not have the facilities to work on the receiver that you have in your own shop. For example, in your shop you probably have a workbench with all the tools and test equipment that you might need at your disposal. In the customer's house, you usually have to work on the floor, the test equipment you have with you is limited, and there are probably many commonly-used replacement parts that you don't have. Even if you should luck out and happen to have the parts you need to complete the job, chances are that it will take much longer to do it in the customer's house than it would at the shop because of the inconvenient working conditions. Don't hesitate to explain to your customer that you are set up to do repair work in the shop and you can do the job much faster; you can check out the set more thoroughly and in the long run will give him a better job at lower cost by taking the receiver to the shop. Give him an estimate of what it is going to cost him to get the set repaired; this will eliminate any doubts from his mind that you are taking it into the shop in order to make unnecessary repairs, and at the same time will give him an opportunity to decide whether or not he wants to go to the expense of getting the set repaired at all.

How much time should you spend on a receiver in home troubleshooting? An experienced serviceman working on a familiar black-and-white receiver will not spend more than 15 minutes. If he cannot find the trouble in that time, any additional time would be better spent with the receiver on the bench. The ability to complete a service call quickly comes with experience. Remember, your time and ability is mainly what you are selling. Time yourself on service calls. Profitable servicing comes from eliminating time-wasting practices.

You will have to establish your own policy on how much service work you do in the customer's home. Doing all repairs in the home may seem like a good advertising gimmick but it is not practical in many cases. The amount of test equipment you must carry

becomes prohibitive. The trips back to the shop or supplier for special parts equalize or exceed the trip required for returning the repaired chassis. If a special part is not readily available -- even one day delay -- means you have the customer's home cluttered with the dismantled set. The set that needs chassis repairs should be run for a test period before it is returned. When you are unsoldering a defective part from the set and soldering the new part in place, there is always the danger of burning a rug or some piece of furniture with your iron or splattering solder on the floor or rug. Except for minor chassis repairs, you can almost always give the customer better service by moving the chassis to the shop.

You will be able to fix the trouble on many service calls without moving the chassis. When a receiver does not respond to tube substitution and adjustment, consult with the owner before you move the chassis. Explain to him in non-technical terms what you have checked and tell him the probable circuit fault. For example: "The picture will not hold still on the screen because there is trouble in the synchronizing circuit of the receiver. I have substituted new tubes in the circuit and this does not improve the operation." Or if the receiver uses transistors explain to him that they are soldered in place and that there are so many different types of transistors that you simply cannot stock them or carry with you all the replacements needed and therefore you want to take the set to the shop to make repairs. If you are convinced that the trouble is not a tube or transistor explain that the trouble is probably in the electrical components that connect to the tubes or transistors in the circuit and in order to fix the receiver you will have to take the chassis to the shop where you can completely test the circuit. Tell him you should be able to have the set ready for him tomorrow or Wednesday at the latest. The customer may ask for a repair estimate or he may ask why it cannot be fixed now in the home. When you have satisfied his questions he will not object to having the set moved to your shop.

Provide a receptacle to hold the knobs, screws, and small parts that are removed when you unfasten the chassis. You may prefer to leave the securing nuts and screws in the TV cabinet. Before you remove the chassis, provide a place to set it. The chassis is usually covered with dust and it should not be set on the rug or floor. After you remove the chassis, put the back on the cabinet and replace the set in its usual place. Return any furniture or lamps to their proper place. Be careful not to scratch or mar furniture -- you can be held responsible for anything you damage.

Be sure to give the customer a receipt for his chassis. Attach a copy to the chassis for identification. Include any pertinent notes such as price estimate, promised delivery date, phone number to call when the set is ready, nature of complaint or complaints, etc. This information is especially helpful if someone else does the shop work or makes the delivery.

After correcting the customer's complaint, carefully check the receiver operation. Make any minor adjustments needed on the receiver. Check for a satisfactory picture on all available channels. Try to leave the receiver with a better picture than it had before the trouble developed. If you find a different defect or that operation on one channel is unsatisfactory, check with the customer before you try to correct it. The trouble may be in the antenna installation and has always existed. Or the customer may be aware of the trouble and does not want it fixed. It does no harm to point out what you find when you give the receiver a final check.

When you complete a repair job in the customer's home, write the bill and show him your written warranty. A sample repair bill is shown in Fig. 1. Itemize the parts you installed and the complaints you corrected. The itemized bill shows what parts you have guaranteed. If other troubles develop later the bill can be referred to and it can be determined if it is the same trouble.

Be sure to let him know that you want him to call you if the set does not perform properly. A surprising number of people are hesitant about calling a serviceman back. Suppose the set breaks down again the day after you fix it. The tube you replaced may be running with a burned screen resistor and the new tube will fail. Or an entirely new trouble may develop. The customer may reason that you must not have done a very good job or it wouldn't break down that soon.

PHONE: SP-6-7986	SPEEDWAY RADIO TV SERVICE CO.

We service: 4619 SPEEDWAY DRIVE
Radio MEGOPOLIS, USA 00900
Tv
Record Changer
Hi Fi   Art Goodman
Recorders   Sole Proprietor

Customer's Name: *Felix Appotron*
Address: *16 Offway Place*
Phone: *ST-3-6000*

SPECIAL INSTRUCTIONS:

QUANTITY	PART	PRICE	
1	17DR6	3	80
1	19AX4	2	40
	TOTAL PARTS	6	20

COMPLAINT: *No light on screen.*

WORK PERFORMED: *Replaced horizontal*

CHARGES

___ Pick-up		
___ Deliver	Service Call	7	50
✓ Home Service	Shop Labor		
___ Brought to shop	Other		
___ Installation	Total Parts	6	20
Ticket No.	Tax		18
B-121657965	Total	13	88

Fig. 1. Sample repair bill. The warranty for the parts and labor is printed on the back of the bill.

Some customers will call a different shop rather than quibble about your repair job, particularly with new customers. It takes only a minute to call them a day or two later and ask if their set is operating satisfactorily. Showing an honest concern for their receiver cements good customer relations.

EQUIPMENT

The service technician who is used to doing bench work never feels that he has enough equipment when he is making a home service call. He feels lost without his special servicing aids and specialized test equipment that he can use to quickly and accurately test certain troubles in a receiver. However, the amount of equipment that is practical to take on home service calls is limited. You will have to decide yourself from experience and from your personal preference just what you will take. First let's discuss the minimum requirements and then consider some optional equipment.

A selection of tubes for substitution is an absolute necessity on service calls. It is almost impossible to carry one of each type used in various TV receivers. Your local supplier can furnish you with an up-to-date list of the tubes most widely used in your area. Also, in a particular area there will often be a predominance of one particular set that will make it easier for you to stock your tube caddy with the most often needed tubes. You will want to carry several tubes of the same type where that type is frequently used. In any case your stock of tubes will grow bigger than is convenient to carry in a single caddy. A partial solution is to have a separate caddy containing seldom-used tubes which you leave in the truck. Your tube inventory represents a sizable investment. When you first start servicing, you will probably want to carry your entire stock with you.

In a tool box, or a compartment in your tube caddy, you should carry an assortment of tools and servicing aids. The list in Table 1 is a sample of what your tool box might include. From experience you will want to add to it or you may find that you never use some of the items. You will probably find a small VOM more convenient than a vtvm for use in the home. A soldering gun is recommended in preference to a soldering iron because of the problem of stowing a hot iron after use. The antenna is listed because you are often faced with trying to determine if the trouble is in the antenna and lead-in or in the set. By substituting your antenna, even if it pulls in only a weak signal, you can judge whether the customer's antenna is at fault.

You will find a crt tester an absolute must for servicing problems involving the picture tube. This is one tube you cannot conveniently test by substitution. By observing the picture and measuring the pin voltages you can pretty well determine in your own mind if the picture tube is at fault. However, a crt checker can give you a definite indication quickly. Also if you find it necessary to sell the customer a new picture tube, showing him the indication of the fault on the tester is convincing. The rejuvenator features of a crt tester can also be used to advantage in servicing.

There are advantages and disadvantages to carrying a regular receiving tube tester on service calls. As a technician you know that tube substitution is a valid test of the tubes. Also you know that a tube may check good in a tube tester and still not work in the set. Likewise, the tube may check bad in a tube tester and work well in the set. If you carry a tube tester, the customer will often want you to test every tube in his set. To pay for your time, you will nearly have to "sell" him new tubes for each one that tests weak or bad. From experience, you know that even though the tube tests weak, but it operates properly in the circuit, it will probably continue to give years of service. You can work up a convincing argument in favor of selling the customer new tubes. However, replacing tubes that are not really needed smacks of sharp practice and is not recommended.

A color bar/dot/pattern generator is almost a must when you service a color receiver. The known quality signal that it produces is helpful in troubleshooting. When you make a final check of the receiver, the color bar pattern enables you to make adjustments quickly and accurately. Trying to judge the receiver operation by observing a live program of doubtful signal quality can be frustrating. Also the customer is usually favorably impressed by the color pattern.

A degaussing coil, gun killer, and a hand mirror are musts for servicing color receivers. You should be prepared to make the complete color setup adjustments any time you go to service a color receiver even though you will seldom have to do it.

1. VOM or VTVM
2. Soldering gun
3. Solder
4. Assorted screwdrivers
5. 1/4" spin-tight wrench
6. 4" & 8" cresent wrench
7. Gas pliers
8. Assorted hex (allen) wrenches
9. Cheater cord
10. Trouble light (AC)
11. Penlite
12. Assorted alignment tools
13. Soldering aid
14. Electrical tape
15. Lubricant (such as Lubriplate)
16. Contact cleaner
17. Drop cloth, 24" x 36"
18. Glass cleaner
19. Assorted fuses
20. Assorted antenna spade lugs
22. Tube puller
23. Tube pin straightener
24. Telescoping antenna
25. Long nose pliers
26. Diagonal side cutters
27. Stubby screw driver

TABLE 1

Most technicians will spend more in-home servicing time and do more chassis work in the home on a color receiver than they would on a black-and-white receiver. The reasons are obvious. The increased complexity of the color receiver requires more time to pull the chassis. When the set is reinstalled, a complete setup is usually required. Some shops will not pull a large color TV into the shop except when it has an intermittent defect or when other special circumstances require it.

The vehicle you use to make service calls can be considered servicing equipment. Your car is adequate if you are just starting or doing part-time servicing. Use the trunk which you can lock for carrying your tools and tubes. Do not set a chassis on the seats. It can bounce off if you hit a bump or stop suddenly. For full-time servicing you will want a light panel truck or a carry-all type vehicle. Professionally lettered signs on the vehicle are good advertising.

SAFETY PRECAUTIONS

Servicing TV receivers in people's homes exposes you to hazards to yourself and to your pocketbook. When you go into a person's home and service their receiver for profit, you become liable for any damage you cause. For example, if you stumble over a dog and drop the customer's chassis in his living room, you can expect to have to repair the damage to his receiver; pay to have the floor refinished; and even pay a veterinary bill for the dog. While these things do not happen often, you should be aware of the possibility. It is easier to avoid accidents by working carefully than to repair the damage of careless acts. You may want to carry liability insurance to cover your service operation.

Exposure to electrical shock is present when working in the home as well as in the shop. A defect in the receiver can cause a part to be hot that is normally at ground potential. The antenna lead-in may be touching a power line and carry voltage to the set. Always work so that you will be protected even if a normally safe part becomes hot. For example, leaning against a metal radiator while reaching into a TV receiver is just asking for a lethal shock. Beware of metal floor lamps that are near the receiver. A frayed power cord to the lamp may make the metal hot.

Always discharge the high-voltage power supply before removing tubes in the high-voltage section or removing the anode lead from the picture tube. While a shock from the residual charge is not dangerous electrically, your sudden reaction to even a minor shock can cause you to break something or badly scratch your hand.

Detailed precautions for handling picture tubes are given elsewhere in this lesson. While working in the customer's home, you must take added precautions. When you are handling the picture tube, ask the customer to keep clear of the area so that he will not be endangered by flying glass if the tube should break. If you install a tube in the home, leave the new tube in the shipping carton until you are ready to install it. Then put the dud into the new tube carton. This provides added protection while the tube is being transported.

SELF-TEST QUESTIONS

(a) Why is it important to write an itemized bill for a TV repair job?

(b) What are the advantages of a written warranty on a repair bill?

(c) What costs should your fixed service charge cover?

(d) What information must you get from a phone call requesting TV service?

(e) How long should it normally take to confirm the customer's complaint when you first examine his receiver on a home service call?

(f) How long should it normally take to locate and correct the trouble in the average home service call on a black-and-white receiver?

(g) What is the advantage of carrying a soldering gun instead of a soldering iron on home service calls?

(h) What extra pieces of service equipment should be carried for making color receiver service calls?

(i) Besides the TV receiver, what other dangers from electrical shock are present when servicing a receiver in the customer's home?

(j) Is it necessary to explain operating limitations of a TV receiver or installation to the customer?

Installing A New Receiver

The proper installation of a new receiver, whether it is black-and-white or color, can have a big effect on the satisfaction that the customer gets from using the receiver. It might be more accurate to say that a poor installation can detract from the set's performance. The objective of a good installation is to make it possible for the customer to enjoy the best performance that the set is capable of delivering in the location in which it is used. Thus a set that was not designed for fringe area reception will never give as good reception in a fringe area as it would if operated near local stations. However, a good installation may make it possible for the owner to get satisfactory reception.

When you install a new receiver, you should think of yourself as a technical advisor to the customer. The salesman who sold him the receiver probably had very little technical know-how. The customer seldom reads the manufacturer's operating instruction. Therefore, you must assure yourself that the customer knows how to properly operate the receiver. Likewise you will have to explain any operating limitations that the installation may have. For example, the salesman may have assured the customer that the set would perform excellently on an indoor antenna. Upon installation you find that it receives all local stations well and also picks up a faint snowy picture from a station in a city 30 miles away. Show the picture to the customer and tell him where the signal originates. Explain that the receiver could probably produce a good picture on that station if it were connected to an outdoor antenna mounted on a suitable mast. If it is a network station, explain that he gets the same programs on the local network station and therefore there is no reason to spend the extra money to try to pick up the additional station. Explanations of this sort assure the customer that his set is performing as it should and prevents possible call-backs.

You may get installation jobs as a result of selling sets, having an agreement with a store that sells sets, or a customer may have you install a set that he has purchased. In any case you want to do a good job that will satisfy the customer. If you plan the installation carefully, you can avoid problems that cost you time.

Installation jobs vary in complexity. Some installations may consist of simply delivering the receiver and demonstrating its operation. Others may include the installation of an outdoor antenna. An installation in a commercial location may require solving problems of locally generated noise and interference. Unless you are quite sure that it will be a normal installation, it may be worth your while to stop by the location before the appointed time of installation. This will enable you to size up the job and you will be sure to have everything you need with you when you arrive to make the installation.

PREPARING THE SET FOR DELIVERY

The receiver should be unpacked, inspected, and tested in the shop before it is delivered to the customer's home. TV receivers come packed in cartons with all the tubes, including the picture tube, installed. Remove the set from its carton and remove all of the packing material. Next, inspect the set thoroughly for any damage that might have occurred during shipping. If the receiver uses vacuum tubes, check to see that all tubes are in their sockets and check the connections at the high voltage lead on the picture tube, the speaker plug, and the antenna. Inspect the set for damaged parts or loose connections and correct any defects.

The initial adjustment of the receiver should also be done in the shop. It assures you that the receiver will work when you install it in the customer's home; any difficulties will then be caused by external conditions rather than some fault in the receiver. Also, checking the receiver in the shop enables you to become familiar with any new or unusual features that the set may have. You can then confidently demonstrate the operation without stopping to figure out a peculiar switch or control.

If possible, it is best to put the set back in its carton when handling it during delivery. This will prevent damage to the cabinet. Special precautions should be taken in transporting a receiver from the shop to the customer's home. As far as possible, it should be kept level at all times to prevent any of its parts from shifting position. To prevent its finish from being damaged, the set should be handled like any other piece of fine furniture. If the set has been removed from its shipping carton, it should be protected by quilted pads while it is in the delivery truck. It should be supported by bands or ropes to keep it from shifting around or perhaps falling over while the truck is moving.

RECEIVER LOCATION

The location of the set inside the home is, of course, up to the customer. If he chooses a very poor location, however, you should point out the disadvantages of the location in a tactful manner and suggest a better one. Remember, if the customer gets eye strain from watching a set that is in a poor location, he will be apt to blame the set rather than its position.

Lighting.

In general, a set should not be placed so that a bright light (such as from a window or from lamps) is behind it or near it, as at A in Fig. 2. The eye will automatically adjust itself to the brightness level of the bright light rather than to the brightness level of the picture, with the result that the picture will seem dark. Neither should the set be located so direct rays of a light can fall upon the face of the picture tube, as at B in Fig. 2. If they do, the apparent contrast and brilliance of the picture will be reduced, and there may be reflections and glare from the tube face. Preferably, the set should be located so that the direct rays of any light entering the room will be at right angles to the line of vision of the person watching the set. Hence, from a
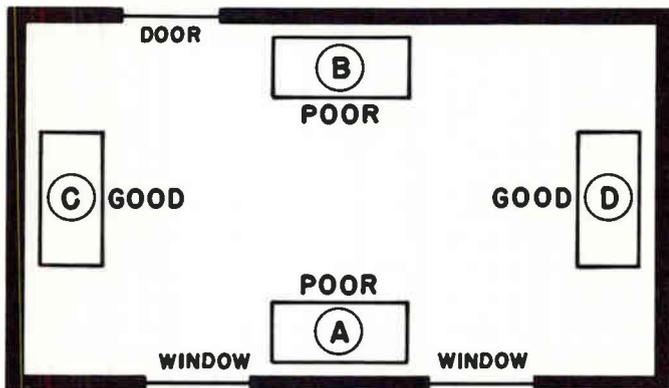
Fig. 2. Two good and two poor positions for a television set. Position A is poor because the bright light from the windows will distract the eye; position B is poor because light from the windows will be reflected from the cover glass and the picture tube.

lighting viewpoint, positions C and D in Fig. 2 are good.

To make viewing easy on the eye over extended periods of time, the room in which the set is located should be well lighted from some indirect source. Ideally, the surfaces near the set should be almost as brightly lighted as the middle or darker grays of the scene on the picture tube. A complete absence of light in the room other than that from the picture on the television screen is very hard on the eyes.

The set should also be placed so that none of its viewers will have to watch the picture at too great an angle. A typical good location both from a lighting and a seating viewpoint is shown in Fig. 3. People sitting on the sofa or the chairs have a good view of the face of the set.

During the day, light from the windows will illuminate the room without lighting the face of the picture tube too much, particularly if there are venetian blinds on the windows. At night, light from the adjacent room may be allowed to come through the door, or indirect light sources may be fastened on the wall in which the door is set. This arrangement is therefore good both
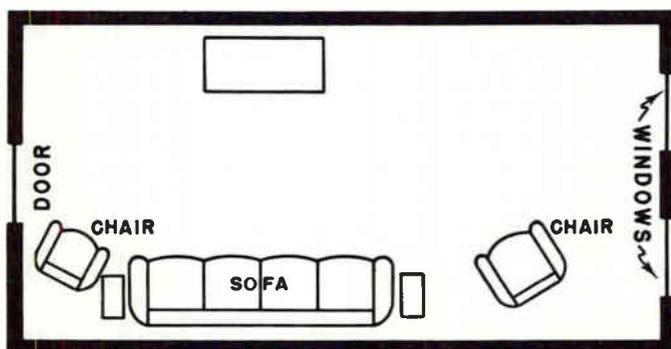
Fig. 3. A good room arrangement for watching television. All light sources are approximately at right angles to the line between the viewers and the set.

from the standpoint of furnishing light at right angles to the line of vision and from that of placing all viewers at some reasonable angle with respect to the picture tube.

Ventilation.

Always keep in mind the fact that many components in a set may prove unstable or may deteriorate rapidly if they are subjected to excessive heat. Since the set becomes quite warm in normal use, it should be located so that it can have enough ventilation. It should not be placed close to radiators or other sources of external heat, nor should any ventilation holes in the receiver cabinet be blocked by doilies or scarves. The set should be several inches out from the wall to allow heat to escape through the back.

If the set is a table model and has ventilation holes in the bottom, as many do, be sure that the table is strong enough to hold the set and that the ventilation holes will not be blocked.

Picture Tube Size	Approximate Viewing Distance
11 inches	3-1/2 ft - 5 ft
14 inches	4-1/2 ft - 6-1/2 ft
16 inches	5 ft - 7 ft
17 inches	5 ft - 7 ft
19 inches	7-1/2 ft - 10 ft
21 inches	8-1/2 ft - 11-1/2 ft
23 inches	9 ft - 12 ft
25 inches	10 ft - 14 ft

TABLE II

Viewing Distance.

One other factor that should be considered is the distance from the set to the chair or sofa from which it will be watched. The optimum viewing distance for each size of picture is equal to 6 to 8 times the height of the picture. Table II lists the best viewing distances for pictures of different sizes. The viewing distance may be greater or less than the optimum distance, of course, but it is desirable to place the set so that most of the seats will be somewhere near the right distance for the picture size.

Perhaps you feel that it is not really the business of the installer of the set to determine where it should be placed. Remember, however, that a large console television set is not like a radio receiver; it cannot be moved about a room readily, because its location is more or less fixed by the placement of the trans-

BALANCED PADS

O TYPE
$R_{2A} = R_{2B}$

H TYPE
$R_{1A} = R_{1B}$
$R_{3A} = R_{3B}$
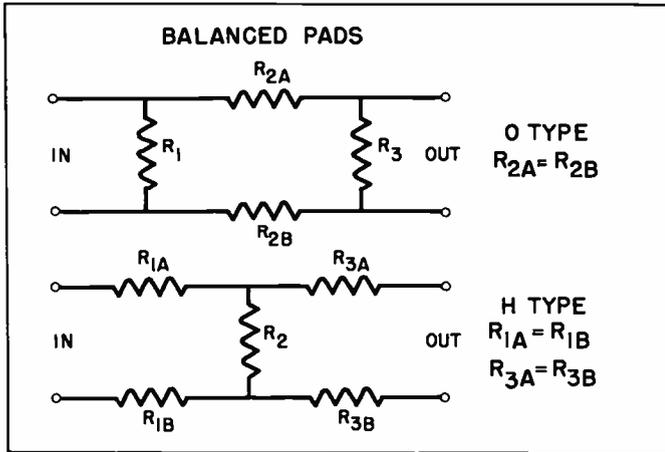
DB ATTENUATION	300-OHM IMPEDANCE O PAD		
	R_1	R_2	R_3
6	1000	100	1000
12	470	300	470
18	390	560	390
24	330	1000	330
30	310	2200	310

(ALL R VALUES ARE IN OHMS)

Fig. 4. Pads of the type shown at A may be connected between antenna terminals and 300-ohm twin lead to attenuate all incoming signals. The chart at B gives resistance values in an 0 type pad for several levels of attenuation.

mission line. Therefore, if it turns out that the customer is not satisfied with the location of his set, he will either call you back to change it or attempt to do the job himself -- and in the latter case he may damage the set or the transmission line.

Antenna.

Once the location of the receiver has been selected and agreed upon, the next step is to install the antenna, connect it to the set and orient it for best reception on all stations to be received. Instructions for installing rooftop antennas and running the transmission line to the receiver location are given in the lesson on TV antennas. If you are working in a strong signal area, this step will often be eliminated because indoor antennas will give satisfactory reception and the improvement obtained by using an outdoor antenna would not justify the added expense to the customer. If an indoor antenna is used, you need only connect it to the set and find its length and position of best reception for the various channels received. Be sure that the customer knows how to adjust the indoor antenna for best reception.

STRONG SIGNAL ATTENUATOR

It is possible that you might make a TV installation in an area where the signal strength from one or more

stations is excessive. There are two conditions that might exist. First, the signal strength from all stations received might be excessive, and second, which is more likely, the signal strength from only some of the stations might be excessive.

To reduce the signal strength of all stations received, you should use a pad that will retain the correct impedance matching for the transmission line but reduce the signal strength. Two types of pads that may be used are shown in Fig. 4A. The chart in Fig. 4B gives resistance values for the O type pad. It may seem that it would be simpler to use series resistors than to use either of the pads shown, but if this were done, the transmission line would no longer be terminated with the correct impedance.

If the signal strength is not excessive on all channels, pads cannot be used, because a pad will reduce the strength of all signals equally. Instead, use parallel resonant wave traps tuned to the frequency of the over-strong station. These should be connected as shown in Fig. 5. If coaxial transmission line is used, only one trap connected to the center conductor is necesary.
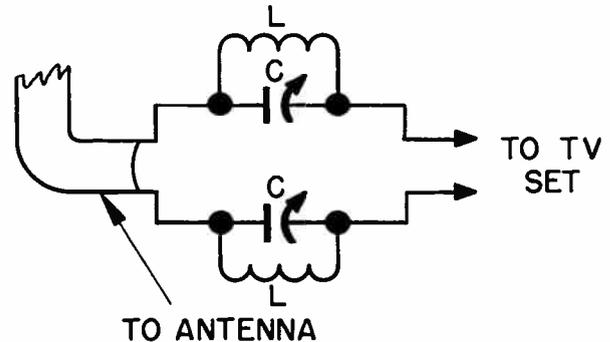
Fig. 5. Parallel resonant traps tuned to the frequency of a strong station will effectively attenuate the signal.

CHECKING THE RECEIVER OPERATION

After the receiver is installed in the location where it will be used and permanently connected to its antenna, check its performance on all active channels. This is the time to observe the picture critically and listen carefully to the sound. Make any needed adjustments and assure yourself that the receiver operates satisfactorily on all stations. If interference is present, take the necessary steps to eliminate it or explain its presence to the customer. As you know, noise filters can be used in the ac power line circuits to help filter out interference that originates in household appliances. Suitable high-pass, low-pass or wave-trap filters can be successfully used in the antenna lead-in to eliminate some types of radiated interference.

Develop a standard routine for checking receivers. Go through this same routine each time you install a new receiver or return a repaired receiver. Also use the routine to check a receiver that needs re-

pair or to check the receiver after performing home service. In general, the routine should include adjusting all operating controls and observing their effect. Observe the response to secondary controls or look to see if they need adjusting. By having a regular routine, you are able to check the receiver quickly and not miss anything. Also you will develop a sure feel for whether a receiver is faulty or if it has normal operating pecularities.

The sample routine given here is for either black-and-white or color receivers. In checking color receivers you will have to be more critical of some adjustments. Be careful about moving adjustments that interact on color receivers. Many of the adjustments should not be touched unless you are prepared to make a complete color setup.

Operating Controls.

Turn the receiver "on" and note how long it takes for the set to come up to operating condition. While you are waiting, check to see that the line cord is plugged in and check the antenna connections to the set. An abnormally long time delay between turn on and operation may indicate that trouble is developing in the low-voltage power supply.

A long delay between normal sound and high voltage may indicate a defect in the horizontal sweep circuit or high-voltage rectifier. As you rotate the channel selector, look for noise in the picture indicating dirty tuner contacts. Get all active channels. Return to the strongest station. Operate the contrast and brightness controls. Look for picture blooming at high brightness levels indicating poor high voltage regulation. Make sure that full rotation of the contrast control gives you more than enough contrast. Readjust agc if needed. On color receivers, check for proper black-and-white tracking at all contrast levels. Observe the black-and-white picture for color fringing indicating misconvergence or other color circuit troubles. Observe a color picture. Check the range of the color control. Observe that proper fleshtones are obtained with the hue control in approximately the center of its travel.

Leave the volume control advanced to a normal sound position while checking the picture. Sound volume and quality should remain quite insensitive to other adjustments including fine tuning. What you hear from the speaker can often give a clue to trouble in a defective receiver.

Secondary Controls.

Roll the picture vertically and observe if it exhibits normal "snap." By that we mean, does the vertical sweep jump into sync or is the adjustment very critical so the picture may roll slowly up or down if the vertical sync control is slightly off adjustment. Adjust horizontal hold and observe the number of bars present before the picture locks in. Check from both directions. Check the set's ability to lock on a weak signal.

Check picture centering, height, width, and linearity. On color receivers, you should not move these adjustments unless the condition requires correcting because their adjustment may upset the convergence of the three beams. Instead, try to decide if the condition is bad enough to warrant a complete color setup ad-

justment. In some cases you may be able to correct the difficulty (for example, not quite enough height) and get by without performing a color setup. Or, after making these adjustments a few touch-up adjustments to the convergence controls are all that is needed. The ability to make touch-up adjustments successfully comes with being very familiar with the effect of each adjustment.

Check the ability of the color receiver to synchronize the color information from a weak station. This check will depend on the type of color killer circuit in the receiver. The killer threshold should be adjusted to a point where all color information is rejected unless the signal is strong enough to produce a solidly synchronized color picture.

Green-stripe Signal Tests.

When a color station broadcasts a black-and-white program, they often provide a green stripe test signal for use by technicians. This signal is normally invisible on both color and black-and-white sets. As shown in Fig. 6, the green stripe signal consists of a short burst of 3.58-mc signal just before the horizontal blanking period and a similar short burst just following the horizontal blanking period. This positions the burst signal on the left edge and the right edge of the screen. This green stripe burst does not occur during retrace time, so it does not pass through the burst amplifier. Thus, the color killer circuit does not sense the presence of the burst and the bandpass amplifier remains cut off.

To display the green stripe signal, the color killer must be disabled. With the killer disabled, the green stripe signal will show up as an unsynchronized stripe of color. The colors will change slowly or rapidly depending on how far out-of-phase the 3.58-mc crystal oscillator is running. The green stripe signal can be synchronized by delaying the horizontal gating pulse to the burst amplifier. Then the left green stripe burst is used as a reference burst and the right green stripe signal is demodulated and displayed in synchronized color.
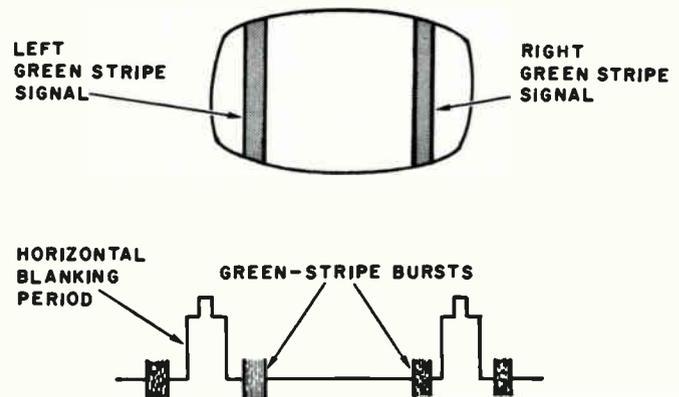
Fig. 6. The green-stripe test signal consists of a 3.58 MC burst that occurs just before and just after the horizontal blanking period.

The horizontal gate pulse to the burst amplifier can be delayed enough to produce a locked green stripe signal by throwing the receiver out of horizontal sync. Some of the green stripe signal gets through the burst amplifier and the slanting, out-of-sync horizontal bars, will display a locked color stripe.

The horizontal gate pulse to the burst amplifier can be delayed by connecting a .005 mfd capacitor between the plate of the sync separator tube and ground. This capacitor delays the time of occurrence of the horizontal sync pulse. In response to this delay, the sweep starts later and the horizontal pulse fed to the burst amplifier occurs at a time when the left green stripe signal is present in the incoming video. The picture can now be synchronized horizontally and the right green stripe observed. All the video including the green stripe is displaced to the left in relation to its usual position on the screen.

The green stripe test signal cannot be used for making all color receiver adjustments but it can be used to indicate whether or not the color section of the receiver is operating. If the receiver displays a colored green stripe signal, you know that the demodulators are working and the color sync section is working properly. Rotating the hue control will change the color of the displayed stripe. Since the stripe should be green, the hue obtained with different settings of the hue control indicates the approximate phase setting and the operating range of the hue control. If you get a normal black-and-white picture on a color receiver and the receiver displays the green stripe signal you can be fairly sure that it will produce an acceptable color picture.

Color Bar Generator Test Signal.

The best device for making adjustments and evaluating the performance of a color receiver is a good color bar generator. Fig. 7 shows the pattern produced by a typical gated rainbow color bar generator. Observing the signal from a color bar generator enables you to work rapidly with a known quality signal. The quality of a received television signal varies widely. You may have difficulty determining if poor picture quality is due to the receiver or to the received signal. With the color bar generator, the signal is always the same so differences in the observed pattern are due to differences in the operation of the receiver. The color bar, dot and crosshatch pattern generator is of course a must for performing a complete color setup on a color receiver. If you carry a color bar generator on service calls, you will always be equipped to make any necessary adjustments if the occasion arises.

CUSTOMER INSTRUCTION

When the installation has been completed, you must show the customer exactly how to operate the set. If the manufacturer supplies a customer manual, see that he gets a copy. If the customer has never owned a television set before, have him tune in each station to make sure that he knows how to adjust all the controls. Don't just show him how the controls should be

adjusted--show him the effect of maladjustment of a control, such as the fine tuning or contrast control, and then show him how to correct it. In other words, take time to make sure that the customer will be able to operate the set to his own satisfaction; you will be saving yourself a call-back or two by doing so.

Mention that the receiver adjustments should not be moved because they may be difficult to adjust properly. Don't tell him not to touch them. He may think you are trying to make work for yourself. And after all, it is his receiver. Some customers become quite proficient at making some simple adjustments. However, he should be informed that some back panel adjustments - especially on color receivers, cannot be properly adjusted without the use of test equipment. Also you should point out the danger of the high voltage that is present inside the cabinet of the receiver.

Don't compare the performance of your customer's set unfavorably with that of other models. Even if the set is not the best one, don't mention that fact. Tell him what he can expect in the way of reception without saying that he could get better reception with a better set. Remember, he is convinced the set is a good one, or he would not have bought it.

Some customers will want to know exactly how the set works. You should do your best to tell him what he wants to know in language that he understands. If he appears to have a good technical background, you may be able to be fairly detailed in your explanation. If, on the other hand, he has no knowledge of electricity, you'll only be wasting time if you attempt to describe the operation of the set from the technical viewpoint. No matter how simple you make your explanation, however, be careful not to give him any misinformation. He may quote your explanation to his
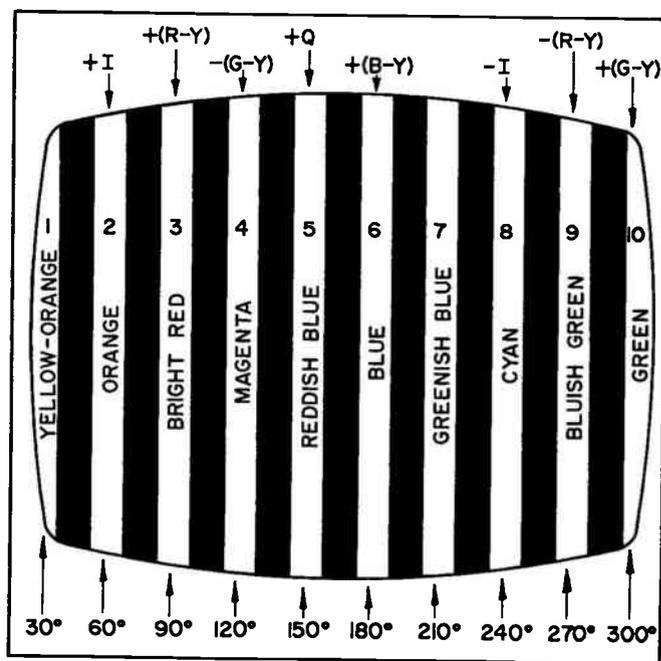
Fig. 7. Color bar pattern showing colors, phase relation, and associated color signals.

friends. If you have misled him, and someone points this fact out to him, he will bear you a certain amount of ill will.

SELF-TEST QUESTIONS

(k) Name two ways that you may get installation jobs.

(l) Where should a new receiver be unpacked, inspected, and tested?

(m) Why would it be undesirable to install a console TV receiver over a floor grating leading to a heating duct?

(n) What would be a good viewing distance for a picture that is 18" high?

(o) Why is it impractical to use a resistive attenuator pad when only one of the received stations produces an excessively strong signal?

(p) How can you guard against missing a minor receiver defect when you are checking a receiver's operation?

Complete Color TV Setup

Setting up a color receiver requires skill, experience, and understanding. You need to understand the effect of each adjustment and its relation to other adjustments. You need experience in making the adjustments to know when the adjustment is correctly made and what limitations to expect in the way of perfect adjustments. With experience you will develop skill in manipulating the adjustment controls. When you have mastered these things, you will be able to perform a color setup quickly and easily. This ability more than anything else, will determine your success in servicing color receivers. Other servicing tasks are no different in color receiver servicing than in black-and-white TV servicing.

As previously mentioned, the setup procedure gives explanations that will help you interpret manufacturer's setup procedures. For this reason, the procedure may seem long and involved. We present the procedure in its necessary sequence. Each step in the procedure is followed by explanations. After you understand the explanations you should be able to go back and follow the steps without reading the explanation. On the other hand, when you apply what you learn here to a manufacturer's procedure, you will want to read the explanations of certain steps in this procedure. This will help you to understand what particular steps are accomplishing in the manufacturer's procedure.

The location of controls, number of adjustments, and adjustment sequence will vary from receiver to receiver. In general, the more recent color receivers are easier to set up and have fewer setup adjustments than older receivers. In any case you must follow the procedure for the particular receiver you are adjusting. You will find this necessary until you have had considerable experience on a particular model receiver. The procedure given here will apply in most part to setting up any modern color receiver.

The color setup procedure can be divided into five major parts. First, you make preliminary adjustments to the receiver that closely parallel the adjustments required for a black-and-white receiver. Second, you make purity adjustments. These adjustments consist of getting each of the three guns to produce their associated color field separately. Third, you make static convergence adjustments. These static convergence adjustments converge the three beams on their correct color-producing phosphors at the center of the screen where the convergence problem is not affected by the geometry of the tube construction. Fourth, you make dynamic convergence adjustments so the three beams converge properly at the edges of the screen. These adjustments involve applying the corrections that vary with the amount of deflection that the beams are instantaneously experiencing. Fifth, you make color balance adjustments to get the receiver to produce a neutral picture throughout the gray scale range.

This section also includes an adjustment procedure

for the color sync section of a color receiver. While this is usually considered an alignment procedure, it is often performed in the home. We present it here as you would perform it in the home with the usual test equipment that you have available there. In a later lesson on alignment, you will be given a shop procedure for performing the same adjustments with shop equipment.

PRELIMINARY ADJUSTMENTS

Most of the color TV receivers manufactured to date use a high-voltage shunt regulator tube. In sets of this type, before adjusting the purity and convergence of a color receiver, you must make a group of preliminary adjustments. These preliminary adjustments affect the purity and convergence. Some have a large effect while others have negligible effect. If you move these adjustments after making purity and convergence adjustments, the quality of the setup job will suffer. It may even be necessary to go through the purity and convergence adjustments again. We'll go through the preliminary adjustments that are typical of those in most sets using a shunt regulator tube. Remember that not all receivers use shunt regulators and the procedures in these sets may be quite different.

Horizontal Deflection Alignment.

This procedure consists of adjusting the horizontal frequency, high voltage, and the efficiency of the horizontal output circuit. Since these adjustments affect focus and width, they must be made before making centering adjustments. The procedure given here is for a typical horizontal circuit. Consult the manufacturer's instructions for any particular set that you adjust.

The circuit is adjusted while measuring the current through the horizontal output stage, current through the high-voltage shunt regulator tube, and the high voltage at the crt second anode. Fig. 8 shows the arrangement of the meters. The circuit is provided with test jumpers that are removed for connecting the current measuring meters. Connect a 0-500 milliammeter in the cathode circuit of the horizontal output stage. Connect a 0-1500 microammeter in the cathode circuit of the high-voltage shunt regulator tube. Be sure to observe meter lead polarities when connecting these meters. The positive lead goes to the cathode in both cases. Connect the vtvm common lead to the chassis ground. Connect the vtvm through a high voltage probe to the crt second anode. Set the vtvm to read on the 0-30,000 volt range.

Once again, we should mention the danger of setting up the high voltage in the receiver to a value higher than that recommended by the manufacturer. If the voltage is set up too high, the chances are that x-rays may be produced by the picture tube, the high-voltage rectifier or the high-voltage regulator tube. These
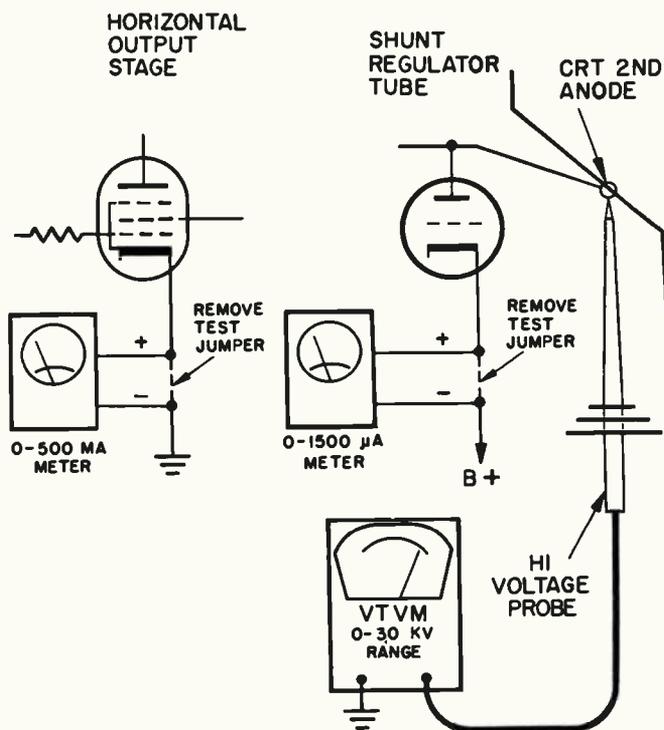
Fig. 8. Meter connections for adjusting the high voltage and horizontal efficiency.

x-rays could be dangerous, particularly to the service technician who is exposed to the set at close range for an extended period of time. Therefore, do not set up the high voltage to a value higher than that recommended by the manufacturer. If you must make an error, it is better to set up the voltage to a value slightly lower than the recommended value.

The high-voltage rectifier tube and the high-voltage shunt regulator are usually inside the metal cage used to shield the horizontal-output transformer. If you find it necessary to remove part of the cage in order to service the high-voltage supply, be sure to put all the metal parts back in place. This provides a shield which prevents the x-rays from radiating. It is not a good idea to operate the set even for a short time with any of the shielding removed, because you have no way of knowing how strong the x-rays produced may be. As long as the shielding is in place, the x-rays will be contained in the metal box and danger from radiation will be kept at a minimum.

We might point out that the technician is probably exposed to the danger of x-ray radiation more than anyone else by operating the set out of the cabinet. Even a plastic or wooden cabinet will have some effect insofar as reducing the x-radiation is concerned. Therefore you should avoid operating a color TV receiver for an extended period of time with the set removed from the cabinet. Also avoid being any closer to the set than is necessary while servicing it. It is unlikely any strong x-radiation is being radiated from the set, but there is no sure way of telling, so it is best to play it safe.

Turn on the receiver and tune in a local station. Let the set warm up for 5 or 10 minutes. Synchronize the picture. Center horizontal hold and adjust the sine wave coil. This can be done in the shop using an oscilloscope. Manufacturer's instructions usually give a field adjustment procedure that you can perform in the home without an oscilloscope. For example: Short the grid of the horizontal frequency control tube to ground. (This point is usually brought out to a test terminal on the top of the chassis.) This step removes the effect of horizontal sync pulses. Put the horizontal hold control in its center position. Connect a short jumper across the ringing coil. Adjust the horizontal frequency coil until the picture syncs or floats by slowly. Remove the short across the ringing coil and adjust it until the picture again syncs or floats by slowly. Remove the short from the grid of the horizontal reactance control tube. Adjust the horizontal hold until there is no evidence of bending at the top of the picture.

Adjust the horizontal efficiency coil for minimum current reading on the milliammeter. Current should not exceed 200 ma. This adjustment "tunes" the horizontal circuit by varying the inductive load produced by the efficiency coil. When properly adjusted, the horizontal circuit produces a minimum load on the horizontal output tube. Therefore the current through the horizontal output tube drops to a minimum.

Adjust the high-voltage adjustment to the value recommended by the manufacturer. In most large screen color sets, 21" or larger, this is usually about 24 kv. Set brightness to minimum (dark screen). Current through the microammeter must be not less than 850 ma. If less than 850 ma, readjust the horizontal efficiency coil slightly to produce 850 ma. Check to see that horizontal output tube current does not exceed about 200 ma. These adjustments set the value of the high voltage and the current through the shunt regulator. With minimum brightness, the beam current is cut off so the shunt regulator tube must pass a large current in order to regulate the high voltage. As brightness is turned up, beam current increases. To keep high voltage constant, the regulator tube passes a correspondingly smaller current as beam current increases. This keeps the total current load constant on the high voltage supply so the high voltage does not vary.

Make the centering, width, and focus adjustments before you remove the meters. Then you can recheck the horizontal efficiency adjustments. When you remove the meters, resolder the test jumpers in place.

Picture Size and Centering.

Tune in a station, preferably a black-and-white transmission, and adjust fine-tuning, contrast and brightness for a normal picture. Or connect a dot pattern generator to the receiver and display a crosshatch pattern. Adjust the height and width control to produce about one inch overscan beyond each edge of the picture with the picture centered. The height adjustment is usually a back panel knurled knob or screwdriver adjustment. The width control may be an adjustable coil or a jumper may be provided for step changes in width. If a width coil is used, its adjust-

ment may affect the horizontal efficiency.

Many receivers have a jumper at the yoke that can be placed in one of two positions for adjusting width.

In one position, a capacitor is placed in the horizontal yoke circuit so that it will increase the width. Horizontal and vertical centering adjustments are potentiometers that vary the dc current through the yoke windings to center the picture. Height and vertical linearity controls interact so they should be made at the same time.

Focus.

Adjust the focus control for best overall definition of fine picture detail. Some technicians prefer to observe the sharpness of the raster lines instead of picture detail. The focus control in color receivers controls the amount of voltage applied to the focusing anode of the crt. The focus adjustment affects only the spot size of the scanning beams, therefore it does not affect purity and convergence.

Degaussing.

To get best purity and convergence in a color receiver, you must demagnetize the receiver by performing the degaussing operation. Place the receiver in the position it will occupy when in use. It is all right to move it out from the wall, but have it facing in the same direction as it will be when in use. Plug the degaussing coil, shown in Fig. 9, into an ac outlet and turn it on. Hold the coil parallel to the front of the cabinet and close to the picture tube screen. Move the coil slowly about the area. Keep the coil away from the magnetic assembly on the neck of the tube. Slowly move the coil away from the receiver and turn the coil off or unplug it. The coil should be at least 6 feet from the receiver when it is turned off.

Many receivers have built-in automatic degaussing systems that demagnetize the face plate area of the receiver each time the set is turned on. These systems usually take care of any small stray fields that develop in ordinary locations. However, if you observe color impurity in a set with this feature, it is still worthwhile to perform the degaussing operation with a separate degaussing coil. Also, before performing purity and convergence adjustments, it is advisable to degauss with a separate coil. It only takes a minute or two and often gives much better results.

Some older color receivers have edge correction magnets to correct for impurity at the edges of the screen. These magnets must be set for minimum effect during the degaussing operation. If you work on a receiver of this type, consult the receiver instructions on how to set them during degaussing.

Black-and-White Tracking.

This term refers to the ability of the receiver to produce a black-and-white picture at all brightness levels. Or we say the picture produces all shades of gray without showing evidence of color. This condition is attained when the correct ratio of the three beam currents is maintained throughout the range of brightness control. The adjustment is made by setting the individual screen voltages for each gun of the picture tube. The screen voltages are set to a point where the beams are just cut off with fixed voltages applied to the control grids and cathodes of the crt. Then the

video drive controls are adjusted to produce a neutral white or gray picture.

To make the adjustments, proceed as follows: Set brightness and contrast to about mid-range. Turn the red, green, and blue screen controls fully counterclockwise. Put the "normal-service" switch in the "service" position. This switch collapses the vertical sweep so only a single thin horizontal line appears across the center of the screen. At the same time, the switch places all three cathodes of the crt at the same positive potential.

Turn the kine-bias control fully counterclockwise or if the receiver uses a "PIX tube bias" switch, position the switch slider in its farthest position toward the top of the chassis. This step biases the control grids negative in respect to the cathodes. All three beams are cut off because of the bias and the low potentials on the screen grids.

Advance the red screen control until a barely visible horizontal line can be seen. Advance the blue screen control until the blue trace is barely visible. Then advance the green screen control until the green trace is barely visible. The screen controls are now all set to just about cutoff.

If you are unable to produce any one of the colored lines by rotating the screen control fully clockwise, you will have to change the kine-bias. Leave the screen control fully clockwise and adjust the kine-bias until the colored line is barely visible. It will then be necessary to go back and adjust the other two screen controls.

Turn the "normal-service" switch to "normal" and adjust brightness and contrast for a normal picture.

Color Temperature.

The color of the white areas produced by the color picture tube can be expressed as being equivalent to
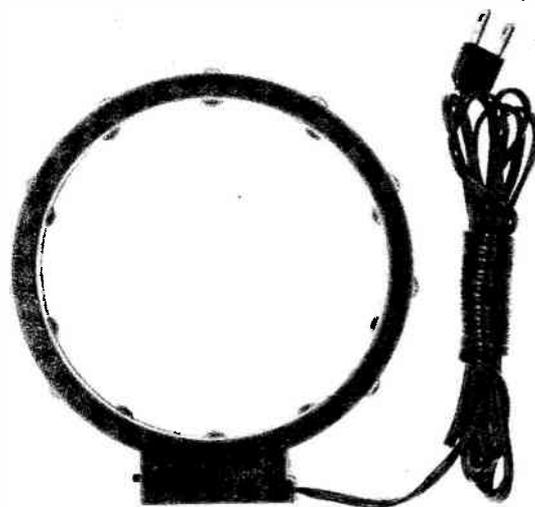
Fig. 9. A degaussing coil. The coil is made of many turns of wire inside a circular case. The coil is connected to the 120-volt power line and the circuit closed by means of a switch. The varying magnetic fields produced by the alternating current flowing through the coil demagnetizes the receiver and the picture tube.

the white light produced by a material that has been heated to a certain temperature. This is not a practical measure for judging the whiteness of a screen. Instead we simply compare the black-and-white picture produced by a color tube to what we are used to seeing from a monochrome receiver. The adjustment is made by varying the relative amount of each of the three primary colors that produce the white light. For example, if the tube is producing too much green, the picture will have an overall greenish cast.

Two controls are usually provided for adjusting the color temperature: the blue and the green video drive controls. These controls adjust the dc potential of the blue and green cathodes and the amplitude of the video drive to them. The red gun cathode gets the full video drive because the red phosphor is normally the least efficient. Most receivers are equipped with detachable connectors in case one of the other phosphors is less efficient.

Advance the green and blue video drive controls alternately until a black-and-white picture displays a normal neutral gray or white appearance. Check the picture at all levels of brightness. If the picture shows a colored cast at some brightness level go back and carefully readjust the screen controls.

PURITY ADJUSTMENTS

The purpose of purity adjustments is to get each electron beam to strike exactly on its associated color phosphor dots. To make the adjustments you observe each color field separately. That is, you bias off two of the guns and observe the field produced by one gun. The adjustments are made with no video or color signals applied to the tube. You strive to produce a single color field that gives off a uniform light intensity from all parts of the screen.

The three beams of the crt should be converged at the center of the screen before making the purity adjustments. If the beams are badly misconveyed, purity will be affected when the static convergence adjustments are made. Thus it is best to make an approximate center convergence before making the purity adjustments. Then the small changes in static convergence that may be necessary after performing the purity adjustments will have little or no affect on purity.

The instructions for some receivers call for making purity adjustments with the receiver oriented in the north-south axis. That is, the receiver should be pointing either directly north or directly south. This orientation places the horizontal component of the earth's magnetic field in line with the center axis of the electron beams so the field has a minimum affect on the beams. When the set is then moved to its viewing position, the maximum affect of the field will occur when the set is pointed due east or due west. This will introduce only half the error that would occur if purity adjustments were made with the set facing due west (or east) and then viewed in a position with the set facing due east (or west). Making purity adjustments with the set oriented in the north-south axis insures more lasting purity with better average purity. This consideration is important with small color sets that
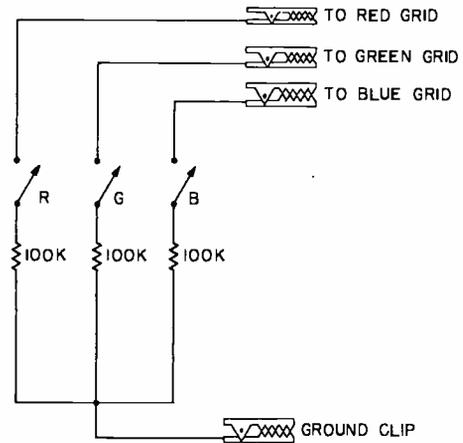
Fig. 10. The grid shunt switch enables you to extinguish selected electron beams of the color tube.

are frequently moved to different viewing positions.

Purity adjustments are made in two steps: neck purity magnets are used to adjust for a pure field at the center of the screen; then the yoke is positioned to attain a pure field at the edges.

Bias-off the green and blue gun of the picture tube using a grid shunt switch. Fig. 10 shows a schematic diagram of a grid shunt switch used for killing individual beams of the tri-color tube. A clip lead connects to the control grid of each gun. A 100K-ohm resistor and a switch are in series with the clip lead to the ground lead. When a switch is turned on, the bias for the gun drops low enough to cut off the beam. The grid shunt switch may be part of the color bar generator or it may be a separate accessory.

Obtain a blank red raster with no video present. One way is to unplug the cable that connects the tuner to the i-f strip. If you are using a color bar generator, a blank raster can be obtained by tuning in the generator signal and then turning down the chroma signal of the generator. Another way is to use an external bias supply connected to the agc line. Apply a large negative bias to cut off the i-f section of the receiver.

Adjust Neck Purity Magnets.

You will recall that the neck purity magnet consists of a split ring assembly similar to the centering magnets for black-and-white receivers. The purity magnet from a modern color TV receiver is shown in Fig. 11A.
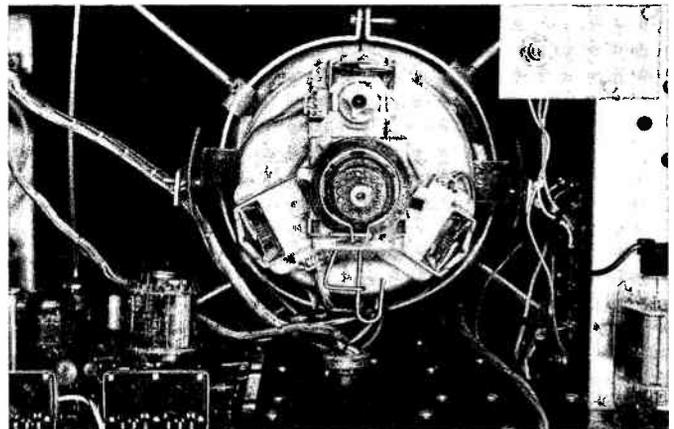
Fig. 11A. Split ring purity magnet on neck of picture tube.

The magnet produces a uniform magnetic field across the neck of the tube where the field affects all three beams equally. Separating the tabs on the neck purity device increases the strength of the magnetic field. Rotating the entire device determines the direction that the beams are bent. Fig. 11B shows how the electron beams are affected by the purity magnet.

Loosen the yoke clamp and move the yoke to the rear on the neck of the tube. This step deliberately upsets the purity at the edges of the screen by changing the deflection centers of the beams. At the center of the screen where the beams experience little or no deflection, the position of the yoke has no effect on purity. Now you can observe the center of the screen and adjust the purity magnets.

Adjust the neck purity magnets to obtain a pure red blob in the center of the screen. Disregard the areas outside of the screen center. The important thing is to get the red blob as nearly centered as possible. Fig.

DIRECTION OF
RADIAL MOTION
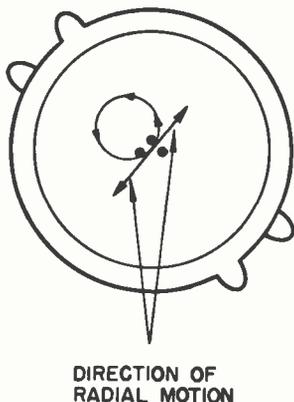
Fig. 11B. Rotating the neck purity magnets moves the colored dots in a circle while spreading the tabs moves the dots in a radial direction.

12A shows the screen before the neck purity magnets are adjusted while Fig. 12B shows the red area correctly centered. Rotating the purity magnet and separating the tabs will both affect the position of the pure red area. Since all three beams are affected the same, it is unnecessary to observe the blue and the green fields at this time.

Yoke Position.

Slide the yoke forward while observing the red field. You are changing the deflection center of the beam in this step. When properly positioned, the electron beam will pass through the shadow mask holes at exactly the correct angle so that the beam lands in the center of the red light-producing phosphor dots across the entire screen. Observe all areas of the screen and look for areas that are dark. Strive for uniform brightness of the red field over its entire area. The accuracy of spot landing can be observed by using a magnifying glass to examine individual dots. Areas where the beam is not centered on the phosphor dots will produce less light output. Fig. 12C shows the uniform red field that results when the yoke is correctly positioned.
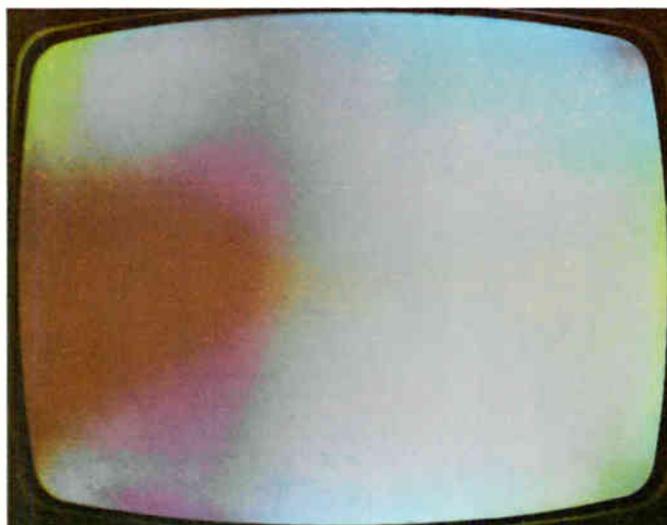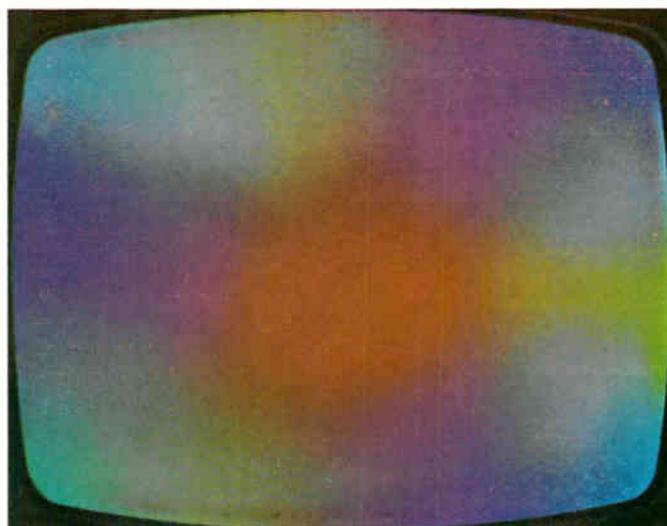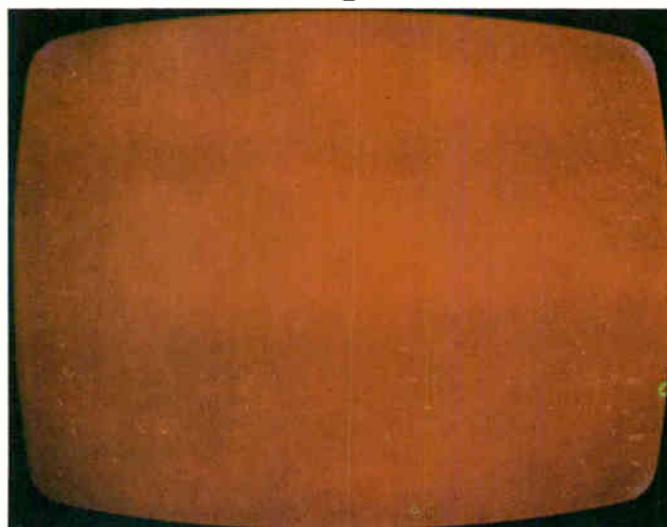
Fig. 12. Purity adjustments correct for off-center red area (A) producing correctly centered red area (B). Correctly positioned yoke produced uniform red field (C).

Check the purity of the blue and green fields. Switch off the red field and switch on the blue field. Observe the field for uniform purity. In the same way examine the green field separately. A slight readjustment of the yoke and/or the purity magnets may be necessary. In some cases you may have to compromise. To get good overall purity in the three fields, you may have to sacrifice perfect purity in one of them.

All three guns may be activated now and the receiver will produce a white raster. It may be of interest to note that errors in convergence of the three beams will not be apparent on the blank raster. Each of the three beams is producing its associated color raster and we see the resultant white raster. Only where objects are present in the picture will misconvergence be apparent.

Improper convergence can be seen by observing edges of objects in a black-and-white picture. The objects will have fringes of color because all three electron beams are not converged at the same point. For example, as the three beams sweep across the screen, they should all cut off at the same place on the screen to delineate a black vertical edge of an object. If one beam is not converged horizontally, it will produce its color in the area which should be black. Purity adjustments have a large effect on convergence so the purity adjustments must not be touched during or after convergence adjustments.

Check the yoke for tilt and clamp it in position. Tilt can be checked by throwing the "normal service" switch to the "service" position. This collapses the vertical sweep putting a single horizontal line across the screen. If necessary rotate the yoke so the line is parallel with the top and bottom edges of the picture tube mask. Tighten the screw on the yoke clamp.

STATIC CONVERGENCE

The next step in the color setup procedure is to converge the three electron beams in the center area of the picture tube. This is called static convergence because in the center area convergence is unaffected by the magnetic fields set up in the yoke by the deflec-
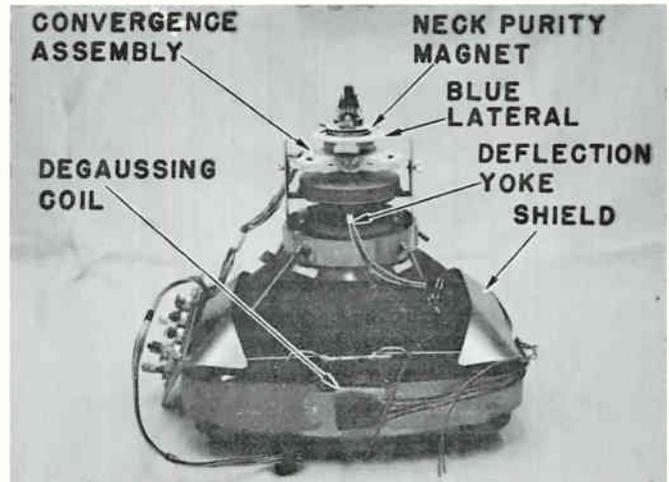
Fig. 13. Relative positions of components attached to the color picture tube.

tion circuits. Static convergence is accomplished by aiming the individual electron beams so that they all strike the same point on the shadow mask. A separate magnetic field is provided to move each beam in relation to the other beams. Some receivers use variable direct current through electromagnets to change the strength of the individual magnetic fields. Other receivers use four permanent magnets to adjust the magnetic fields. Three of these magnets (one for each color gun) are located on the convergence assembly shown in Fig. 13. The fourth permanent magnet is the blue lateral convergence magnet located on the neck of the picture tube.

The convergence assembly must be properly located on the neck of the picture tube in relation to the internal pole pieces within the gun structure. The three magnets of a convergence yoke are identified in Fig. 14A. Each of these magnets affect its associated electron beam. Fig. 14B shows a cross-section drawing of the external electromagnets in relation to the internal pole pieces. The static convergence permanent magnets are attached to the external electromagnets so they affect the magnetic flux between the in-
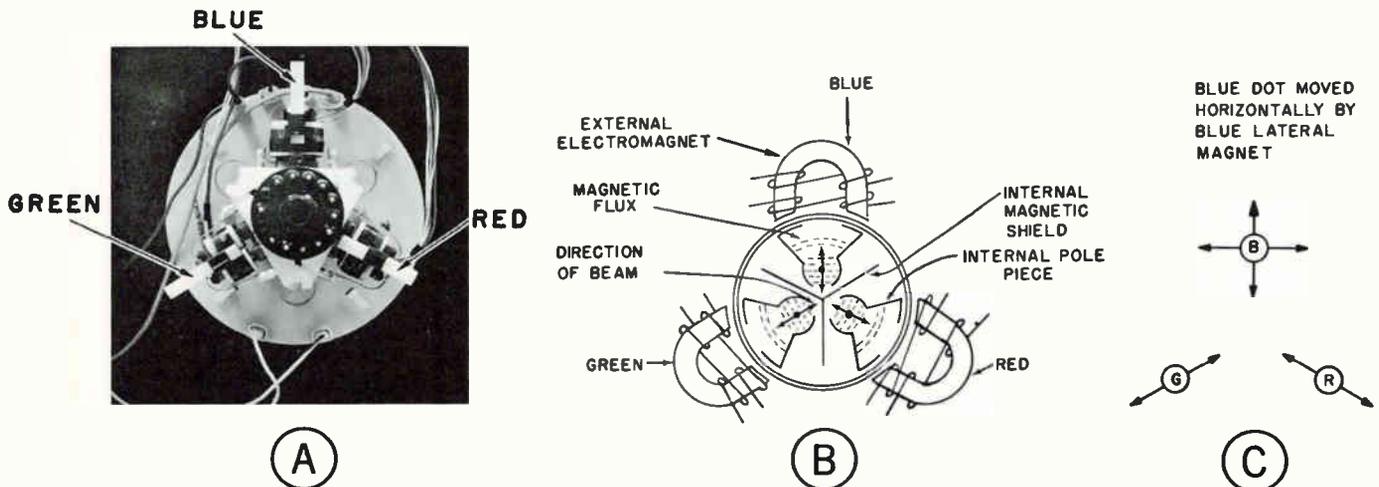
Fig. 14. Convergence assembly on neck of tube (A); relation of fields of external magnets to the internal pole pieces (B); and direction of movement of colored dots (C).
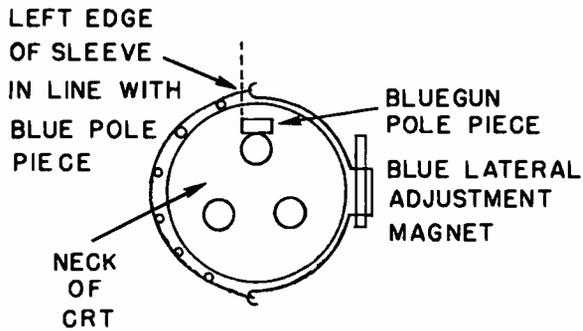
Fig. 15. Location of Blue lateral adjustment magnet in relation to internal pole piece.

ternal pole pieces. As shown, the electron beam from each gun passes through a separate internal pole piece. Changing the strength and/or polarity of the magnetic field moves the electron beams in the direction indicated by the arrow in Fig. 14C. The blue beam can be moved in a horizontal direction by adjusting the blue lateral magnet.

The blue lateral magnet must be positioned on the neck of the tube in the correct relation to the blue lateral internal pole piece. Fig. 15 shows the relative position of the blue lateral adjusting magnet for one receiver. Consult the manufacturer's notes for any particular receiver.

The static convergence adjustments are made while observing a dot pattern on the receiver. Lower the brightness control enough to produce small well defined dots. A small handmirror is an aid to observing only the center dot while reaching the adjustments on the neck of the tube. Hold the mirror at a sharp angle close to the center of the screen. Steady the mirror by supporting it on the safety glass or face of the tube.

Converge the Red and Green Dots.

Bias off the blue gun of the picture tube while converging the red and green dots. The best way to do this is to use the grid shunt switch to extinguish the blue beam. Adjust the red and green gun convergence

magnets to merge the red dot with the green dot at the center of the screen. Fig. 16A shows the dot pattern misconverged and Fig. 16B shows them converged in the center area of the screen. In some receivers, the magnets are adjusted by sliding a plastic tube containing the magnet up and down within a holder.

If you are unable to get enough movement of the beam through the total throw of the adjustment, reverse the polarity of the magnets. This is done by removing the plastic sleeve from the holder, rotating the sleeve 180° (not end for end) and reinserting it in the holder. If you have difficulty getting enough adjustment, check the position of the convergence assembly. Also it is possible for the permanent magnet imbedded in the plastic to loose its magnetism. Try interchanging the plastic sleeve with one from one of the other guns. Make sure that the plastic sleeve has not been rotated 90° (axis of the magnet parallel to the axis of the picture tube).

Some receivers use convergence magnets that rotate in sockets located in the pole pieces of the convergence assembly. One full turn moves the magnet through its full range of adjustment.

Converge the Blue Dot.

Turn on the blue beam and move the blue static convergence magnet to merge the blue dot with the red and green dots. This adjustment moves the blue dot up and down. If the blue dot is off to either side, it can be moved into line with the blue lateral magnet. This adjustment will have some effect on the red and green beams. Go back and readjust the red and green static convergence magnets; then readjust the blue magnet. The dot of the dot pattern that is located at the very center of the screen should now be white with no evidence of individual colors at any edge of the dot. Some technicians prefer to use a crosshatch pattern when performing the static convergence adjustments. It is usually possible to adjust the static convergence adjustments more critically using a dot pattern, but if you prefer to use a crosshatch pattern and carefully perform the static convergence adjustment, you will
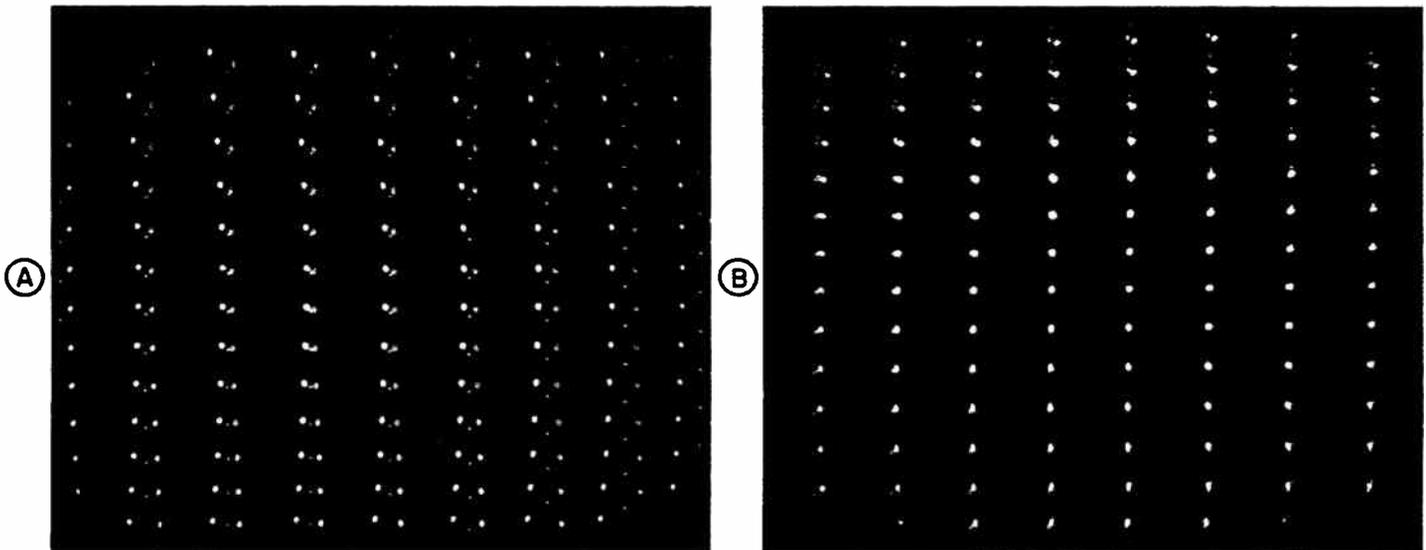
Fig. 16. (A) Red and green dot pattern on picture tube. Notice the dots are not converged in center area of tube. The static convergence adjustments converge in the center area as shown at (B).

usually find that you get satisfactory results.

DYNAMIC CONVERGENCE

Convergence corrections that change depending on the position of the swept beam are known as dynamic convergence corrections. The geometry of the tube is mainly responsible for dynamic misconvergence. As shown in Fig. 17, the distance between the shadow mask and the deflection center is greater at the edges of the screen than at the center. When the beams are correctly converged at the center of the screen they tend to converge short of the mask as the beams are deflected toward the edges of the screen. To correct this misconvergence, the magnetic convergence fields are altered in accordance with the sweep scanning signals. The current through the coils wound on the convergence pole pieces is altered in accordance with the sweep waveforms. The magnetic field is opposed and weakened as the beams approach the edges to the screen.

Fig. 18. The convergence board is temporarily bolted to the rear of the cabinet in the position shown while the technician performs the dynamic convergence adjustments.

Fig. 17. The three electron beams converge short of the mask at the picture tube edges because the distance from the deflection centers to the mask is greater at the edges than in the center of the screen.

This weakens the converging forces and the beams converge at a greater distance.

Other factors affect the exact waveform required to drive the convergence electromagnets. For example the beams are displaced from the exact center of the tube axis so they travel farther when deflected to one edge of the screen than when deflected to the opposite edge. By proper control of the convergence waveforms, the beams can be kept in convergence throughout the vertical and horizontal sweep excursions.

Control Board.

Dynamic convergence adjustments are usually made with a crosshatch pattern on the face of the picture tube. A group of adjustment controls, usually twelve, are provided for adjusting the current waveforms to the dynamic convergence coils. These controls are used only when making dynamic convergence adjustments. If they are touched at any other time, it will seriously upset the displayed colors. Therefore the board is usually located in a place that is accessible only to the technician. Some receivers use a pull-out

front panel to hide the adjustments. This is convenient for the technician because the controls are easily reached while observing the picture tube closely. Other receivers mount the board inside the back part of the cabinet. When the board is used for adjustment, it is unbolted and then mounted along the back rail of the cabinet as shown in Fig. 18. In this position the controls can be reached while observing the picture tube display.

Fig. 19 shows a drawing of the control board of a typical color receiver with the controls identified. The six controls to the left of the center, labeled "vertical", control the current waveforms through the vertical windings on the convergence magnets. In general, these waveforms are made up from signals originating in the vertical output transformer. Likewise, the controls to the right of the center, labeled "horizontal", control the current waveforms through the horizontal windings on the convergence magnets and the signals originate from the horizontal output transformer.

The location of the controls on the board can help you know which part of the display the controls affect. In general, the four controls across the top adjust the horizontal lines of a crosshatch pattern. The middle horizontal row of four controls adjusts the vertical lines of the crosshatch pattern. The bottom row of four controls adjust the blue horizontal lines. Now look at the controls as four vertical columns with three controls in each column. The first column, labeled "bottom", affects the bottom section of the screen while the second column of controls affects the top section of the screen. The third column affects the left side of the screen (your left facing the screen of the receiver) and the fourth column affects the right side of the screen.

The lettering by each control indicates the colored lines you should observe while adjusting that control. The number in the center of the control indicates the sequence in which the controls are adjusted. While
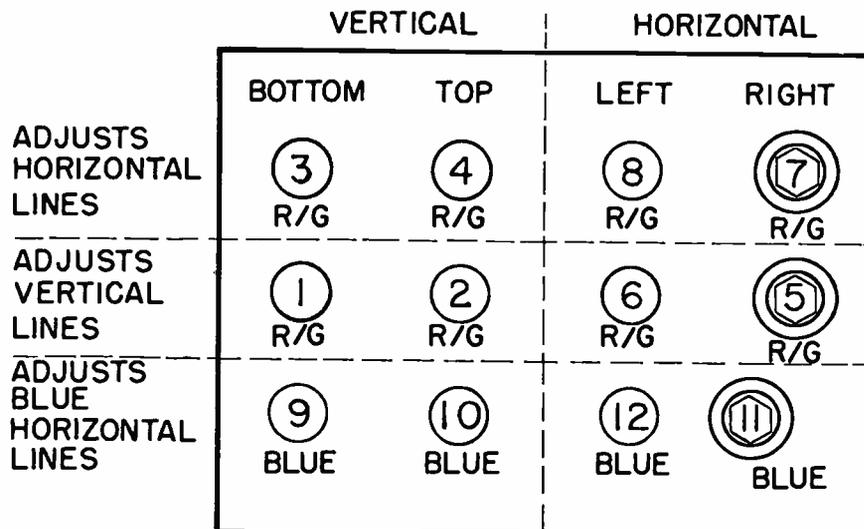
Fig. 19. Dynamic convergence control board of a late model color receiver.

the controls are lettered either R/G (indicating red and green lines) or blue, all the controls interact to a certain extent. The controls on any particular board may be lettered in a different manner. Also the numbers shown on the controls do not appear on the equipment.

Vertical Convergence.

In this step you adjust the four vertical controls labeled R/G in Fig. 19. Before starting the dynamic convergence adjustments, use a dot pattern to be sure the beams are statically converged at the center of the screen. If the static convergence is satisfactory, display a crosshatch pattern on the face of the tube. Bias off the blue gun so that only the red and green guns are operating. Proceed with the following steps that correspond to the numbers on the convergence control board drawing in Fig. 19. In Fig. 20, the simplified drawing associated with each step shows only those lines of the crosshatch pattern that you are concerned with in that particular adjustment.

Step 1. Observe the vertical center line near the bottom of the screen and adjust control 1 to merge the red and green lines.

Step. 2. Observe the vertical center line near the top of the screen and adjust control 2 to merge the red and green lines.

Repeat steps 1 and 2 as necessary to obtain the best convergence along the entire vertical line at the center of the screen.

Step 3. Observe the horizontal bar near the center bottom of the screen and adjust control 3 to merge the red and green lines.

Step 4. Observe the horizontal bar near the center top of the screen and adjust control 4, to merge the red and green lines.

Repeat Steps 3 and 4 as necessary to merge the

horizontal red and green lines at both the top and bottom center of the screen.

Switch the generator to a dot pattern. Turn off the blue gun grid shunt switch to energize the blue gun. Reconverge all three colors of the center dot, if necessary, using the static convergence magnets. Switch back to the crosshatch pattern.

Horizontal Convergence.

You are now ready to adjust the current waveforms to the red and green horizontal windings of the dynamic convergence coils. Turn on the blue grid shunt switch to extinguish the blue beam. Perform the below listed steps:

Step 5. Observe the vertical red and green lines at the right side of the screen. Use a hexagonal alignment tool to adjust control 5 to merge the two into a single yellow line.

Step 6. Observe the vertical line at the left of the screen. Adjust control 6 to merge the green and red vertical lines.

Step 7. Observe the horizontal lines at the right side of the screen. Use a hexagonal alignment tool to adjust control 7 so the red and green horizontal lines merge at the right side of the screen.

Step 8. Observe the horizontal lines at the left side of the screen. Adjust control 8 to merge the red and green horizontal lines at the left side of the screen.

Repeat Steps 5 through 8 to correct for any interaction of the controls.

Blue Beam Convergence.

Turn off the blue grid shunt switch to energize the blue gun grid.

This completes the red and green dynamic convergence adjustments. The remaining convergence adjustments are used to converge the blue beam on
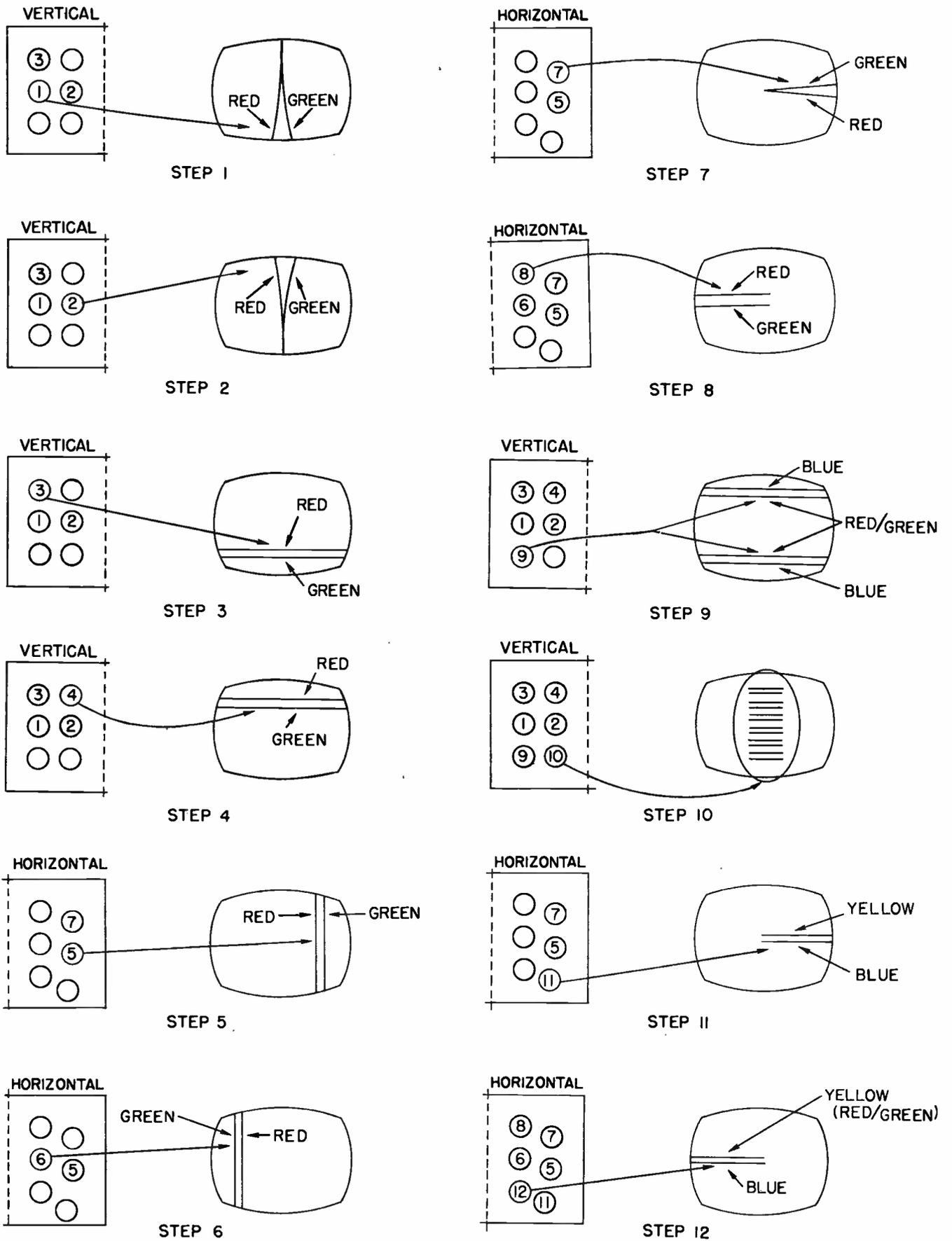
Fig. 20. Twelve dynamic convergence adjustments.

the already converged red and green beam which together produce a yellow crosshatch pattern.

Step 9. Observe the center area of both the top and bottom horizontal lines. Adjust control 9 to converge the blue line with the red-green (yellow) line.

Step 10. Observe all horizontal lines along the center section of the screen. Adjust control 10 to converge the blue lines with the red-green (yellow) lines along the center section of the screen.

Repeat Steps 9 and 10 to obtain best convergence of the horizontal lines in the center section of the screen.

Step 11. Observe the horizontal line at the right center of the screen. Use a hexagonal alignment tool to adjust control 11 so the blue horizontal line merges with the red-green (yellow) line.

Step 12. Observe the horizontal lines at the left side of the screen. Adjust control 12 to merge the blue horizontal line with the yellow (converged red and green lines) line.

Repeat Steps 9 through 12 to correct for interaction of the controls. The pattern should now show proper convergence at all areas of the screen.

Since all the controls tend to interact to a certain extent, you can usually produce a better convergence by going through the adjustment procedure twice rapidly, than by making painstakingly accurate adjustments once.

Recheck the "color temperature" and "black-and-white tracking". The receiver is now properly set up for color reception.

COLOR SYNC ADJUSTMENTS

As mentioned previously, the adjustment of the color sync section of the receiver is usually considered an alignment procedure. However, when you set up a color receiver in a customer's home, either during installation or after repair, you will always check to see if the set synchronizes the color information. The procedure given here enables you to realign the color sync section using only the test equipment normally available on a home service call.

Check the operation of the color afpc (Automatic Frequency and Phase Control) by observing a color bar pattern. Connect a color bar generator to the receiver and tune in the bar pattern. With the hue (tint) control centered, the receiver should display the correct colors in each of the bars. If you have to rotate the hue control more than about 30° in either direction to get the correct colors, the color phasing control should be adjusted.

The color phase adjustment usually consists of adjusting the core of the burst transformer. This adjustment is used to shift the phase of the burst signal just enough so the proper colors are produced with the hue control in its center position. Most manufacturer's literature will give a "field" adjustment procedure for setting the phasing adjustment on a particular set.

Check the ability of the receiver to synchronize the colors on a weak color signal. Disable the color killer for this check. Turn down the color control on the color bar generator. This reduces the amplitude of the color burst signal as well as the color bars. The colors should remain in sync until the color almost disappears from the bars. Readjust the killer threshold. The adjustments to the system can be made while receiving a color telecast or the green stripe color signal but a color bar generator gives more uniform results.

Making the alignment adjustments is a valuable troubleshooting procedure for isolating trouble in the afpc section. Since you disable individual stages of the afpc system during adjustment, you can tell which stage is not operating properly. Fig. 21 shows a simplified schematic of a typical afpc system with adjustment points identified. Follow the steps on this diagram as we go through the adjustment procedure.

Tuning the 3.58-mc Oscillator.

This step tunes the 3.58-mc oscillator transformer for maximum output amplitude. Measure the dc voltage produced by the oscillator signal at the phase detector to indicate when the transformer is properly tuned. It is necessary to eliminate the burst signal input to the phase detector so the indication will be due entirely to the amplitude of the oscillator signal. To do this, short the input to the burst amplifier. Perform the following steps:

Step 1. Short the control grid of the burst amplifier V_1 in Fig. 21 to ground with a short jumper.

Step 2. Connect a vtvm to pin 1 of V_2, the phase detector diode. Set the vtvm to read -dc voltage on the 0 to 50 volt range.

Step 3. Adjust the slug in the oscillator transformer, T_2, for maximum negative voltage reading on the vtvm. The voltage will be -20 to -30 volts depending on the receiver being adjusted.

The oscillator transformer is now properly adjusted. From the results of this adjustment, you know that the oscillator is operating and producing the correct amplitude signal.

Tuning the Burst Transformer.

In this step we tune the burst phase transformer for maximum burst signal into the phase detector. Again we use the vtvm at pin 1 of the phase detector to indicate when the transformer is properly tuned. Perform the following steps:

Step 1: Remove the short from the grid of the burst amplifier, V_1 in Fig. 21. The reading on the vtvm should increase indicating the additional voltage produced by the burst signal.

Step 2. Adjust the slug in the burst transformer, T_1, for maximum reading on the vtvm. It is pos-

sible for the reading to go as high as -45 volts.

The burst transformer is now properly tuned to couple the maximum amplitude burst signal into the phase detector. From the results of this adjustment you know that the burst signal is getting through the burst amplifier and is being applied to the phase detector.

Tuning the Reactance Coil.

The purpose of this step is to adjust the reactance control stage so the oscillator produces the correct frequency without a correction voltage from the phase detector. This is similar to adjusting the frequency coil on a horizontal oscillator. Perform the following steps:

Step 1. Connect a short jumper from the control grid of the reactance tube, V_4, to ground. This shorts out any correction voltage produced by the phase detector. In most receivers the control grid circuit is brought out to a convenient test point.

Step 2. Observe the color bar pattern and adjust the slug in the reactance coil, L_1. The color bars will appear broken up into a number of horizontal color bands depending on how far the oscillator frequency is off from 3.58 mc. Adjust the slug of L_1 in the direction that decreases the number of horizontal bands. As you approach the correct setting, the color bars will lose the horizontal breaks and be a uniform color from top to bottom but the hue of the bars will change slowly. The oscillator is now free running at the correct frequency.

Step 3. Remove the short from the control grid of the reactance tube. The color should lock solidly in response to the correction voltage from the phase detector. The hues of the individual color bars may

not be correct but they will remain the same color.

The reactance coil is now properly adjusted. This adjustment step has shown that the crystal oscillator is capable of running at the required frequency. If, for example, you could not get uniform color bars in Step 2 above, it would indicate defective components in the 3.58-mc oscillator or a defective reactance control stage. The fact that the color locks in step 3 above indicates that the phase detector circuit is working properly.

Phase Adjustment.

The final adjustment to the afpc system consists of adjusting the phase of the oscillator signal in respect to the incoming burst signal. In most receivers, this is done by readjusting the burst transformer slightly. This shifts the phase of the burst signal that is applied to the phase detector circuit. In response to this change, the phase detector sends a correction voltage to the reactance control stage which in turn shifts the phase of the oscillator. In this way the oscillator signal is set to the phase that will cause the demodulators to operate on the correct axis and produce the correct colors. An approximate adjustment can be made as follows:

1. Carefully tune in a color bar pattern on the receiver. Adjust the receiver and the generator to produce a low-level color bar pattern. By "low-level" we mean that the colors in the bars should not be heavily saturated so they spill over the bar pattern edges.

2. Set the hue (tint) control at the mid-position of its range.

3. Adjust the slug in the burst transformer, T_1, so the bars display their correct colors. A partial turn of the slug is all that should be required.

The afpc system is now properly adjusted. Adjust the color killer threshold so the killer stage enables the bandpass amplifier on a weak color signal.

SELF-TEST QUESTIONS

(q) How can you determine if a green stripe test signal is available on a TV channel?

(r) What is one advantage of using a color bar generator signal in preference to a color program signal for checking a color receiver?

(s) Why must steps of a setup procedure be carried out in a particular sequence?

(t) What ability is very important for your success in color receiver servicing?

(u) What setting of the brightness control will produce maximum current through the high voltage shunt regulator tube?

(v) When adjusting the horizontal efficiency coil, what condition of current through the horizontal output tube do you strive for?

(w) What operation do you perform to demagnetize a receiver?

(x) What adjustments need to be made if a black-
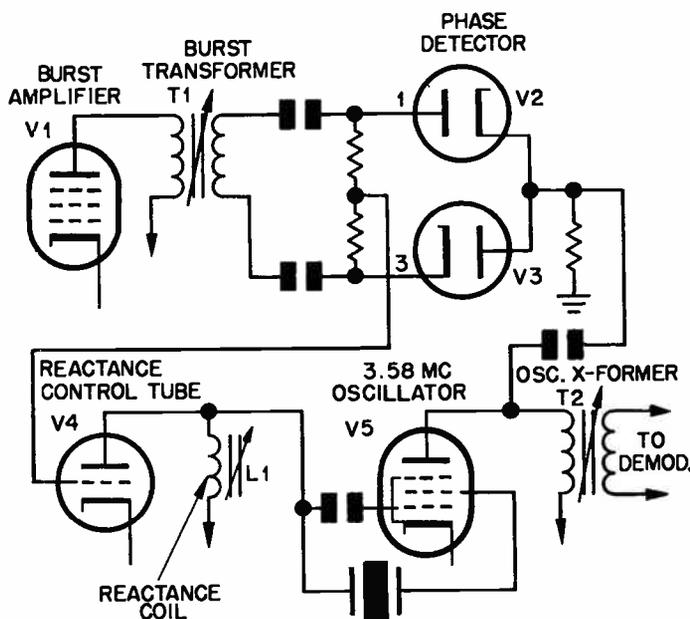
Fig. 21. Simplified schematic showing the adjustment points in the color AFPC system.

and-white picture has a pinkish hue?

(y) What controls are used to adjust purity at the center of the screen?

(z) What area of the screen is most affected by the position of the deflection yoke when making purity adjustments?

(aa) Why do you use a dot in the center of the screen when making static convergence adjustments?

(ab) What two beams do you adjust first when making the static convergence adjustments?

(ac) In what direction does the blue dot on the screen move when adjusting the blue lateral magnet?

(ad) How are dynamic convergence errors corrected electrically?

(ae) Which procedure will usually produce the best convergence: making all adjustments very accurately once or going through the adjustment procedure twice rapidly?

(af) What piece of test equipment is most useful for checking the color sync adjustments?

(ag) What condition do you tune for when you adjust the 3.58-mc oscillator transformer.

(ah) How do you adjust the reactance coil in the plate circuit of an afpc reactance control stage?

Installing Picture Tubes

Test, installation, and adjustment of picture tubes present special problems. The picture tube is large and bulky compared to other parts of the receiver and it is an expensive item. The high vacuum within the large space of the tube presents a safety hazard that is not found elsewhere in the receiver. You must be able to pinpoint picture tube faults in a home service call and determine definitely whether the tube is defective or not. New picture tubes are often installed in the home, especially for large console-type receivers. While installing a picture tube is a routine job, it is important to do it safely and correctly. The final tests and adjustments after installation are especially important when installing a new color picture tube.

SAFETY PRECAUTIONS

Working close to a picture tube is like working near a small bomb. As long as nothing causes it to explode – or implode in the case of the picture tube it is perfectly safe. Fortunately picture tubes seldom break. When they do break, air rushes into the vacuum imparting high velocities to the shattered pieces of glass. The glass can cause painful cuts anywhere on the body, but the biggest danger is getting flying glass in your eyes. For this reason you should always wear safety goggles while handling a picture tube. Many servicemen do not wear goggles but the little time lost and the small discomfort of wearing them is well worth the protection they afford.

What makes picture tubes break? Obviously a hard blow will break the glass. The fragile neck is especially susceptible to breakage by being hit with tools. Anything that puts a strain on the neck is liable to break it. A less obvious cause of breakage is scratching the glass surface anywhere on the tube. Remember that the glass is under stress at all times due to the vacuum inside. Even a minor scratch can weaken the structure and cause the glass to rupture. Observe the following safety rules when working on picture tubes:

1. Wear safety glasses (or goggles) when installing or handling unprotected picture tubes.

2. Store picture tubes in the manufacturer's carton until ready to use.

3. Never transport an unprotected picture tube. Have the tube in a carton or cover the tube (receiver if the tube is installed in an open chassis) with a blanket or furniture mover's pad.

4. Never pick up a picture tube by the neck. Hold it near the face plate.

5. Always set a tube on a soft surface such as corrugated cardboard or a cloth. A hard gritty surface can mar the face or cause breakage from scratching the surface.

6. Never place meters, tools, or other heavy objects above (at higher levels) than the picture tube on your workbench.

7. Don't put old picture tubes in the trash unless the vacuum has been released.

8. Always discharge the high voltage anode to the outside aquadag coating before installing or handling a picture tube. While the shock may not be dangerous electrically, it may cause you to drop or break the tube.

TESTING PICTURE TUBES

When you suspect that a picture tube is defective, you need definite tests to prove whether it is good or bad. This is especially important when you are troubleshooting a receiver in the customer's home. Also there are some picture tube defects that can be corrected. A repair job that gives the customer six months or a year's extra service from his picture tube is often appreciated.

Defects.

Picture tubes suffer from the same types of failure as receiving tubes. Open heaters, open or shorted electrodes, low cathode emission, and gas are the common causes of failure. An open heater is easy to spot because the light given off by the heater is normally visible in the neck of the tube. Shorted elements within the tube structure can sometimes be measured with an ohmmeter. However the short may not occur until the tube is up to operating temperature. Low cathode emission shows up as a weak picture (insufficient contrast and/or brightness). Usually the picture will improve as the set warms up. Loss of detail in the brightest areas of the picture may also be an indication of low emission. The appearance of silvery blotches in bright areas of the picture with loss of detail or even a negative appearance to the picture can be caused by a gassy picture tube.

Intermittent or open connections to any electrode can be caused by defective connections at the picture tube base pins. Some picture tubes have wires that are brought out through the glass seal. The wires are then soldered into the pins on the picture tube base. Sometimes the solder crystalizes making an imperfect connection. If the base becomes loose, strain on the base may open one or more of the connections. An intermittent connection can often be detected by tapping the base lightly while the set is operating.

The open connection can be repaired by removing the picture tube socket and resoldering the pin connections. Heat the pin with a soldering iron or gun. Feed new solder in through the hole in the end of the pin. If necessary file another hole in the pin about half-way from the end of the pin. This enables you to

get solder around the wire in the hollow pin. Remove excess solder from the outside of the pin so the socket will fit on easily.

Picture Tube Testers.

Many receiving tube testers have an adapter cable for testing picture tubes. The adapter enables you to connect the picture tube to the tester and perform tests. With this arrangement you can measure tube emission and test for shorts, opens, and gas.

Separate picture tube testers usually have added provisions for rejuvenating weak tubes and correcting some types of defects. The better testers will have the following provisions:

1. Test all crt types (including color tubes).
2. Check heater continuity.
3. Check cathode emission.
4. Check cut-off bias requirements.
5. Check for inter-element leakage and shorts.
6. Rejuvenate weak cathodes.
7. Clear shorts and weld open elements.

The use of a separate crt tester-rejuvenator usually enables you to pin-point the exact defect that makes the tube unusable. Depending on the results of the tests, you can try to correct certain types of defects.

The use of a tester-rejuvenator involves certain precautions. Use the tube test data supplied with the tester to determine the correct heater voltage setting for the tube you are testing. Some testers have data for setting certain operating voltages for different tube types. Connect the tester to the picture tube using the cable, socket, and if necessary, an adapter to match the picture tube base. The tester will indicate if the heater is open. Next test the tube for shorted elements. Shorts are usually indicated by a neon bulb that glows if the selected element is shorted. If no shorts are indicated place the function switch to the "beam current" position. Depress the "read meter" button and read an indication of cathode emission. The scale is usually marked good, ?, bad. The relative amount of deflection on the meter is a measure of the tube quality. Rotating the negative bias control indicates the cut-off point of beam current. The change in bias from normal to beam cut-off is an indication of the contrast ratio that the tube is able to display.

Consult with the customer before you attempt to rejuvenate a tube that shows shorts or tests weak. If the tube is producing an unsatisfactory picture, the customer will probably want you to attempt to rejuvenate the tube. Even so, you should explain to him that attempted rejuvenation can cause complete failure of the tube. Rejuvenation involves applying higher than normal voltages to the elements. These high voltages can permanently damage elements of the tube. The only recourse then is to install a new picture tube. Explaining this ahead of time can avoid embarrassing misunderstandings.

The rejuvenator clears shorts by applying a voltage between the shorted elements. The voltage is often able to dislodge the material causing the short or the material is burned away.

Open elements can sometimes be rewelded by applying a high voltage to that element. This technique is often effective for repairing an open cathode. A voltage is applied across the break in the element. An arc forms, welding the break together. The repair should be tested by tapping the neck of the tube lightly to see if the repair is permanent.

Low emission is overcome by overheating the heater. This will often reactivate the cathode surface. The emitting surface of the cathode tends to build up a scale of inactive material that retards emission. When a high voltage (100 to 200 volts) is applied to the grid, a current arcs between the elements breaking off the scale. You can actually see bits of material produce sparks in the gun of the tube. This exposes new active cathode material allowing the emission to come up to normal.

Allow time for the temperature of the cathode to return to normal and retest for adequate emission. Check the emission at reduced heater voltage. This is an indication of the life expectancy for the tube. The emission of a new tube will fall off only slightly or not at all with reduced heater voltage. If the emission falls off to about half with a 20% reduction in heater voltage the life expectancy of the tube is poor.

CRT Booster.

A picture tube brightener, or booster, contains a small transformer for increasing the heater voltage to the picture tube. A booster can be placed on the picture tube to hold the emission up to the required level after rejuvenation. Some servicemen prefer to try the booster first. If it gives an acceptable picture they do not have to risk rejuvenating the cathode. Picture tube brighteners come in two general types besides the obvious difference of pin-basing. One type is for parallel heaters while the other type is for series string heaters. Some types, called universal boosters, have a plug that can be inserted in either of two holes for either parallel or series operation. When you install a booster, observe the brightness of the heater before and after installing it. The heater light in the neck of the tube should appear noticeably brighter if the booster is effectively raising the heater voltage.

CRT Check Tube.

Specially built small picture tubes are available for substitution. These tubes, usually 5-inch round or 8-inch rectangular, are designed to give an acceptable picture over a wide range of operating voltages. The check tube is simply substituted for the regular picture tube. If the check tube shows an acceptable picture, the picture tube must be defective. This substitution method is seldom used. The check tube finds its biggest utility in the shop where the check tube is installed in the chassis while repairs are being made. This makes it possible to leave the large picture tube in the home and remove only the chassis.

Operating Tests.

The picture tube can be tested in the home with only a vtvm. Slide the picture tube socket back far enough to expose the pins. Observe the neck for a lighted filament. Measure the voltages between the pins and chassis with a vtvm. The first anode should measure

between 200 and 400 volts. The difference between the control grid voltage and the cathode voltage should be near zero with brightness turned all the way up. The difference should change to about 100 volts, grid negative (or grid 100 volts less positive than the cathode), with brightness turned all the way down. Measure the high voltage or draw an arc from the second anode. If the voltages are correct to the picture tube pins and the tube does not operate, you can suspect the tube.

A defect within the tube can affect the voltages at the picture tube socket. Read the pin voltages with the socket connected to the tube. Then remove the socket and read the voltages at the socket. A noticeable change in reading indicates that a defect within the tube is upsetting the voltage readings.

Picture quality can give a misleading indication of the condition of the picture tube. The vtvm reading of the pin voltages gives no indication of the quality of the picture that the tube will produce. For example, your voltage readings may all be correct but the set produces a negative picture. The trouble could be low cathode emission and the presence of gas in the tube. Or the trouble could be a defective video amplifier stage.

REPLACING A COLOR CRT

The removal of a defective picture tube and the installation of a new picture tube is similar for black-and-white and color receivers. Since the color tube is heavier and has more devices attached to it, replacement is more complicated. In this section we discuss the replacement of a typical color crt. Most of the discussion also applies to the replacement of black-and-white tubes. You will find numerous variations in the mechanical mounting of the tube and the chassis. Therefore it is helpful to have the service literature for the particular model you are working on. Service literature gives instructions on the proper sequence for removal of the various parts of the set. Without the instructions it may not be obvious exactly which bolts or fasteners hold the parts in place. Of course, after you have had some experience, you will seldom find it necessary to refer to the service notes.

Usually, the first step in replacing the crt is to purchase the new tube. On occassion you may want to remove the old tube and take it with you when you get a new tube. This may be practical if you are doing the job in your shop. When replacement is performed in the customer's home, it is more convenient to arrive with the new tube. Then, you do not have to leave the set disassembled in his home while you go for the new tube. In either case it is important to get an exact replacement tube. Find the tube number either on the neck of the tube, stamped on the bell of the tube, or on a paper sticker attached to the tube. Try to avoid using a different tube number even if the tubes are electrically interchangeable. Too often you will run into mechanical differences in the tube that will make the installation difficult, shoddy, or impossible.

When the manufacture of a particular type picture tube has been discontinued, the manufacturer makes provisions for a replacement type. A mounting kit is available at the distributors to provide the necessary hardware so the substitution picture tube can be used in place of the discontinued tube. When you have such a problem, consult with the distributor for the recommended substitution on the exact model receiver that you have.

Plan the replacement job so you can work safely and conveniently. You need space to set the chassis, the new tube, the new tube carton, and the old tube while you are making the exchange. Be sure to provide a soft surface on which to set the tubes to prevent scratching the face. If working in a customer's home, provide a drop cloth to set the dirty chassis and your tools on. On most large receivers, the picture tube is attached to the cabinet so you need to support the cabinet on a soft surface, face down, on the floor.

Chassis Removal.

Disconnect the ac power cord and the antenna connections. Remove the back cover from the cabinet. Remove the control knobs from the front of the cabinet by pulling them straight out. The receiver shown in Fig. 22 has three secondary controls on the side of the chassis. Pull these controls straight out until they clear the shaft of the control but leave them attached to the cabinet. Some receivers have a decorative panel on the control section that must be removed before some of the knobs can be removed. In other cases, some of the small knobs may remain attached to the shaft and are removed with the chassis.

Next, you remove the plugs and cables that connect from the chassis to the tuner cluster or to the picture tube. Remove the picture tube socket, unplug the tuner cluster cables at the chassis, unplug the convergence board cable at the chassis, unplug the i-f input cable at the chassis. Disconnect the speaker leads at the speaker. Unplug the yoke plug at the chassis. Unplug the automatic degaussing coil cable at the chassis. Some of these plugs are easier to reach if you slide the chassis a couple of inches to the rear before you unplug them. Discharge the picture tube high voltage
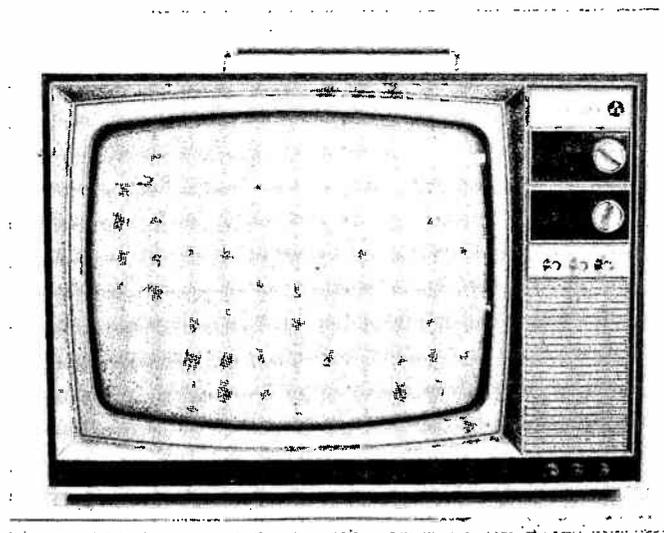
Fig. 22. Photo of a Sylvania color TV receiver.

Fig. 23. Discharging the picture tube.

Fig. 24. The cabinet with the receiver chassis removed.
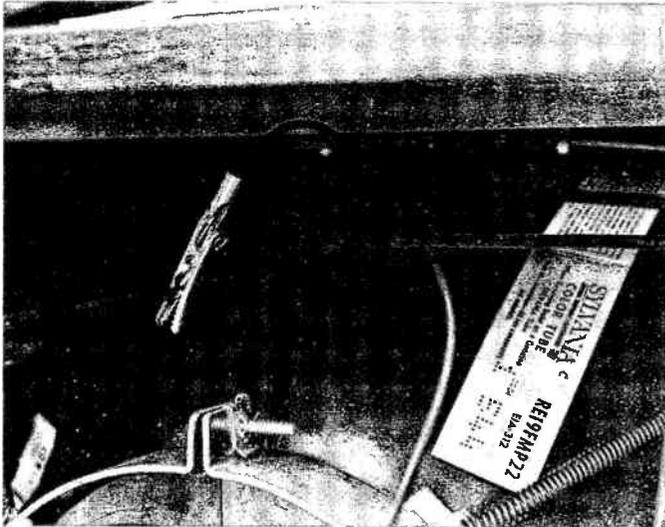
anode as shown in Fig. 23. Then disconnect the high voltage lead at the picture tube.

Remove the screws that hold the chassis to the cabinet and slide the chassis to the rear until it clears the cabinet. Set the chassis in a safe place. For some table model receivers, the cabinet becomes unstable and may tend to tilt forward when the weight of the chassis is removed. In this case, support the cabinet against an upright surface to prevent it from falling forward and damaging the face of the cabinet or picture tube. Fig. 24 shows the chassis removed. The tuner cluster is located behind the convergence control board.

Remove the tuner cluster. Loosen the two screws that secure the convergence board to the mounting bracket at the rear of the cabinet. Unhook the convergence board and temporarily lay it in the bottom of the cabinet. Remove the screws that secure the tuner cluster to the cabinet. Then swing the bottom of the tuner cluster out and up so the two slots in the

top of the tuner cluster bracket clear the two securing hooks. Remove the tuner cluster from the cabinet and mount it in the service position on the chassis. Two screws on the rear left edge of the chassis fit slots in the tuner cluster bracket. Tighten the screws to hold the tuner cluster securely. By attaching the tuner cluster to the chassis, the tuner will not be accidentally damaged.

Picture Tube Attachments.

These may be removed with the cabinet in the upright position. Or, some servicemen prefer to remove them after the cabinet has been placed face down. The service literature instructions usually give steps for removing individual items rather than all items in sequence. For example, instructions may tell you how to remove the degaussing coil without removing the chassis or yoke. Since these items have to be removed to replace the picture tube, it is easier to remove them before removing the degaussing coil.

Refer to Fig. 25 to identify the picture tube compo-

Fig. 25. Picture tube with neck mounted components.
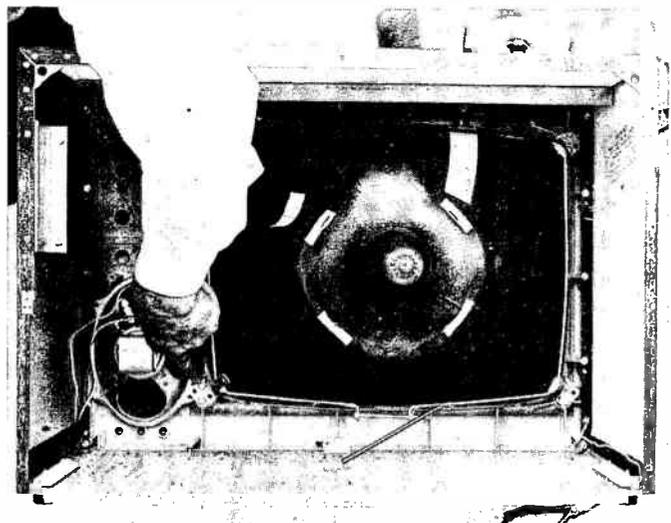
Fig. 26. Photo showing picture tube corner mounting brackets.

nents as we go through the removal steps. Loosen the screw on the securing ring of the blue lateral and purity adjustment magnet assembly. Slide the assembly off the neck of the tube.

Remove the convergence yoke assembly by sliding it off the neck of the tube. Rubber cement may have been used to hold the assembly in position on the picture tube neck. Rotate the assembly a small amount to break loose the cement. This will allow the assembly to slide easily on the neck of the tube.

Remove the four springs that pull the deflection yoke mounting bracket against the bell of the picture tube. Be careful not to let the springs gouge your hand as you release them. If you use pliers to detach the springs, be careful not to strike the picture tube with the pliers. Slide the yoke and mounting bracket from the neck of the picture tube. The yoke mounting bracket often has rubber bumpers between it and the glass picture tube. The rubber may stick to either the bracket

Fig. 27. Removing the picture tube from the cabinet.

or to the picture tube. Carefully pull the bumpers loose and save them for the new picture tube.

Remove the degaussing coil. This coil was held against the front of the cabinet by the tension of the yoke springs holding the yoke spring retaining straps against the degaussing shield. These straps protrude through slits in the degaussing shield. Pivot the straps as necessary so that they clear the slit as you lift the degaussing coil and shield assembly. Carefully lift the coil clear of the picture tube and cabinet.

Position the Cabinet.

Lay the cabinet face down on a soft surface, such as a blanket, to protect the picture tube face and cabinet finish. Cabinets that have protruding surfaces can be supported on a rolled up rug. This will support the cabinet without putting pressure on the protruding parts of the cabinet.

If the cabinet is equipped with safety-glass it should be cleaned when the picture tube is replaced. The safety glass is usually removable from the front of the cabinet. You can clean the safety glass before or after you replace the picture tube. If the inside of the
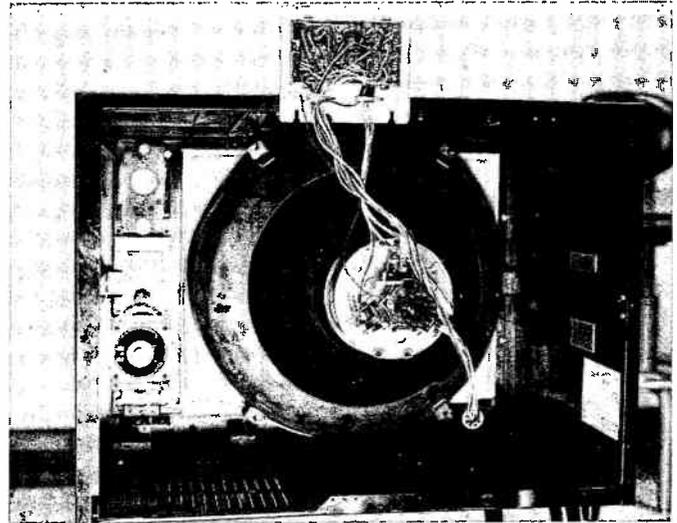
Fig. 28. 21" round tube and associated mounting hardware.

mask trim is very dirty, you may want to clean it while the picture tube is removed. Most technicians prefer to remove the glass for cleaning after the picture tube has been replaced. This enables them to remove any small bits of dirt that may have gotten on the picture tube during handling.

Remove the Picture Tube.

Loosen the securing bolts which hold the picture tube to the cabinet. For the mounting in Fig. 26, loosen the mounting strap tightening bolt. Remove the picture tube grounding spring. Remove the screws holding the picture tube mounting bracket to the cabinet at the four corners of the picture tube. Remove the four brackets and the mounting strap.

USE GOGGLES AND GLOVES to protect yourself in case the picture tube implodes. Stand close to the cabinet with your feet spread well apart. Be sure you are on firm footing, because the picture tube is quite heavy and it can unbalance you. Reach two hands under the face of the picture tube and lift it from the cabinet as shown in Fig. 27. On some cabinets you will have to tilt the tubes slightly to clear the rails of the cabinet. Set the tube face down on a soft surface.

Many color picture tubes are removed from the cabinet with the mounting bracket attached. Then the bracket is installed on the new picture tube before it is placed in the cabinet. Fig. 28 shows a 21" round tube with a metal shield that is part of the bracket holding the tube in the cabinet. With this version you place the face of the set down and then remove the bracket while the tube is in the cabinet. This enables you to remove the tube.

In the receiver shown in Fig. 28, before removing the picture tube you remove the chassis from the cabinet and place the cabinet face down on a soft surface. Slide the blue lateral magnet from the neck of the crt. Leave the ground wire of the magnet attached to it and to the convergence board assembly. Remove the purity ring magnets. Unbolt the convergence board bracket from the cabinet and slide the convergence magnet assembly off the neck of the picture tube.
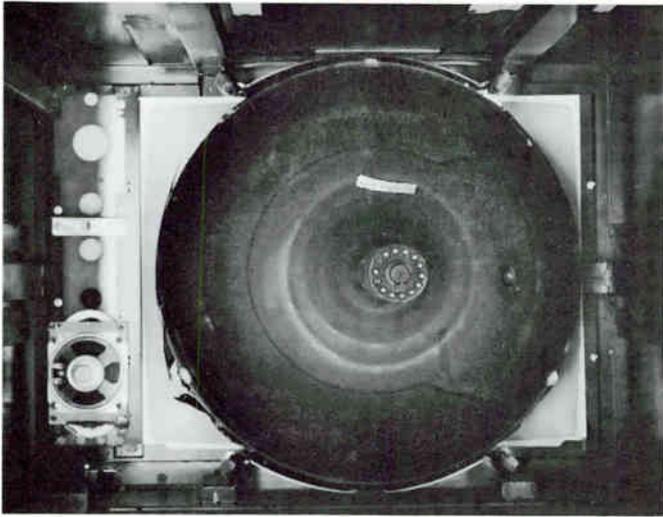
Fig. 29. 21" round picture tube with mounting bracket removed.

Loosen the deflection yoke clamp screw and slide off the deflection yoke. Remove four 5/8" hex head bolts that secure the picture tube assembly to the cabinet mask.

Use goggles and gloves to protect yourself in case the picture tube implodes. Lift the picture tube mounting bracket from the cabinet. This will leave the picture tube as shown in Fig. 29. Now carefully lift the picture tube from the cabinet and place it face down on a soft surface such as a blanket as shown in Fig. 30.

Installing the New CRT.

The service literature usually tells you to perform the disassembly instructions in the reverse order to assemble the receiver. This is easy to do because you became familiar with the way the parts are attached when you performed the disassembly. It is usually worthwhile to look back over the steps to be sure you have attached everything correctly. Take particular care that you reconnect any ground wires since they often are a protection against shock hazards. Also you may want to refer to the part sketches if you forget the exact replacement of parts.

Before you set the new tube in place, inspect the mask area. With bonded face tubes it is possible to catch something, such as a fold in the blanket, between the picture tube and the mask. If you secure the picture tube this way, you will probably have to again disassemble the set to remove it.

To install a rectangular color tube, set the tube in the cabinet with the anode connection toward the top of the cabinet. Position the four picture tube mounting brackets at the corners of the tube as in Fig. 26 and secure them to the cabinet with screws. As you set each bracket in place, make sure it fits the contour of the tube. Although the four brackets are interchangeable try to get them back in their original place as they will fit better. Make sure the cork (or rubber) spacers are intact between the bracket and the tube. These spacers bear against the glass and prevent direct metal-to-glass contact. If a spacer is lost or torn up, you can usually substitute several layers of electrical tape.

As you tighten the picture tube mounting brackets in place, the cabinet will be drawn up to the face of the tube. Make sure it draws up evenly. Usually it is better to tighten the brackets partially at diagonally opposite corners. Then go back and finish tightening them as you check for a proper fit.

Next, fit the picture tube mounting strap over the hooks on the ends of the picture tube mounting brackets. Position the straps with the tightening bolt toward the bottom of the cabinet as shown in Fig. 26. You may have to loosen the mounting strap bolt to fit the strap over all four hooks. Connect the picture tube grounding spring. Then tighten the mounting strap bolt.

Sit the degaussing coil assembly over the tube and mounting brackets. The cable to the coil should be on the right side (from the back of the set). Pivot the yoke spring retaining straps on each mounting bracket as necessary so that the straps protrude through the slits in the degaussing shield. The metal shield will touch against the four mounting brackets at the front of the cabinet.

Slide the yoke and yoke mounting bracket over the neck of the tube and up against the bell of the tube. Position the yoke so the yoke plug extends toward the bottom of the cabinet. Position the four plastic stand-offs on the yoke mounting ring at the four spring positions. These plastic stand-offs prevent metal-to-glass contact between the yoke mounting bracket and the picture tube. Stretch each yoke spring and connect it to its corresponding retaining strap on the four picture tube mounting brackets. The tension of these springs over the degaussing shield holds the degaussing assembly in place.

Attach the convergence yoke and blue lateral and purity magnet assembly. Position these parts in relation to the crt gun structure as shown in Fig. 31.

Set the cabinet upright and install the tuner cluster. Attach the convergence control board to the bracket on the side of the cabinet. Slide the chassis part way into the cabinet and connect the cables. Connect the degaussing plug, the yoke plug, i-f input, tuner cluster

Fig. 30. 21" round picture tube resting on soft blanket.

plug, convergence plug, and the speaker leads. Slide the chassis all the way into the cabinet and secure it with the two screws. Connect the high-voltage connector to the picture tube. Connect the picture tube socket being careful not to bend the picture tube pins.

Installation steps for the 21" round color tube varies depending on how the mounting strap is attached. If the mounting harness was transferred to the new tube, you oriented the mounting brackets in relation to the tube at that time. It is then only necessary to set the tube, with the mounting bracket attached, into the cabinet and secure the bracket to the cabinet. With the type shown in Fig. 29, you set the picture tube in the cabinet and orient it with the blue gun toward the top of the cabinet. Then, put the metal shield over the tube and fit the mounting bracket holes over the studs in the cabinet. At this time, check the orientation of the tube with the shield. Since the shield is fixed to the cabinet, you will have to rotate the tube to line them up. Rotate the tube so the letter U embossed on the rim of the tube lines up with the hole at the top of the metal shield. Attach four 5/8" nuts to the studs. Tighten the nuts firmly to draw the shield down against the picture tube and hold it firmly to the cabinet.

Many minor variations exist in the way the tube and shield are attached to the cabinet. Some installations have a plastic mask that is fitted on the rim of the tube before the mounting harness is attached. Careful observation of the parts placement during disassembly will make it easy to reassemble the parts. Refer to the service literature for any particular model that you are not familiar with.

Clean the safety glass at this time if the cabinet has a separate safety glass. A portion of the trim strip is usually removable. This allows you to remove the safety glass. Use glass cleaner or soap and water to remove any dirt or film from the inside of the glass. Rinse it well and dry it with a lint-free cloth such as cheesecloth. Clean the mask area inside the safety glass and check for dirt or fingerprints on the face
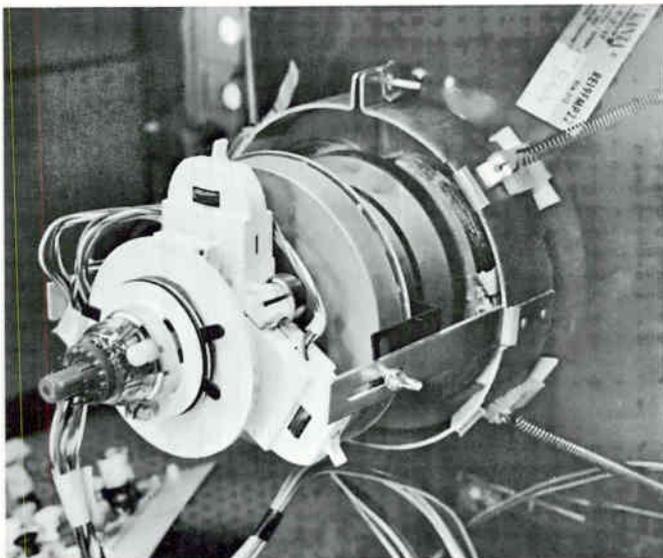
Fig. 31. Photo showing components mounted on neck of picture tube.

of the tube. Carefully replace the safety glass and clean the outside of the glass.

FINAL ADJUSTMENTS AND TESTS

With the new tube mechanically secured in the cabinet, you are ready to test it for proper operation. At this time, take a few minutes to carefully inspect the installation. Look critically at all areas in the cabinet. Are any cables unplugged? Ground wires disconnected? Check to see that cable clamps are in place. Check for missing mounting bolts and loose brackets in the cabinet.

Operate the set with the back cover removed. Watch carefully as the receiver voltages come up to their operating values. If you have pinched a wire causing a short circuit, you can quickly unplug the set before serious damage occurs. Let the set operate for a few minutes as you make preliminary adjustments such as picture size, centering, etc. A replacement picture tube will sometimes arc momentarily in the gun structure when it is first turned on. This does not necessarily indicate that the tube is defective. Small bits of material may lodge in the gun structure during shipment. Once they burn out, the tube will operate normally.

When you install a new black-and-white picture tube, the set will usually produce a nearly acceptable picture without adjustment. However, on color sets, you can expect the focus, brightness, screen controls and video drive controls to be way out of adjustment. On some replacement picture tubes you may find it impossible to make the color temperature adjustment. The picture may have too much red in it producing a magenta appearance. Most receivers are arranged so the red gun cathode gets the maximum video drive. With the replacement picture tube, rotating the green and blue drive controls to maximum, may not produce enough green and blue color to equalize the red. In this case, interchange the cathode lead from the red gun with the cathode lead from the green (or blue) gun. The drive control marked "green" (or blue) will then control the video drive to the red gun. You will then be able to equalize the light output from the three colors and produce a neutral gray screen.

Perform a complete check out of the receiver as a final test for proper operation of the new picture tube. With a color receiver you will want to go through the complete color setup procedure. As previously pointed out, you will get better results by going through the setup twice. Perform the adjustments quickly while the receiver is warming up. This will take care of large adjustments that have to be made and will minimize the interaction of the adjustments when you make the final color setup adjustments.

SELF-TEST QUESTIONS

(ai) Why is it important to wear safety goggles while working with a picture tube?
(aj) What precautions should you take before disconnecting a picture tube?
(ak) Name four common picture tube defects.
(al) What type of picture tube defect can often be

overcome by using a booster?

(am) Why is it important that round color tubes be rotated to one position?

(an) What should your first step be in replacing a color picture tube?

ANSWERS TO SELF-TEST QUESTIONS

(a) Tells exactly the work you did and parts installed. This limits your warranty liability.

(b) Shows you are a responsible businessman. Spells out the limits of your guarantee.

(c) Your actual cost of performing the service call.

(d) Name, address, phone number, and time of appointment. Also desirable: make and model of receiver and description of complaint.

(e) Two to three minutes.

(f) Fifteen minutes. With experience you should be able to complete many home service calls in this length of time.

(g) The soldering gun cools quickly so that it can be safely stored in the tool box.

(h) Color bar generator, degaussing coil, gun killer, and a hand mirror.

(i) Faulty appliances, such as lamps, near the TV receiver and hot antenna lead-in.

(j) Yes. If you explain limitations, customer will not be expecting better performance than the set or installation is capable of giving.

(k) Install sets that you sell. Have an agreement with a store that sells sets. Install sets that your customer has purchased.

(l) In your shop before delivery.

(m) Any external heat shortens the life of the receiver.

(n) Nine to twelve feet.

(o) A resistive attenuator reduces all signals the same amount.

(p) By having a regular routine that you use everytime you check a receiver.

(q) Disable the color-killer and fine-tune for un-

synchronized color stripe at edges of the picture.

(r) Known quality signal.

(s) Because the adjustments interact.

(t) Ability to perform color receiver setup adjustments.

(u) Minimize brightness setting (dark screen).

(v) Minimum current.

(w) Degaussing.

(x) Color temperature adjustments. Adjust the green and blue video drive controls until the picture displays a neutral gray or white screen.

(y) Neck purity magnets.

(z) Edges of the screen.

(aa) The electron beams are unaffected by the vertical and horizontal sweeps when the beams are producing a dot in the center of the screen.

(ab) Red and green.

(ac) Left and right.

(ad) The magnetic convergence fields are altered in accordance with sweep scanning signals.

(ae) Twice rapidly, because all the adjustments interact to some extent.

(af) Color bar generator.

(ag) Maximum amplitude of the output signal.

(ah) Short the grid of the reactance control stage to ground. Observe the color bar pattern and adjust the reactance coil slug until the color in the bars is uniform (not broken) and the color stops or moves slowly.

(ai) If the tube breaks, the flying glass could damage your eyes.

(aj) Discharge the high-voltage anode to be sure there is no charge stored in the tube or high-voltage supply.

(ak) Open or shorted elements, low emission and gas.

(al) Low emission.

(am) The guns must be positioned so the blue gun is on top.

(an) Read the manufacturers service information to get all the information you can on how the tube should be removed.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. Where do most direct contacts occur between the customer and your TV service operation?

2. If you have a choice, should a receiver be located where the light strikes it from the sides, front or from the back?

3. What precaution should you observe concerning the secondary controls when you are checking a color receiver?

4. What three things are adjusted when you perform the horizontal deflection alignment on a color receiver?

5. Does the focus adjustment affect purity or convergence?

6. What should you try first if a receiver shows evidence of color impurity?

7. What adjustment needs to be made if the hue (tint) control is not centered when the receiver displays correct hues in the color bar pattern?

8. What can cause a picture tube to break, besides dropping it or hitting it with a hard object?

9. What adjustments need to be made if the displayed picture has a purplish appearance at low brightness levels?

10. What kind of an attenuator can be used to reduce the signal strength from only one TV station?

USING THE TV RECEIVER AS A SERVICING TOOL

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STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

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USING THE TV RECEIVER
AS A SERVICING TOOL

Television receiver servicing consists of applying your knowledge of the television system to repairing defective receivers. You have studied the TV signal in detail. You learned how the signal is handled at the transmitter and what must be done with the signal at the receiver. You learned how the color TV signal differs from the black-and-white TV signal. The receivers, both color and black-and-white, were presented in functional block form. Then you studied the circuits of each section of the receivers in great detail. The whole purpose of all this information is to enable you to locate defects in TV receivers and to repair the defects.

Applying what you have learned requires some practical experience. You need experience in using hand tools, identifying parts, and tracing circuits within receivers. Before you attempt to repair a TV receiver you should develop some of these basic skills. For example, you must be able to make good solder connections, remove and replace parts, and operate your test equipment. These may sound too obvious to mention, but it is a very important part of servicing. Many a repair job has been botched by a sloppy solder job. You may know exactly what tests you want to perform on a circuit, but if you cannot operate your test equipment properly, your test results will be meaningless. You may have developed these skills in repairing radios. Many successful TV servicemen learn their basic servicing techniques while repairing radios.

What about the beginner who has not had a great deal of radio servicing experience? Can he be successful in television servicing? The answer to these questions is yes, providing he goes about obtaining practical experience in the correct way. Obviously, you will be able to find your way around more easily in a 5-tube receiver than in a 20 or a 30 tube receiver. But since the same basic servicing techniques are used in repairing both radio and television receivers, any prac-

tical experience you get in radio receiver servicing will be of benefit to you in doing television receiver servicing. Therefore, you should get some experience first on radio receivers before starting on television receivers. Try tracing out the circuits in one or more radios -- identifying the parts, the various stages, etc. If possible, try repairing a few defective radio receivers. Once you develop the ability to use professional isolation procedures on sound receivers, it will be comparatively simple to apply your knowledge to the more elaborate television receivers. You will find it far easier to move from radio receiver servicing to television receiver servicing than to start directly into television receiver servicing.

The large number of stages in a television set makes it essential that you localize the trouble as much as possible by effect-to-cause reasoning. We will go into this in detail in this lesson.

At first you might think it difficult to isolate a defect in a television receiver because it is such a complex device. However, the complexity of the receiver and the fact that a number of sections in the set perform more or less separate functions actually simplifies the task of isolating the defect to one section. As we will show later in this lesson, the fact that there are separate paths for the sound, sync, and picture signals will often let you identify the section or even the stage containing the defect simply by watching the picture and listening to the sound. Once you have managed to isolate the defect to one section of the set, it is usually comparatively simple to isolate it further to one stage, then to one circuit, and finally to the defective part.

As you know, there are many possible variations of the basic TV circuits. You will have to examine these variations if they are in circuits that you are working on. In most cases, the defect will be such that you can immediately isolate it to one section. Obviously, then,

you need not be concerned about the sections of the receiver that are operating properly.

For example, if in servicing a receiver you discover that you have normal sound, but instead of a picture, you have only a horizontal line across the center of the tube, you immediately know that the defect is in the vertical sweep circuit. You do not need to be concerned with the circuit variations that may exist throughout the receiver. You can go directly to the vertical sweep system and proceed to isolate the defect to either the vertical oscillator, the vertical sweep amplifier or the vertical deflection coils.

It is important to you as a beginner to obtain the schematic diagram of the television receiver you are servicing. It will greatly simplify your task of isolating the defect to one section. In addition, once you have located the defective part, you can usually find sufficient information on the schematic diagram to enable you to select a suitable replacement.

Of course, it is not always possible to obtain a schematic. However, in many cases you can get a diagram of a similar receiver made by the same manufacturer. Although this diagram will not be as valuable to you as the correct one, it will usually be very helpful. After you get some TV servicing experience, it will probably be all you will need. Later, after you become a thoroughly experienced serviceman, your need for schematic diagrams will decrease. Servicemen who have been doing TV service work for four or five years can usually isolate the defect to one stage without any reference to the schematic. You will eventually learn how to do this. You will also learn what the characteristic troubles of certain brands of receivers are, and many other details that will simplify your work.

If you service only one brand of receiver, as some service organizations do, you can usually get service information directly from the manufacturer. Generally, you can get your name on the manufacturer's mailing list, either through the distributor or by writing directly to the manufacturer. However, if you operate or work in a service shop where you may be called upon to fix all types of sets, you will need television service manuals that cover all sets. These manuals can be purchased from most wholesalers, and they will soon pay for themselves.

In this lesson, we will assume that you are a beginner in television servicing, and that you have had a minimum of experience in radio servicing. If you are a radio serviceman and have had considerable radio servicing experience, you will find this lesson rather easy. However, avoid skipping over any of the material in the lesson texts; you will find it is all important to you.

TV TROUBLES

In studying the performance of a TV receiver, keep in mind that different brands of receivers may vary considerably in their picture reproduction and sound quality. This is also true of different models of a particular brand. Some sets have very high sensitivity and will operate well in fringe areas, whereas others may have somewhat lower sensitivity and work well only in primary signal areas. In addition, some sets are capable of reproducing more picture detail than others. Therefore, if you find that a customer's set is not the type he should have for his particular desires or location, you should recommend a more appropriate set. Don't try to modify his set to make it work the way he wants it to work. Your job as a serviceman is to make the receiver work as the manufacturer intended it to work -- redesigning the set to improve its performance is not your job.

The complaints you are likely to encounter can be divided into three groups.

Group 1

Improper receiver operation due to a defective antenna or transmission line, a weak signal from the transmitter, or excessive interference either coming in over the power line or being picked up by the receiver antenna. These complaints are not due to defects in the receiver. Therefore, we will not discuss them here.

Group 2

Improper receiver operation due to misadjusted controls. You are likely to run into this type of complaint most frequently from new set owners. However, sometimes someone will tamper with the pre-set controls on the rear of the receiver and misadjust them to such an extent that the set owner cannot readjust them properly, even if he is used to the set.

Group 3

Improper receiver operation due to a defect in the receiver. The defect may cause a complete failure of some section of the receiver, or it may merely upset the performance of that section. Defects of this type may be due to complete failure of one or more components, or they may be due to gradual deterioration of components with age.

In this lesson we are mainly concerned with the complaints in Group 3. However, the use of the controls, both operating and the secondary controls are a useful tool for isolating defects in the receiver. Therefore, receiver response to controls is treated in some detail.

Servicing Procedures

Defects in television receivers can be located and corrected by using any one of several procedures. The exact procedure that you use may depend on the defect, the test equipment you have at hand, or your personal preference in attacking the problem. The successful serviceman knows many servicing procedures. He chooses the one most suited to the servicing problem he is working on. He is always ready to try a different procedure if the receiver does not respond to one servicing procedure.

In your last lesson we discussed the home service call and outlined a logical procedure to follow. In many ways this section is an extension of that procedure. In troubleshooting a receiver during a home service call, you are working in strange surroundings with a minimum of test equipment. Your objectives are to get the receiver operating properly with what you have at hand. You cannot expect to fix circuit defects on home service calls. Rather you go through a procedure that eliminates all simple defects, such as defective tubes, that could cause the trouble. When servicing a receiver in the shop, you go through this same procedure but also you have the equipment to complete the repair job regardless of the type of circuit defect in the receiver.

In this section we discuss several alternate servicing procedures that can be used to pinpoint defects in a receiver. All these procedures have several things in common. They all rely on a logical approach to isolating the defect. They all follow the principle of effect-to-cause reasoning. All these procedures can be fitted into the general framework of the NRI 10-Step Plan for locating and correcting defects in electronic equipment.

10-STEP PLAN

Television receivers are fairly complex devices. It is practically impossible to try to repair a television receiver by checking part after part, hoping to stumble across the defective one. You must use some system to isolate the defects as quickly as possible to one section of the receiver. Usually, the television receiver itself is the best and most valuable test instrument in your shop. The manner in which the receiver performs will provide excellent clues that should lead you to the circuit in which the defect exists.

Fig. 1 outlines a 10-step plan of action that you can follow to troubleshoot any television receiver. You should follow this plan whether you are troubleshooting a receiver in the home or on the shop bench. With experience, you'll go through this logical sequence automatically. Until you get the experience, conscientiously follow the plan. Review a job after it is completed. Try to see how the job fitted into the plan. Look to see how you could have avoided time wasting steps. A little effort in this direction will greatly improve your troubleshooting techniques. Let's consider each of these ten steps:

1. Determine the Complaint.

It is often possible to save valuable time by question-

ing the customer to determine exactly what the complaint is. This is particularly true when the defect is an intermittent one that may perhaps occur only once or twice in an hour. Also, by questioning the customer, you can find out exactly what his chief complaint is. Sometimes there may be more than one defect in the receiver, and the customer may not wish both defects eliminated. For example, you may be called into service a receiver because it loses horizontal sync. At the same time, you might notice that the picture is quite dim and discover that the dimness is due to a defective picture tube. The customer may be willing to accept the dim picture rather than go to the expense of replacing the tube. Of course, when minor defects other than the one about which the customer
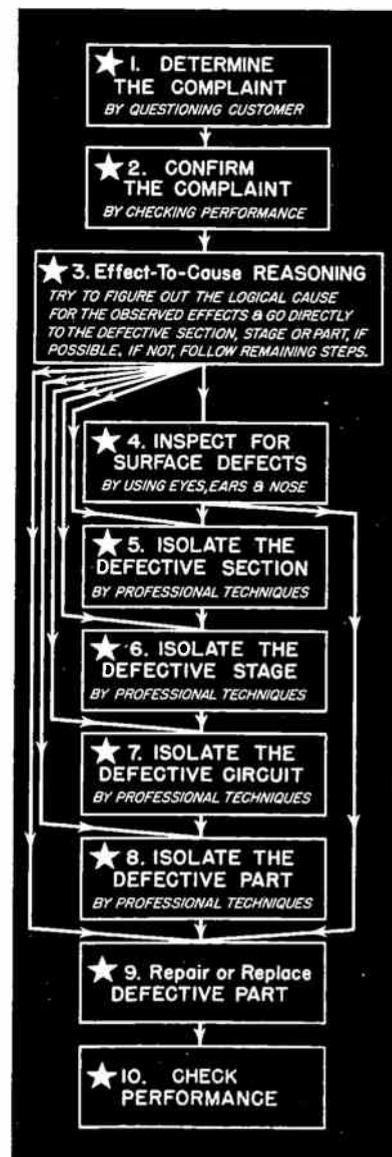
Fig. 1. A 10-step servicing plan for locating and repairing defects in a TV receiver.

complains can be corrected inexpensively, it is to your advantage to make the necessary repairs and return the set in top-notch operating condition. However, if the additional repairs will be costly, obtain the customer's permission before making them.

In questioning the customer, remember that he does not understand many of the technical terms used in radio and television. Therefore, ask questions in such a way that he will understand you and will give you the information you need. By asking him to describe exactly what it is that he can see on the screen of the tube or can hear from the loudspeaker, you can get a much better idea of the exact nature of the complaint.

Often it is impossible to question the customer. The set owner may have a friend who knows nothing about the performance of the receiver who will deliver the set to your shop and simply tell you to fix it. Sometimes when you go to the customer's home and pick up the receiver, the customer will be away and the person who gives you the receiver may know nothing about its performance. In these cases, go on to Step 2 at once.

2. Confirm the Complaint.

Checking the performance of the receiver yourself to confirm the customer's complaint is a very important step in servicing any TV receiver. Frequently it is obvious that the defect is a simple one and that the set can be repaired in the customer's home. This will save you considerable time and avoid removing the set and carrying it to the shop only to find that it could have easily been repaired in the customer's home.

You should make sure at this time that the trouble is caused by a defect in the set and not by a defective antenna, an open or shorted transmission line, or outside interference.

3. Effect-to-Cause Reasoning.

Once you have determined and confirmed the complaint, you should try to apply reasoning to isolate the defect to one section. Often the indication given by the picture or by the sound will lead you directly to the defective section, and sometimes you can go directly to one stage or even to the part that is defective. Of course, at other times the indications may be so general that you cannot reach any definite conclusion by effect-to-cause reasoning. Then you must make tests to isolate the defect to one section. However, after making each test, you should try to reapply reasoning to isolate the defect to as small a section of the receiver as possible.

4. Inspect for Surface Defects.

Although this is given as a separate step, it may well be a part of the confirmation of the complaint, or the effect-to-cause reasoning process, or it might be the first step after you have isolated the defect to one section. Look for possibilities such as a burned out tube, plug out of the wall socket, antenna disconnected or shorted, etc., before you make any effort to remove the chassis from the cabinet. You will want to see if the tubes light or get warm. Then, notice odors that would indicate overloaded parts, listen for noises, and watch the screen of the picture tube as you rotate the controls while trying the set.

If you find it necessary to remove the chassis, again make a careful inspection. A burned-out resistor or a shorted capacitor may be entirely obvious once you have the chassis in a position where you can examine the parts underneath it.

5. Isolate the Defective Section.

As we will point out later in this lesson, there may be many clues that will help determine which section of the set is at fault. The fact that some defects will affect both the picture and sound, whereas other defects will affect only one or the other, means you can determine quickly the approximate location of many common troubles. By applying effect-to-cause reasoning, you can often by-pass this step and proceed to the next step. However, in some cases it may be necessary to make some preliminary tests to isolate the defect to one section of the receiver before proceeding to isolate the defective stage.

6. Isolate the Defective Stage.

Use signal tracing, signal injection or other servicing procedures to isolate the defect to a single stage within the section. Once you have localized the trouble to one stage, effect-to-cause reasoning will lead you to make certain tests. Unless the trouble is obviously not due to a tube or transistor defect, try a replacement. Do not depend solely on a tube tester or a transistor tester to determine whether or not a tube or transistor is good.

7. Isolate the Defective Circuit.

Frequently, once you have located the defective stage, you can go directly to the defective part. However, if you are unable to do this, you should isolate the defect to one circuit by means of voltage measurements, continuity tests, and other servicing procedures.

8. Isolate the Defective Part.

Once you have isolated the trouble to one circuit, it is usually possible to go directly to the part that could be the most logical cause of the trouble. However, it may be necessary to continue the testing procedure within the circuit you have found to be defective until you actually do isolate the defective part. In this step you may have to test individual parts to determine which part within the defective circuit is at fault.

9. Repair or Replace Defective Part.

In most cases, a standard replacement may be substituted for the defective part. However, as we pointed out previously, and as we will discuss in more detail later, in some cases it is important that you obtain a replacement having exactly the same characteristics as the original component. Generally speaking, the video i-f stages, the video amplifier, the tuner, color circuits, and the sweep output stages are the most critical stages in a television receiver.

10. Check Performance.

After making the repair, try the receiver to make sure that the customer's complaint has been eliminated. If the customer is coming into the shop to pick up the receiver, if possible, let him see the receiver in operation. If the set is to be delivered to the owner's home, make sure that the set is in good operating condition before you leave.

After you have completed the repair, allow the re-

ceiver to operate for some time to be sure that no intermittent defect is present and also be sure that the set continues to operate satisfactorily after it has reached normal operating temperature. Of course, this step is not practical when the set is serviced in the customer's home. But even under these circumstances, as soon as you have completed the repair, turn the receiver on and allow it to continue to operate. It will probably be five or ten minutes after you have completed the repair before you leave the customer's home, and if you allow the set to operate at least for this length of time, it will be better than no operating test at all.

EFFECT-TO-CAUSE REASONING

The logic of effect-to-cause reasoning is so simple that it is easy to overlook. We use this logic so much that we may fail to recognize the mechanics of doing it. Let's examine exactly what we mean by effect-to-cause reasoning. Then when you follow the troubleshooting examples, you will understand the mental process that is necessary to apply this reasoning to servicing problems.

Take for example the screen grid circuit of a defective pentode amplifier stage. The screen decoupling capacitor is shorted and the screen grid resistor is open. From your knowledge of electronics, you know that the resistor is probably open because it passed excessive current. The excessive current was caused by a shorted capacitor. Here is the cause and the effect. The capacitor is the cause; the open resistor is the effect.

When we test the circuit our sequence of tests may have gone like this: We knew the stage was not amplifying so we decided to use voltage tests at the stage. When we measured the screen grid voltage, we found it to be zero volts. Then we measured the voltage at

the other end of the screen resistor and found it to read 130 volts which is the correct B+ voltage. An ohmmeter test confirms that the resistor is open and the capacitor is shorted.

Notice how we have used effect-to-cause reasoning throughout the test. We observe an effect such as zero screen grid voltage. Then we try to think of what caused this observed effect. Loss of B+ at the other end of the resistor could cause the screen voltage to read zero. Since B+ is present there, we reason that the cause is either an open screen resistor or a short to ground at the screen, or probably both. From experience, we know that the screen resistor is not of a high enough wattage to drop the entire B+ voltage without overheating so we may feel the resistor to determine if it is hot or look to see if it is burned. Again we are observing effects and trying to reason out what is the most probable cause.

Our effect-to-cause reasoning process is not a guessing game. In each step of our reasoning process we are making a logical, educated estimate of the cause that is producing the observed effect. Here is where your study of the TV system and receiver circuits pays off. The more electronic knowledge that you can bring to the reasoning process, the quicker you can locate the trouble. Thus, each time you work on a receiver, you are adding to your understanding of causes and effects.

Isolating a Defective Section.

Let's use effect-to-cause reasoning to isolate observed defects to one section of the receiver. You do not need a schematic diagram for isolating the trouble to a section. Instead you should think of the receiver in block diagram form. Follow the discussion on the block diagram of a typical monochrome receiver shown in Fig. 2. All the problems you will encounter in black-and-white TV servicing will also be encountered in color TV.
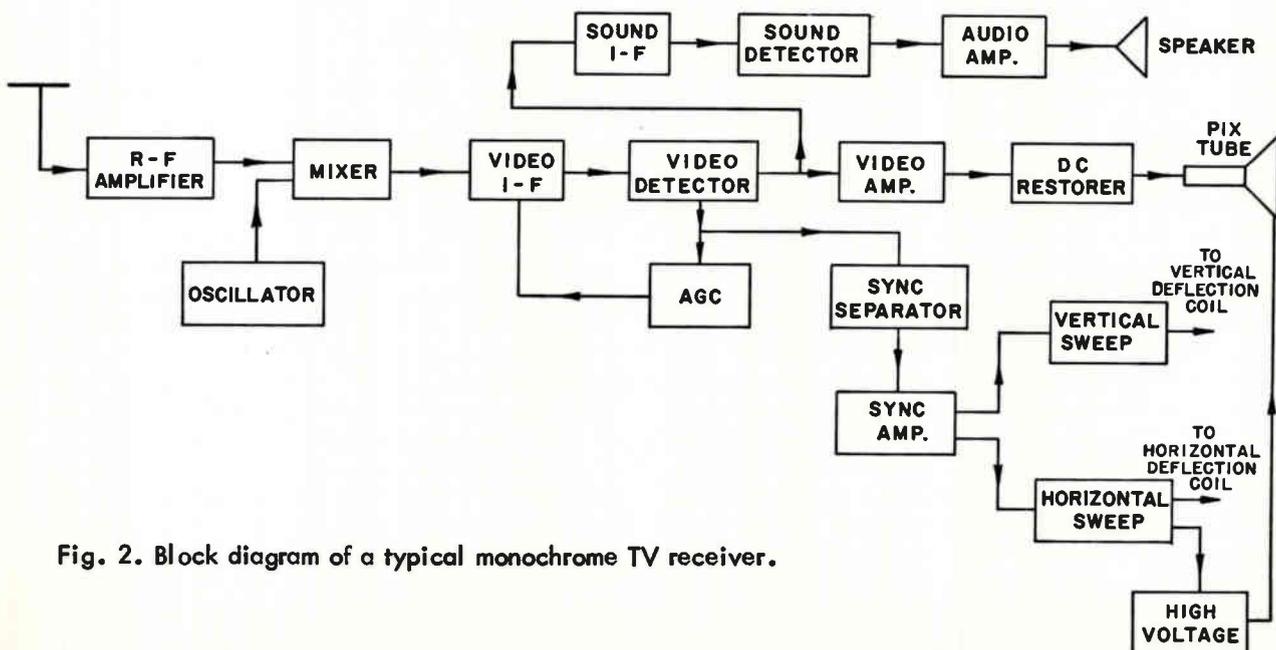
Fig. 2. Block diagram of a typical monochrome TV receiver.

The complaint is no picture and no sound. You confirm the complaint and observe that the raster is normal. In which section of the receiver would you expect to find the trouble? Let's apply effect-to-cause reasoning to see if we can isolate the defect. Could the trouble be a power supply defect? No, it is not likely that there is a defect in the power supply, because if there were, the operation of the sweep and high voltage supply would be upset and you would not have a normal raster on the picture tube. Of course, there could be a defect in a voltage divider network used to supply low voltages to some of the video or sound stages. This is a possibility that can be considered, but first let's look at the more obvious possibilities.

Study the block diagram in Fig. 2 and locate the section of the receiver in which the sound and video signals are handled together. The tuner, the video i-f stages, and the video detector are most likely to be causing this trouble. A defect in these stages could cause the loss of both sound and picture.

You might wonder if there may be two defects; one possibly in the audio amplifier and another in the video amplifier? Two defects of this type would cause the loss of both sound and picture signals. However, it is not nearly as likely that these two defects would occur simultaneously as a single defect would occur in the tuner or in one of the i-f stages.

Sound and Raster Normal-No Picture.

This complaint quickly isolates the trouble to a small section of the receiver. Again, look at the block diagram in Fig. 2. Since both sound and picture information pass through the video detector, the signal path must be all right through the video detector because we have normal sound. Therefore the defect must exist somewhere between the video detector and the picture tube. The most likely stage to be defective is the video amplifier.

No Sound-Picture and Raster Normal.

From Fig. 2 you can readily see that the defect must exist in the sound section of the receiver. Since the picture is normal, the entire picture signal path is good. The sound signal follows the picture signal path to the video detector so the defect must lie in that section of the sound signal path that is not common to the picture signal path. The only possible stages are the sound i-f, sound detector and the audio amplifier.

No Raster-Normal Sound.

With normal sound and a completely blank screen, we know that the low-voltage power supply is working and we are getting some received signal through the receiver. With this complaint it is easier to work directly back from the observed defect. The most likely cause of no light on the screen is loss of high voltage. We know this could be caused by loss of horizontal sweep or a defective high-voltage rectifier. But suppose we test for high voltage by drawing an arc from the second anode of the picture tube with a screwdriver. If high voltage is present, we must immediately change our line of thinking. The presence of high voltage implies that our horizontal sweep circuits are good. What could cause the tube to be dark? Is the picture tube filament lighted? If so, the picture tube beam must be held cutoff by dc voltages on the control grid and cath-

ode. The defect is most likely in the brightness circuit, dc restorer circuit, or it is remotely possible that the trouble is in the video amplifier stage.

Horizontal Line Only.

If you discover that when you advance the brightness control on a defective receiver you obtain only a horizontal line across the picture tube, you should know immediately that the trouble is in the vertical sweep circuit. Let's see how we reach this conclusion.

The fact that you have sound indicates that the tuner, the video i-f stages through which the sound signal passes, the sound i-f amplifier, the detector, the audio amplifier, and the power supply are operating properly. Further reasoning indicates that you must have high voltage on the picture tube, because if you did not have high voltage, you would not obtain any light at all on the face of the tube. You know that the horizontal sweep circuit must be working, otherwise you would not obtain any high voltage. The fact that you have a horizontal line across the tube is further proof that the electron beam is being swept across the tube. However, the beam is not being moved vertically. What moves the beam vertically? The vertical sweep circuit. Therefore, the trouble must be in this circuit.

Tests can then be performed to isolate the trouble further. The defect could be in the vertical oscillator, the vertical amplifier, or the vertical deflection coils.

These examples of effect-to-cause reasoning should get you started toward using this technique. As you study the servicing procedures described in this lesson, watch how we use effect-to-cause reasoning. In some troubleshooting examples we will skip over many of the reasons. You can fill in the reasons with a little thought. As you gain experience, your thinking will leap-frog directly from effect to cause without going through many of the reasons behind the conclusions. You will know the reasons but you do not have to take time to consciously reason out the steps that lead to the conclusions.

SIGNAL TRACING

One of the most accurate methods of troubleshooting a defective TV receiver is to use a signal tracing procedure. This procedure consists of testing at selected points in the circuitry to see if the signal is present. As you test for the presence of signals in the signal path, you are able to quickly determine the defective stage. Each point that you test tells you that the circuitry in the signal path is good up to that point. As soon as you test a point and find the signal missing, you know that the trouble lies between that point and the previous test point where you did get a signal. In this way you can quickly narrow down the defective section of the receiver -- usually to a single stage. And often you can pinpoint the trouble to one circuit or one component of the defective stage.

By using an oscilloscope to observe the signal, you are able to examine the shape and quality of the signal as well as to check for the presence of the signal. The importance of this feature cannot be over-emphasized. In fact, some defects that occur in a TV receiver are almost impossible to locate without the use of an oscilloscope. Other defects that might take hours to lo-

cate, can be isolated in minutes using a scope. If you are not now using an oscilloscope, get one. The cost of the instrument and the time spent learning to use it will be repaid over and over again in time saved on troubleshooting.

The signal tracing procedure is normally done in the shop. The receiver will have already been checked for simple defects such as defective tubes. The trouble may have been isolated to one section of the receiver by observing the picture and listening to the sound. Ordinarily, the chassis will be out of the cabinet and set up on the bench in an operating condition. The underside of the chassis is exposed so it is easy to trace the wiring and locate desired test points.

When should you use a signal tracing procedure for servicing a receiver? This is primarily an isolation technique so it should be used early in your investigation of a receiver's trouble. However, don't use it until you have made preliminary checks. Confirm the complaint by operating the receiver and use effect-to-cause reasoning to try to isolate the defect to one section of the receiver. Now that the chassis is out on a bench, inspect the wiring and parts for obvious defects such as a burned resistor. The nature of the defect should determine your next step. If you suspect trouble in the power supply, it may be best to take a few voltage readings. On the other hand, if the trouble is in the video signal path, sound circuits, color circuits, sync or sweep circuits, go directly to signal tracing with the scope.

Unless you are already quite familiar with the receiver, you will need a schematic diagram. Experienced servicemen will usually start signal tracing without the schematic because they can locate many test points at a glance. If possible, they will repair the receiver without consulting the diagram because it takes at least several minutes to locate the diagram. During this time they may be able to find the trouble. However, don't waste time puzzling through the wiring. As soon as you are lost, stop and get the schematic along with any other servicing literature that is available on that particular set.

Several test points in the TV receiver are particularly important for isolating defects. A critical examination of these test points determines whether large sections of the receiver are operating correctly. Observe the signal path in Fig. 2. If a video signal is present at the output of the video detector, all circuits of the receiver from the detector back to the antenna must be operating correctly. The presence of a good signal at the cathode or grid of the picture tube checks the operation of the video amplifier and its associated circuits. The presence or absence of a detected audio signal at the output of the sound detector determines if the trouble is in the circuitry toward the speaker or back toward the video detector. The presence of horizontal and vertical sync pulses at the output of the sync separator or sync amplifier in Fig. 2 indicates that the sync section of the receiver is operating properly. The drive waveform on the control grid of the horizontal output tube isolates horizontal trouble to either the horizontal oscillator section or the horizontal output section of the horizontal sweep circuit.

Let's discuss in detail the observation of the waveform at the output of the video detector. This will familiarize you with what to look for in using the scope to observe waveforms.

Video Detector.

The best place to start signal tracing in a defective receiver is at the video detector. The signal has adequate amplitude, usually 1 to 3 volts, to view conveniently on the oscilloscope. The video detector is easy to locate physically in the receiver because it usually consists of a crystal diode. Or the detector output can be viewed by observing the signal at the control grid of the first video amplifier. More important, the waveform viewed at the video detector contains all the received signal. A critical examination of this waveform can tell you a great deal about the operation of the receiver. If the waveform is good at the video detector, you know that the tuner, i-f amplifiers, agc, and video detector circuits are operating normally. You have eliminated a large portion of the receiver as a possible cause of trouble.
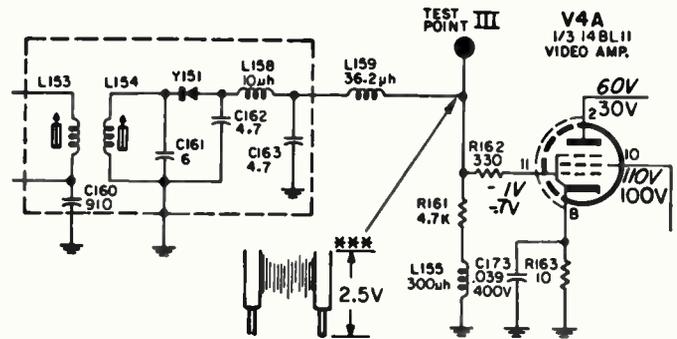
Fig. 3. Video detector circuit of a black-and-white receiver.

The schematic diagram in Fig. 3 shows a portion of a typical black-and-white receiver. Let's see what we can learn about the receiver operation by observing the detected video signal. The most convenient place to view the detected video signal in this circuit is at test point III on the diagram which is the output of the video detector and the input to the control grid of the video amplifier. Attach the scope probe to this point. The scope ground lead attaches to the chassis which is B- in this chassis. The detected video signal consists of frequencies up to 4.5 mc so we can use a direct probe. The circuit impedance is low at the output of the video detector so our scope probe will not load this circuit or seriously distort the signal.

Adjust the oscilloscope to obtain a synchronized pattern on the scope. To view the waveform at the vertical rate, set the horizontal scope frequency to about 30-cps so you see two fields of video as shown in Fig. 4A. Or, set the horizontal scope frequency at about 7850-cps so the scope displays two horizontal lines of video as shown in Fig. 4B.

Adjust fine tuning as you observe the detected video signal. This is important when you do not have a picture on the screen of the receiver. Of course you will tune the channel selector to a known active station.
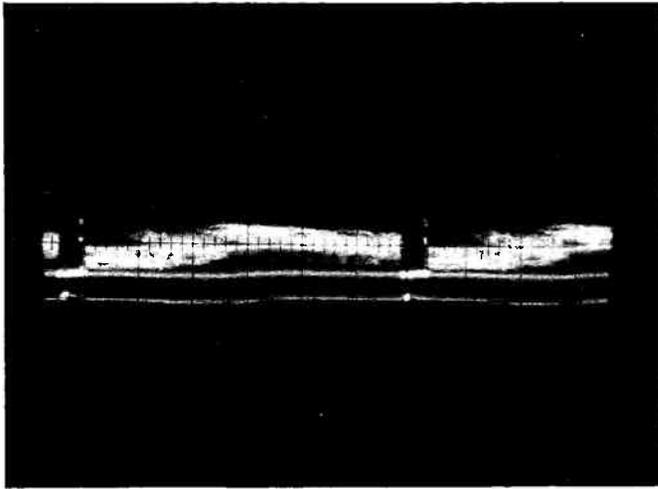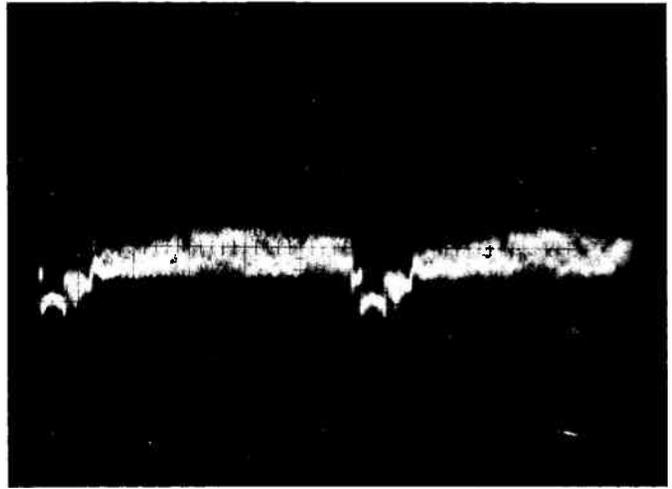
Fig. 4. Oscilloscope pattern of the detected video signal viewed at the vertical rate (A) and at the horizontal rate (B).

Then adjust fine tuning as you observe the video waveform. Usually you can adjust fine tuning for a maximum amplitude video signal. This will assure that you are tuned to receive a signal and should adjust the fine tuning very nearly to the correct tuning point.

Observe the detected video at both the vertical and at the horizontal rate. Determine the approximate peak-to-peak amplitude of the signal. Fig. 3 shows a waveform for test point III with a peak-to-peak amplitude of 2.5 volts. This schematic is copied from the manufacturer's service literature and carries much helpful service information. For example, the three asterisks by the waveform indicate that the waveform was taken with the scope synchronized at one-half the horizontal frequency. When you use a schematic, read the notes; they will enable you to interpret the markings on the schematic.

The scope you are using will affect the patterns you see. Most good service type oscilloscopes have a frequency response up to about 4.5 mc so you will see good clean detail in the trace. However, if your scope has limitations, you can still tell if the signal is good. Observe the detected signal from a receiver that is operating properly and use that for comparison. Even if your scope has rather poor response, you can get most of the information you need.

Examine the height of the sync pulses. The sync pulses should be one-quarter of the total height of the waveform. The video must not extend beyond the blanking level. Look for noise in the signal. It will show up as sharp spikes that may be bad enough to nearly obscure the video. At the horizontal rate, the video should show up as clean sharp lines that change in shape with changes in picture content. A clean video signal is necessary to produce a sharp picture free from smear.

If the station is transmitting in color, look for a color burst on the horizontal blanking waveform. Adjust your scope to observe the horizontal line rate as in Fig. 4B. Turn up the scope gain and center the

horizontal sync pulse. Look at the part of the blanking signal just following the horizontal sync pulse. While you normally cannot see the 3.58-mc sine waves, the burst should show up as a fuzzy enlargement of the trace at this point. You should be able to detect the color burst on black-and-white receivers as well as color receivers, when the station is transmitting a color program.

Practice observing the video waveform at the output of the detector on every receiver you repair in the shop. You will soon get so that you can tell at a glance if the signal is good and also you will develop a feeling for recognizing normal signal variations from one receiver to another.

Signal Tracing in a Color Receiver.

The complete schematic diagram of a color TV receiver is reproduced in Fig. 5 along with waveforms at significant test points in the receiver. This figure is taken from the manufacturer's service literature and is the kind of schematic that is very helpful for servicing. Included in the service literature are pictorial diagrams to help you find the test points in the receiver. (Fig. 5 is on pages 22 and 23.)

The waveforms in Fig. 5 were taken with the signal from a color bar generator applied to the antenna terminals of the receiver. Waveform 1 is taken at the grid of the first video amplifier and shows a 1.5-volt peak-to-peak detected video signal. Since the detected video waveform was discussed previously, it will not be repeated here. The only other waveform shown for the brightness channel is waveform 14. This shows a 100-volt peak-to-peak video signal that is applied to the cathode of the picture tube. If a defect exists between these points you would view the video signal at the plates and grids of the three video amplifier stages to isolate the trouble.

Two waveforms are shown in Fig. 5 for checking the input to the keyed agc circuit. Waveform 2 shows 750-volt peak-to-peak horizontal pulses from the horizontal circuit applied to the plate of the agc tube. Waveform

3 shows a 25-volt peak-to-peak video signal from the plate circuit of the first video amplifier applied to the control grid of the agc tube.

The separated sync signals are shown in waveform 4. Waveforms 5 and 6 show that the horizontal sync signal is being applied to the horizontal afc diode circuit. Waveform 11 shows the 210-volt peak-to-peak drive signal for the control grid of the horizontal output stage.

Waveforms 7 and 8 show the correct operating waveforms for the vertical oscillator. Waveform 10 is taken at the cathode of the vertical output tube. This waveform shows one of the vertical signals applied to the dynamic convergence circuits. Waveform 9 is a further check of the operation of the vertical circuits. It is taken at the secondary winding of the vertical output transformer showing the waveform applied to the vertical windings of the deflection yoke. Waveforms 12 and 13 are taken at the low-voltage power supply circuit to check for excessive ripple in the dc supply voltage. Waveforms 15 through 26 are used for checking the chroma circuitry of the receiver.

Waveforms 24, 25 and 26 show the color difference signals that are applied to the control grids of the picture tube. The color bar generator signal produces waveforms of predictable shape and amplitude. For example waveform 24 is the R - Y color difference signal that drives the grid of the red gun of the picture tube. Careful observation of the polarity and amplitude of each of the ten pulses representing the displayed bars tells you if the circuit is producing the correct R - Y signal for each bar. Pulses 1 through 5 are in a positive direction intensifying the red gun beam. Pulse 3 has maximum positive amplitude while pulse 2 and pulse 4 have equal positive amplitudes. Pulse 6 is approximately zero while pulses 7 through 10 are in a negative direction producing color bars without any red in them. Waveforms 25 for the G - Y signal and 26 for the B - Y signal can be analyzed in the same way.

Waveforms 19, 15 and 16 are in the chroma signal channel. Waveform 19 shows the chroma signal at the grids of the demodulators. The signal consists of ten bursts of 3.58-mc color signals representing the colors of the bars. The amplitude of this waveform varies with the setting of the "color control" which sets the saturation of the displayed color. Waveform 15 shows the same chroma signals at the plate of the bandpass amplifier while waveform 16 shows the input chroma signal at the grid of the bandpass amplifier.

Waveforms are provided for checking the color sync section of the receiver. Waveform 22 shows the 3.58-mc reference signal that is applied to the R - Y demodulator. This same signal is applied to the killer detector. Waveform 21 shows the recovered color burst signal at the plate of the burst amplifier. Waveform 20 shows positive horizontal pulses from a winding on the flyback transformer. These pulses are applied to the grid of the burst amplifier to gate the tube into conduction during horizontal retrace when the burst signal is present in the video signal. Waveform 17 shows the burst signal from the secondary of the burst transformer applied to the phase detector. Wave-

form 18 shows the 3.58-mc oscillator signal from the oscillator transformer applied to the phase detector. Waveform 23 shows the 3.58-mc oscillator signal at the plate of the oscillator.

Viewing the waveforms shown in Fig. 5 should enable you to isolate a defect to a fairly small section of the receiver. When signal tracing within a section, you will want to take waveforms at many more points than are indicated on the schematic. By referring to the waveforms shown, you will be able to predict what the waveforms should look like at intermediate points between the points where the waveforms are shown. As previously mentioned, signal tracing procedures are most useful as an isolation technique. Once you have isolated the trouble to a stage, or one circuit of the stage, you will usually have to resort to other tests to determine definitely which component is defective.

SIGNAL INJECTION

Signal injection provides a simple and effective method of isolating defects in the signal path of the TV receiver. This procedure is simpler than signal tracing because the TV receiver can be used as an indicating device. Signal injection works well in sections of the receiver, such as the tuner, where the received signals are too small to be conveniently viewed on a scope. One disadvantage of signal injection is that it tests only the ability of the stage to pass a signal. However, this is often all you need to isolate a defect to a particular stage.

When using signal injection to locate a defect in a TV receiver, the usual procedure is to work from the picture tube toward the antenna if the defect is in the picture. When the defect is in the sound, you work from the loudspeaker back toward the antenna. In each section where you inject a signal, the frequency of the signal must be such that the section will pass it. For example, in the i-f section, the injected signal must be of a frequency somewhere within the passband of the i-f amplifier. Follow the block diagram in Fig. 2 as we relate suitable signals for injecting into different sections of the receiver.

An audio frequency signal is suitable to inject in the video amplifier section of the receiver. The video amplifier must pass signals from zero up to about 4 mc. A 400-cycle signal will produce about 6 horizontal bars on the face of the picture tube. This frequency is normally available from a signal generator. If you inject a signal at the grid of the video amplifier and observe the bars on the face of the picture tube, you know that the video amplifier is working.

Next, inject a signal at the grid of the last video i-f amplifier. A suitable signal is a modulated rf signal having a frequency in the approximate center of the i-f passband. For example, 43 mc modulated by 400 cycles will pass through the tuned i-f stages. The video detector will detect the 400-cycle modulation and put bars on the picture tube. This step checks the video detector and the last i-f amplifier. Now move the injected signal to the grid of each of the preceding i-f stages. The amplitude of the signal should be reduced at each stage. By observing the effect of a re-

duced amplitude signal, you can determine if each stage is amplifying the signal.

The Tuner.

Signal injection is particularly useful for isolating tuner defects because the received signal is too small to view with most service scopes. As you can see in Fig. 2, the tuner has three stages, the rf amplifier, the oscillator, and the mixer. Signal injection can be used to isolate the fault to one of the three stages. You can inject an i-f signal into the mixer plate circuit by "floating" a tube shield on the mixer tube. Position the shield so that it is not touching the chassis and connect the "hot" lead of the signal generator to the shield. The signal is radiated into the mixer plate circuit of the tube by capacitive coupling between the shield and the tube. A modulated i-f signal at this point should produce bars on the screen. You must use a large signal because much of the signal is lost by the poor coupling into the tube. Also remember that this step tests only the plate circuit of the mixer stage.

Most tuners have a test point that enables you to inject a signal into the mixer grid circuit. Again use the modulated i-f signal. The signal amplitude can be much smaller because you have the gain of the stage to amplify the signal and the coupling is more efficient. Use a small value capacitor (about 200 pf) between the "hot" generator lead and the test point. If this test puts bars on the screen, you can be pretty sure that the mixer stage is operating.

The local oscillator can be checked by injecting a modulated rf signal to the mixer stage and observe if the local oscillator signal converts it to an i-f signal. For example, set the tuner to channel 2. Set the signal generator to produce a modulated rf signal in the channel 2 frequency range (54 to 60 mc). Inject this signal into the mixer grid (mixer test point). If the local oscillator is working, the mixer will convert the signal to the i-f frequency and the receiver will display the bars.

Table I lists the channel numbers and the corre-

CH.	FREQ. (MC)	CH.	FREQ. (MC)	CH.	FREQ. (MC)
	VHF	28	554-560	57	728-734
2	54-60	29	560-566	58	734-740
3	60-66	30	566-572	59	740-746
4	66-72	31	572-578	60	746-752
5	76-82	32	578-584	61	752-758
6	82-88	33	584-590	62	758-764
7	174-180	34	590-596	63	764-770
8	180-186	35	596-602	64	770-776
9	186-192	36	602-608	65	776-782
10	192-198	37	608-614	66	782-788
11	198-204	38	614-620	67	788-794
12	204-210	39	620-626	68	794-800
13	210-216	40	626-632	69	800-806
	UHF	41	632-638	70	806-812
		42	638-644	71	812-818
14	470-476	43	644-650	72	818-824
15	476-482	44	650-656	73	824-830
16	482-488	45	656-662	74	830-836
17	488-494	46	662-668	75	836-842
18	494-500	47	668-674	76	842-848
19	500-506	48	674-680	77	848-854
20	506-512	49	680-686	78	854-860
21	512-518	50	686-692	79	860-866
22	518-524	51	692-698	80	866-872
23	524-530	52	698-704	81	872-878
24	530-536	53	704-710	82	878-884
25	536-542	54	710-716	83	884-890
26	542-548	55	716-722		
27	548-554	56	722-728		

Table I. Table of channel numbers and corresponding frequencies.

sponding frequency band. The picture carrier lies 1.25 mc above the low frequency end of the band. The sound carrier lies .25 mc below the high frequency end of the band.

Another way to test the local oscillator is to set the channel selector to a local station and connect the receiver to an antenna. Set the signal generator to produce an unmodulated rf signal at the correct frequency at which the local oscillator should operate. To determine the correct signal generator frequency, add the video i-f frequency to the video carrier frequency. For example, for channel 2 the video carrier frequency is 55.25 mc and the receiver video i-f frequency is usually 45.75 mc. Simply add the two, 55.25 mc + 45.75 mc to get 101 mc, the correct local oscillator frequency to convert channel 2 to an i-f signal. Inject this 101 mc unmodulated signal to the mixer stage. Vary the setting of the signal generator dial to compensate for inaccuracy in the signal generator calibration. Observe the screen of the receiver. If you now receive the station, the local oscillator in the receiver is not working or it is oscillating at the wrong frequency.

Test the rf amplifier of the tuner by injecting a modulated rf signal to the antenna terminals. Set the tuner selector to a low channel, such as channel 2 and inject a strong modulated rf signal at the channel 2 frequency (55.25 mc). If the rf stage is dead, you should still be able to drive a large signal through the rf amplifier and get bars on the screen. If the rf amplifier stage is working, a very small signal will produce a full contrast on the picture tube. If it takes a large signal to produce an indication and since you should have already tested the local oscillator and the mixer stage, the rf amplifier must be defective.

Sound Circuits.

Signal injection can be used to quickly isolate the trouble in a sound section. As you can see from Fig. 2, the trouble probably exists between the sound take-off point and the loudspeaker. The stages carrying the signal are the sound i-f, the sound detector, and the audio amplifier. Inject an audio signal at the grid of the audio amplifier. A convenient injection point is the slider of the volume control. If this produces an output, the audio amplifier and speaker are good. The audio signal is carried as FM on the 4.5-mc sound i-f carrier. However, an amplitude modulated 4.5-mc signal will usually contain enough frequency modulation to produce an output from the FM detector. Inject a modulated 4.5-mc signal into the grid of the detector. If you get an audio signal from the loudspeaker, the detector is probably operating all right. Next, inject the modulated 4.5-mc signal at the input to the sound i-f stage. If a small signal here produces a good audio output, investigate the possibility that the receiver is tuned far enough off the station so that the sound signal is not reaching the video detector.

Signal Injection Devices.

Besides rf signal generators, several commercial devices are marketed that can be used for injecting signals into a TV receiver. Some of these are simple and inexpensive; others are expensive and complex. The simplest consists of a probe containing a battery-

operated transistor square wave generator that produces square waves in the audio frequency range. The square wave signal is rich in harmonics and produces usable rf injection signals up into the TV station frequencies. Injecting the output of the probe anywhere into the TV signal path will produce some kind of a circuit response. Some technicians like this type of device because it is simple and quick to use.

Other signal injection devices produce one or more of the signals present in a TV receiver. A complex device of this type is the B and K TV Analyst. It generates all the TV signals and makes them available for injection at various points in the receiver. The technician who regularly uses a device of this type develops troubleshooting procedures around the capabilities of the instrument. Detailed instructions for use of these instruments are usually included. The instructions help you apply your knowledge of TV systems to troubleshooting with the instrument.

CIRCUIT AND COMPONENT TESTS

After you have isolated a trouble to a single stage or to a circuit of that stage, you must locate the defective part. The results of signal tracing or signal injection isolate the defect to a circuit that may contain anywhere from one to a dozen components. At this point, tests on the circuit or on suspected components of the circuit is the quickest way to locate the defect. In this discussion we assume that the tube or transistor used in the stage is good.

The first step in testing a circuit is to know what functions the circuit is performing. Normally a stage performs one or more of the following three functions. It generates a signal, as an oscillator stage; it amplifies a signal or it shapes or modifies the signal passing through the stage. This last function includes stages such as gating circuits that combine two or more signals. Your signal tracing procedure will have determined if both signals are applied to the circuit.

If a stage fails to amplify or pass the signal, what are the possible reasons? Fig. 6 shows a typical pentode amplifier stage. Suppose we have a signal on the control grid of V_5 but no signal on the plate. We know the tube is good. The plate circuit could be open; the

cathode circuit could be open; grid bias could be highly negative cutting off the tube; screen voltage could be missing; or the filament circuit could be open. Since the plate circuit contains a tuned rf transformer (tuned to the i-f frequency), it is remotely possible for the circuit to be badly detuned. In this case we would still get some signal at the plate although its amplitude would be low. Likewise, if the screen bypass capacitor were open, the stage would not produce adequate amplification but there would be some signal at the plate.

From the above listed possibilities, the best test to perform is voltage readings at the pins of the tube. Suppose you read 175 volts at both the plate and the screen. This indicates that the tube is not passing any current because there is no voltage drop across the dropping resistor, R_{52}. Next, measure the cathode voltage. Suppose it reads above 100 volts. This tells you that the cathode resistor, R_{53}, must be open. The tube would conduct if the path through the resistor to ground were complete. Confirm the open cathode resistor by taking a resistance measurement, with the receiver off, from cathode to ground or directly across the cathode resistor.

But suppose the cathode voltage measured zero volts. Again, this indicates that the tube is not conducting so measure the control grid voltage. Suppose it reads -15 volts. This is sufficient to cut the tube off. It also indicates that trouble is in the agc circuit. However, in this circuit this is unlikely. A high negative agc voltage would have cut off the second video i-f amplifier, V_4, therefore no signal would have been present on the grid of V_5. Measure the voltage on the agc line. Suppose it reads zero volts. This is what you would expect because with no signal through the video detector, the agc circuit produces an output proportional to a no-signal condition.

How can we account for the -15 volts on the control grid of V_5 when the agc line measures zero volts? Suppose R_{50} in the grid circuit of V_5 is open. This would produce an open grid circuit and block V_5. The positive signal swing on the control grid of V_5 would cause the grid to draw current. With R_{50} open, the grid has no return path so the grid current would charge C_{50} putting a large negative bias on the grid and cutting off V_5. Turn off the receiver and take re-

Fig. 6. Typical amplifier stages.
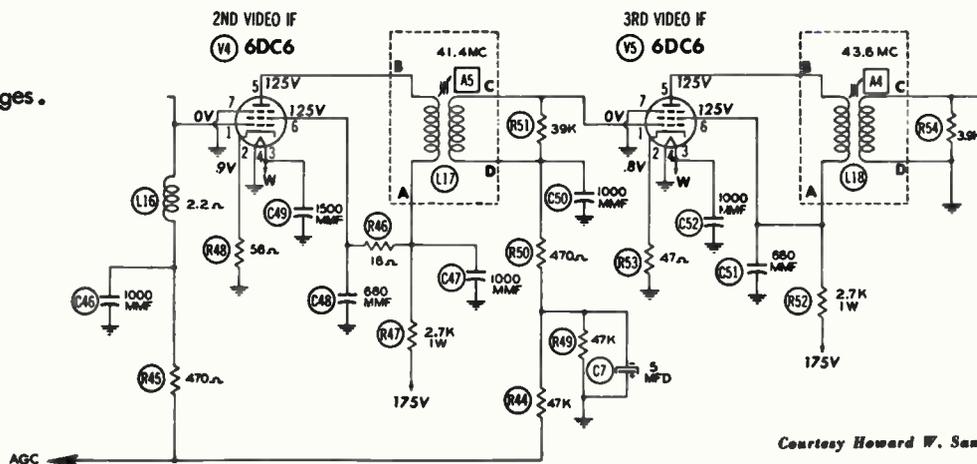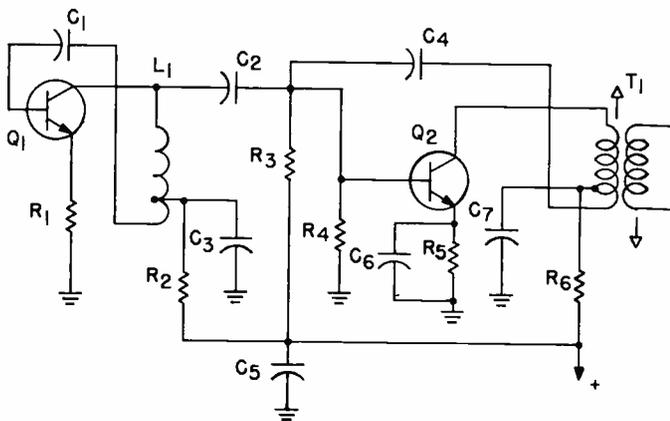
Fig. 7. A transistor video i-f stage.

sistance measurements in the grid circuit to pinpoint the defective component.

Suppose all voltage readings on stage V_5 in Fig. 6 are normal but the stage still does not amplify or has low gain. Don't overlook the possibility of a defective tube socket. The circuit may read good up to the pin connection but a defective tube socket could prevent the signal or operating voltages from reaching the pin of the tube. Also, check for low filament voltage. Normally you will look to see the glow of the filament in the tube so you do not need to measure the filament voltage. However, in some cases the filament may glow but the voltage is low enough to cause low cathode emission and low stage gain. Another possibility causing low gain is detuning or rf losses in the plate transformer. Troubles of this sort can best be located by going through the alignment procedure for that section of the receiver. For example, a shorted turn in the plate transformer would show up as low gain but you could not detect the trouble with an ohmmeter.

The same test procedures can be used on a transistor stage. For example, in the circuit shown in Fig. 7, if signal tracing disclosed that you had a signal on the base of Q_2, but none on the collector, you know there must be some defect in the stage. The defect could be a component defect that has upset the operating voltages on the transistor or it could be a defective transistor.

Since transistors are usually soldered into the circuit, you cannot test a transistor as conveniently as you can a tube by trying a replacement. However, often transistors can be tested in the circuit with a transistor tester. However, this is not always a positive indication of the condition of the transistor. In some cases the circuit defect may cause the transistor to test bad when it is actually good. Therefore, if you remove a transistor that tests bad in a circuit, be sure to test it again after you remove it to see how it tests.

The transistor circuitry can be tested by taking voltage and resistance measurements. Zero voltage on the emitter of Q_2 may indicate an open in the primary winding of T_1, open R_6, shorted C_7, a shorted transistor, or a combination of these defects. An emitter voltage equal to or almost equal to the collector voltage would indicate R_5 is open. Zero voltage or a

very low voltage on the base of Q_2 may indicate that R_3 is open.

Remember when checking the voltages on a transistor that the forward bias across the emitter-base junction will usually be only a few tenths of a volt. Therefore when checking these voltages, be sure to read your voltmeter very carefully to get an accurate reading of the forward bias across the junction.

Component Test.

Resistors and capacitors far outnumber any other components in a TV receiver. Resistors are easily tested with an ohmmeter. In some cases you may want to heat a resistor with a soldering iron while the ohmmeter is attached to see if the resistance value changes radically with temperature changes. Capacitors are easily tested for a short with an ohmmeter.

A capacitor can be tested with a capacitor checker such as the Conar Model 311 shown in Fig. 8. This instrument will measure the value of the capacitor, test it for leakage, and in some cases measure the power factor of the capacitor. If you do not have a capacitor checker, you can check the suspected capacitor by substituting a known good capacitor.

The kind of test you perform on a capacitor is often determined by what the capacitor does in the circuit. A capacitor that is used as a coupler or a decoupler can be tested by bridging the capacitor with a known good capacitor and observing the circuit operation. The exact value of the test capacitor is unimportant. For example, suppose you bridge a .1 mfd coupling capacitor with a .01 mfd capacitor and thereby get a signal through the circuit. This indicates that the coupling capacitor is open so you cut it out and replace it with the correct value. But for the test, the exact size is unimportant. However, if the suspected capacitor is part of a frequency determining or signal shaping circuit, you will have to substitute one of the exact value.

Coils and transformers make up the next most numerous components in a TV receiver. The windings
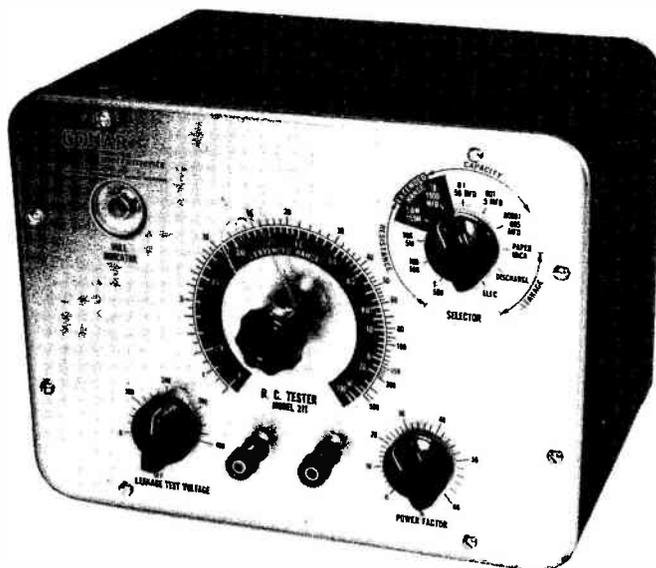
Fig. 8. A resistance-capacitance checker.

can be tested for opens and shorts with an ohmmeter. Power transformers, audio output transformers, and vertical output transformers handle sizable amounts of current. Therefore when they fail, the indication is usually easy to detect. One of the windings will open or the windings will overheat and show evidence of burning. Signal handling coils and transformers develop faults that are harder to detect. Leakage between windings, a single shorted turn, or rf losses may be difficult to measure. Since these parts are usually not stock items, they are tested by substitution only as a last resort.

Many one-of-a-kind components in a TV receiver are tested by special procedures. Included in this category are the horizontal output transformer and yoke. The test of these components will be included in the troubleshooting procedure for the section of the receiver where they are located.

TOUGH DOG HINTS

Every service technician encounters servicing defects that are almost impossible to locate and when a receiver does not respond to usual servicing procedures, it is often called a "dog". Locating a defect in such a receiver offers a real challenge to your servicing ability. You almost always learn something new when you complete such a job. It may be that you get a new slant on exactly the way a particular circuit operates. Or you find that certain signal indications take on new meaning. Or, you find a different way to check a component that has a marginal defect. The discipline of having to test all possible facets of a circuit's operation improves your skill with test equipment and sharpens your reasoning process.

A circuit defect that is a "tough dog" for one technician may be a routine servicing job for another technician. The intelligent application of servicing procedures will prevent many routine defects from becoming dogs. Spending many hours locating a defect may have some benefit in that you are bound to learn a lot about the circuit. What you should try to avoid is endless checking routines hoping to stumble across the defect. Usually you will find that you have made a faulty assumption about a signal or a circuit. Based on this faulty assumption you spend hours checking circuitry that is not related to the defect.

For example, suppose you have a horizontal sync problem that shows up as unstable horizontal sync. You change the horizontal oscillator tube and the sync separator tube. After readjusting the circuit, sync seems much improved but it still shows signs of instability. Next you try a signal tracing procedure. The waveforms are fairly good up to the horizontal afc circuit but in this circuit they have low amplitude and are unstable. You spend an hour checking the horizontal afc circuit and find nothing wrong. You had assumed that the trouble was strictly horizontal sync but now you notice that the raster lines show signs of pairing – poor interlace.

You assumed that the trouble was in the horizontal circuit so you concentrated on that circuit. When you viewed the sync pulses at the output of the sync separator, you did not compare their amplitude with that given in the service literature. You failed to check the relative amplitude of the sync pulses compared to the overall amplitude of the video signal. The sync instability just described could be caused by a gassy tube in the video i-f amplifier. When you view a waveform you must definitely decide whether it is good or bad before you proceed.

There are other ways to make a routine defect into a "tough dog." A defect in a receiver can give several indications. If you track down only one indication, you may eventually find the trouble but it may be the hard way. For example, a color receiver shows a coarse picture that is badly overloaded. You find that adjusting the agc control has very little effect on the overload. Apparently the agc circuit is not operating correctly. A new agc tube does not help. Next you measure agc voltage and it is nearly zero. You know that it should be quite negative.

With the help of the schematic shown in Fig. 5, you start checking out the agc stage. The scope shows good horizontal pulses at the plate of the agc tube and the video signals are present although they are not clean. The voltage readings around the agc tube are not right so you measure B+ power supply voltages and they check within normal tolerances. You decide that the agc tube is not producing the correct negative bias because the screen grid voltage (at pin 8) is low. You measure the voltages along the screen grid circuit. Voltage is low at the junction of C_{136B} and R_{129}. Voltage is normal on the supply end of R_{129}. You trace the circuit from R_{129} through R_{325} to the screen grid of the first video amplifier. The screen voltage reads very low so you remove the tube and the screen voltage comes up above normal (160 volts). When you test the tube, it shows a short. A new video amplifier tube restores the set to normal operation. A coarse picture should always lead you to suspect a video amplifier stage. In this case, the faulty operation of the agc circuit was simply another indication of the basic defect. You should have considered all the indications and tried the simple remedies first.

Intermittents.

Defects that show up only at irregular intervals are difficult to locate because just as you start to make a test, the trouble clears up. Try to determine if the intermittent condition is related to temperature, voltage, or mechanical disturbances. A crack in the wiring of a circuit board may intermittently make and break connections in response to vibration. A fault of this type can usually be located by selective wiggling or tapping of parts or areas of the circuitry. Sometimes it is easier to resolder all the connections in an area where a cold solder connection is producing an intermittent.

An intermittent may result when a capacitor breaks down under a critical voltage value. For example, house line voltage may vary considerably over the period of a day. When the line voltage is low or normal, the set may function correctly. High line voltage may produce enough additional B+ voltage to exceed the breakdown voltage of a defective capacitor.

The capacitor may arc over only occasionally producing picture defects. An intermittent of this type can

sometimes be quickly located by applying a higher than normal voltage to the receiver. Use a voltage step-up device such as a Variac to produce a line voltage of about 135 volts. This should cause the defective capacitor to break down continuously so that you can run regular tests and locate it. The use of high line voltage is a standard procedure for uncovering components with marginal defects. The higher voltages produced throughout the receiver puts additional stress on the components. A partially defective or intermittent component can often be made to break down completely. Then the defect can be isolated by usual testing procedures.

In servicing a color TV receiver, you have to be very careful about operating it on higher than normal input voltages. If you raise the line voltage 10%, chances are the high voltage will go up 10%. This may cause excessive x-ray production. You must avoid this; x-radiation can be very dangerous.

If you want to operate a color set at higher than normal line voltage in order to try to locate an intermittent defect, you should first reduce the high voltage by about 10%. Then when you increase the line voltage to the receiver the high voltage should not exceed the value recommended by the manufacturer. Even when you follow this procedure, you should check the high voltage after you have increased the input voltage to the receiver to be sure the high voltage has not exceeded the recommended value.

As mentioned before, make sure all shielding used in the high-voltage section is in place when you are operating the receiver. This will reduce the possibility of your getting a shock and at the same time should contain any x-radiation produced by the receiver.

The use of low voltage is an effective procedure to induce defects that occur only when line voltage drops below normal. An example of this type of defect is an oscillator that drops out when voltage is low or a picture that does not fill the screen.

Defects that show up only under high operating temperatures may appear to be intermittent. A receiver may exhibit a defect while it is in the cabinet but show no defect when operating on the bench. A heat lamp focused on the suspected area can be used to heat up the parts and cause the defect to appear. A soldering iron can be used to heat individual components. When you apply heat to the intermittent component, the defect will appear. An alternate method is to cool selected components by spraying them with a coolant. When the heat sensitive component is cooled, the symptom disappears.

Some intermittents occur randomly at various time intervals. You may have only a minute or two to work on the set before the defect goes away for another hour or so. In this case, you simply connect the test equipment to perform the tests you want. Then go about other work until the symptom appears. Although this requires time and patience, you will eventually be able to run enough tests to isolate the trouble.

Multiple Defects.

On rare occasions you may find a receiver with two or more independent defects. This can produce confusing symptoms. You will probably be trying to think of a single defect that could be causing all the symptoms. In many cases, signal tracing procedures will confirm the fact that two defects are present. Or you may not realize that two defects exist until you have fixed one defect. When the symptoms of each defect influence the test results, try working from the power supply toward the signal handling circuits. For example, suppose a defective voltage divider network and a defective stage are both contributing to faulty B supply voltages. Disconnect the sections from the B supply line to isolate the stage that is loading down the circuit. Voltage measurements in the remaining portion of the B supply line should lead you to the defective component in the voltage divider network. After this defect is corrected, use standard techniques to locate the other single defect.

SELF-TEST QUESTIONS

(a) Name several manual skills that you must acquire to successfully repair TV receivers.
(b) What is your most valuable aid for locating troubles in TV receivers?
(c) Why is a background of Radio Servicing useful to the technician planning to do TV service?
(d) Why is the complexity of a TV receiver sometimes useful in isolating a defective circuit?
(e) What are several advantages of using a uniform plan, such as the NRI 10-step plan, for locating receiver troubles?
(f) Why is it important to operate the receiver and confirm the customer's complaint as a first step in troubleshooting?
(g) In using effect-to-cause reasoning to isolate a defect to one section of the receiver, should you think in terms of the schematic diagram or of the block diagram of the receiver?
(h) What is one advantage of the signal tracing procedure over the signal injection procedure for troubleshooting?
(i) What is one advantage of the signal injection procedure over the signal tracing procedure for troubleshooting?
(j) In isolating a defect during troubleshooting, what is gained by performing a circuit test that proves the circuit is working properly?
(k) Should signal tracing and signal injection procedures be used as a last resort or early in your investigation of a TV problem?
(l) If the waveform observed at the output of the video detector is normal, what sections of the receiver are eliminated as possible defective areas?
(m) Where on the detected video waveform should you look for the color burst signal?
(n) What does noise look like when viewing the detected video waveform?
(o) What is the best signal source for signal tracing in a color receiver? Why?
(p) What frequency response is needed in an oscilloscope in order to view all the signals in the detected video waveform?

(q) What frequency is suitable for injecting a signal into the i-f amplifier of a receiver for test purposes?

(r) What section of the tuner is probably defective if you receive a station when you radiate an rf signal into the mixer stage of a receiver?

(s) Before performing a circuit test, what should you know about the circuit?

(t) What are the three general functions that a circuit may perform?

(u) What troubleshooting technique is usually most useful for determining if a circuit is performing its correct functions?

(v) What troubleshooting procedures are usually most useful for locating the defective component after the defect has been isolated to one circuit?

(w) What is one technique that can sometimes be used to force an intermittent defect to act up continuously?

Troubleshooting Sections of a TV Receiver

Early in your TV Servicing Course you learned to think of the TV receiver in terms of sections. These sections were represented as blocks of circuitry that process certain signals or perform certain functions. You again used this block diagram approach to isolate troubles to various sections of the receiver. Once the trouble is known to exist in a particular section of the receiver, you are ready to confine your tests to that section. As you gain service experience you will associate certain test procedures with particular sections of the receiver. Also you will tend to remember particular defects by associating those defects with a certain section of the receiver.

In this part of this lesson, we examine circuitry for various sections of TV receivers. We discuss typical defects and troubleshooting procedures for each of these sections. Some sections of a receiver develop peculiar problems and defects. Knowing what to look for ahead of time will shorten your troubleshooting time when you work on similar circuits.

In these discussions we assume that the trouble has been isolated to that section of the receiver. Also, it is assumed that tubes have been eliminated as the source of trouble. We do not limit our discussion to the exact circuitry shown for a particular section. It is impractical to show all possible circuit variations so we will show only typical circuits. Common defects and test procedures may be mentioned even though they do not apply to the circuit shown.

LOW VOLTAGE POWER SUPPLY

The low voltage power supply section of a TV receiver consists of only a few components and is usually quite easy to troubleshoot. You suspect trouble in this section when the receiver is dead; when B+ is exceptionally low or high; or when the receiver blows fuses. Let's examine the circuit in Fig. 9 to determine where to test the section.

When the dc voltage produced by the power supply is low, you must determine if the supply is defective or if the defect in the receiver is putting an excessive load on the power supply. Suppose you read 300 volts at the 405-volt point on the power supply in Fig. 9 and the 270-volt and 140-volt points in the voltage divider network are proportionately low. Disconnect the wires that are attached to the 405-volt point. This removes the load. If the voltage rises above 405 volts, it indicates that a short or partial short on the 405-volt line is overloading the supply. You would then take voltage and resistance measurements on the 405-volt line to isolate the defect.

Suppose after removing the 405-volt line from the 405-volt point, the voltage still reads low. This indicates that the trouble is in the power supply. Measure the voltage at the junction of L107 and C118A. This point is labeled 420 volts. If it measures low, remove the 420-volt line connected to this point. Again measure the voltage. If it now reads normal, there must be a short or partial short on the 420-volt line. If the 420-volt point still measures low, suspect capacitors C124A and C118A. Since the normal drop across L107 is 15 volts, measure both ends of L107. If the voltage drop across L107 is excessive, C124A probably has excessive leakage. Disconnect the capacitor and again measure the voltage. If the voltage comes up to normal, the disconnected capacitor has excessive leakage. If the voltage is still low, the input filter capacitor C118A could be open causing low B+ voltage. It is usually easier to check this capacitor by bridging it with a good electrolytic capacitor.

If the filter network checks out good, test the rectifiers in the bridge circuit. With the circuit disconnected, measure the forward and reverse resistance of the rectifiers. An open (high forward resistance) rectifier will cut down the output voltage. If a rectifier shorts, it will usually put an excessive load on the supply and trip the circuit breaker.

Fig. 9. Power supply section of a color TV receiver.

12   3V. P-P

13   30 V. P-P
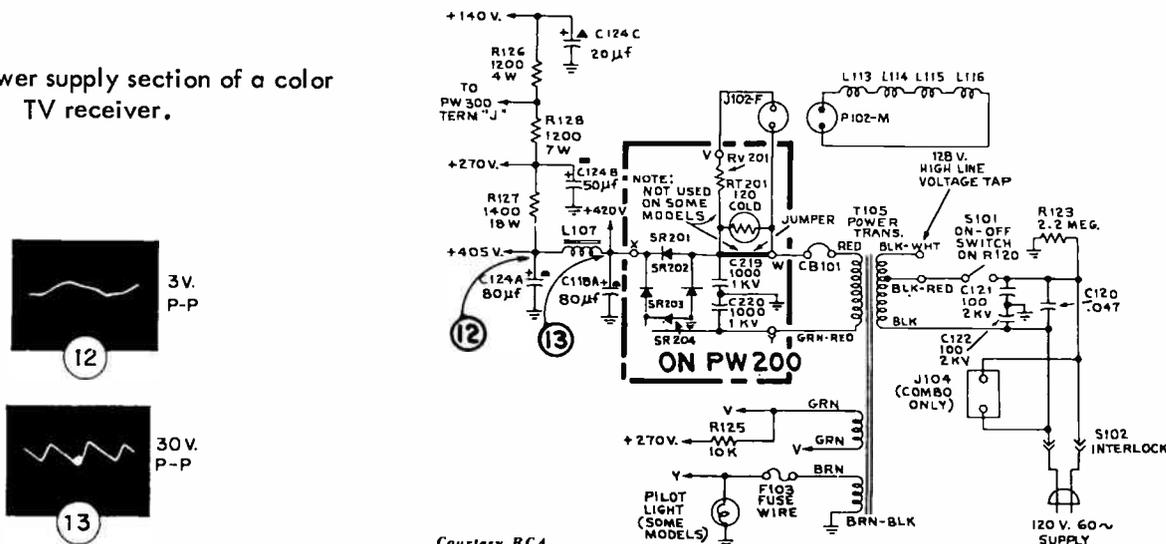
Courtesy RCA

In the circuit in Fig. 9, the automatic degaussing coils are in the power supply circuit. If you suspect faulty operation of either the varistor or thermistor, for example, an open RT201, install a jumper as shown in the drawing. This shorts out the degaussing circuit. If it is defective, the B supply will come up to normal.

A power supply that produces no output is usually easy to troubleshoot. Test for dc voltage at points near the rectifier. If no dc voltage is present, measure the ac voltage across the transformer secondary. In Fig. 9 you would measure at both sides of the circuit breaker, CB101, to make sure that there is continuity through it. If no secondary voltage is present, check the primary circuit, through the on-off switch, interlock, and finally the line cord. If the tube filaments are lighted, you know of course that the primary is energized. If voltage is present at the primary, measure continuity through the primary and secondary windings of the transformers. An open winding will prevent the power supply from producing dc voltage.

A receiver that blows fuses as soon as it is turned on has a short circuit defect. A short circuit in the rectifier, filter, or B+ lines in Fig. 9 would trip the circuit breaker. A defect of this kind can be located using an ohmmeter with the circuit de-energized. Take ohmmeter readings on the B+ line and work toward the point of lowest resistance.

For example suppose you read nearly 2000 ohms from the 420-volt point to ground. You move the ohmmeter probe to the 405-volt point and read about 1500 ohms. You know from these two readings that you are getting closer to the shorted point. Next you move the probe to the 270-volt point and read nearly zero ohms. Since C124B connects to this point, disconnect it and again measure the resistance. If the 270-volt line is now clear, confirm the shorted capacitor by measuring its resistance with the ohmmeter. If the 270-volt line reads zero ohms with the capacitor removed, you would trace the 270-volt line to isolate the short.

If the receiver power supply, shown in Fig. 9, blows house fuses when it is turned on, the defect must be in the power transformer. (If the short were in the dc section of the power supply, the circuit breaker would trip open.) A power transformer is an expensive item that is time consuming to replace. Therefore you must be sure of the defect before you condemn it. With the receiver disconnected from the power line, measure the resistance from the primary and secondary windings to the frame (chassis ground) of the transformer. If the resistance measures near zero the insulation is burned and shorted so the transformer is bad. Since the resistance of the transformer windings are quite low, it is difficult using an ohmmeter to determine if it has shorted turns. A final test of a transformer is to disconnect all the secondary windings. If it still blows fuses, or overheats, the transformer must be defective. As a last resort disconnect the primary winding and plug in the line cord. If it blows a fuse the wiring from the line cord to the transformer is defective and the transformer is probably all right!

One other type of defect occurs in the power supply. Excessive ripple on the dc voltage supply produces hum bars in the picture, hum in the sound, or insta-bility in the sync circuits. The ripple can be measured with a scope at points 12 and 13 in Fig. 9. The accompanying waveforms show a normal 30-volt peak-to-peak sawtooth waveform at the input filter capacitor and a 3-volt peak-to-peak ripple at the 405-volt output. Loss of capacitance in the filter capacitors or a shorted choke coil causes excessive ripple.

An annoying audible hum is sometimes produced by the transformer in a power supply. This does not affect the electrical operation of the circuit but the customer may complain of the noise. The hum is almost always caused by loose laminations in the transformer stack. It can be corrected by tightening the bolts that hold the laminations together. This same condition can develop in any device with a laminated core including the choke, audio output transformer, or vertical output transformer.

THE TUNER

The tuner section of a TV receiver is difficult to work on. The low amplitude, high-frequency signals present in the tuner are almost impossible to view on the scope. Also, the tuner unit is compact with closely spaced components. Before you start troubleshooting within the tuner be sure you definitely isolate the trouble to the tuner by signal injection or other test procedures.

Before you go into the tuner, check the tubes and measure operating voltage. Use tube substitution to check the tuner tubes because many marginal tube defects will not show up on the tube tester. These defects are significant at the high frequencies present in the tuner. Usually you have only three voltages applied to the tuner. These include B+, filament, and agc. Measure the B+ and filament voltages to be sure they are within limits. Since you are not getting a signal through the tuner, agc to the tuner should be close to zero volts. If there is any doubt about agc use a bias box and observe the operation with various values of agc voltage.

Check the wiring at the antenna input and the i-f output. Make sure the output lead from the tuner to the i-f strip is not shorted to the chassis. The output is often through a shielded cable; make sure the cable is not physically damaged.

The antenna terminals usually connect to a balun transformer that may be located outside the tuner. Check it for physical damage. A quick check of the rf section of the tuner is to wrap the antenna lead-in around the mixer tube. If the received signal is from a local station, it will usually induce enough signal into the mixer to produce at least a faint picture indicating that the trouble is in the rf section.

Remove the shield from the tuner and carefully examine the components within the tuner. Most tuners are constructed with high quality parts so the components do not fail without good reason. A common defect is a burned resistor that became overloaded. A shorted tuner tube is the usual cause. The resistor may be open or changed in value. Confirm the defect with an ohmmeter before you replace the resistor. Use an exact size replacement, both physically and
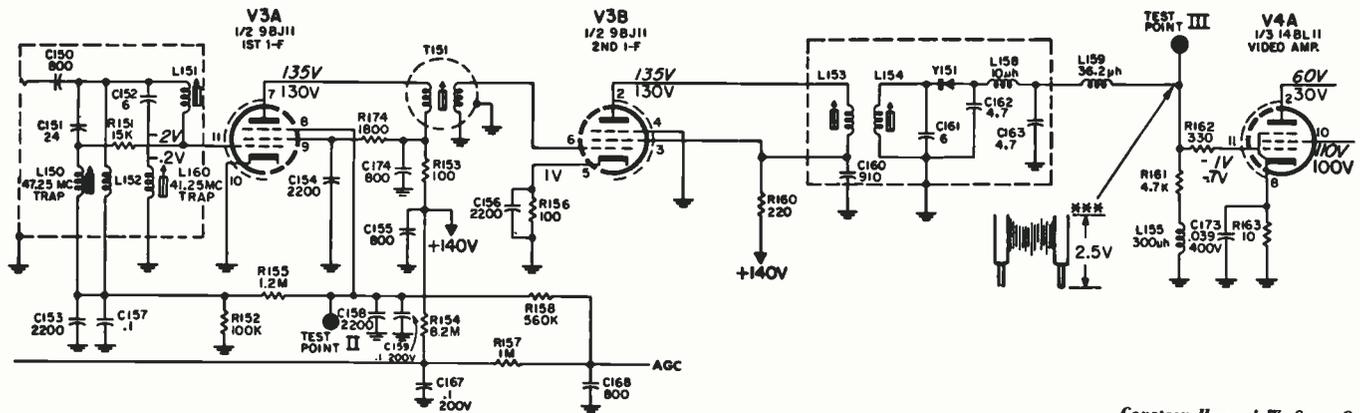
Fig. 10. Video i-f amplifier and video detector sections of a black-and-white TV receiver.

electrically. Since you are working in close quarters, be careful not to damage other parts. Do not change the physical location of parts. It is usually easier to cut out the defective part than to try to unsolder it. Shorten the leads on the replacement part and bend the leads as necessary so the part fits exactly in place. Then solder the connections. Do not attempt to make hook joints; secure the part in place with good soldered connections. Parts seldom burn out in transistorized TV tuners because the operating voltages in these tuners are quite low.

Mechanical defects often occur in tuners. In switch-type tuners, the switching wafers may become worn from excessive use or broken from rough treatment. You must replace the worn or broken wafers with exact replacements. In some cases you may be able to bend the contact surfaces of worn switches enough to make contact.

Tuners with dirty contacts can often be made serviceable without disassembly. A spray type contact cleaner is marketed in a pressure can for this purpose. A flexible plastic tube enables you to direct spray through holes in the tuner shield and reach all contact surfaces of the tuner. This special tuner contact cleaner will not damage any parts of the tuner so you can use it freely. Rotate the tuner while the contacts are wet to distribute the cleaner in the contact areas. This treatment will clear up all but the most stubborn cases of dirty contacts. As a last resort the tuner must be disassembled for cleaning.

Except for simple tuner repairs, it may be worth your while to consider having a tuner repair service handle your tuner problems. These companies specialize in tuner repairs and can save you time on difficult tuner problems. They stock the special parts often needed to repair a tuner; your profit on these repairs may be small, but the time you save can be spent on more profitable repairs.

I-F AMPLIFIER AND DETECTOR

You probably used an oscilloscope to isolate the trouble to these sections so it is easy to continue using the scope within the section. Fig. 10 shows the video i-f amplifier and video detector sections of a black-and-white receiver. Test point III calls for 2.5-volt

peak-to-peak video signal. If this signal is not present, use a detector probe to view the waveform at the plate of the second video i-f amplifier, V3B. The detector probe performs the same circuit function as the video detector. That is, it detects the amplitude modulation on the 45.75-mc i-f signal so the scope displays the detected video signal. If the video signal is present on the plate of the second i-f, the trouble is isolated to the detector section.

Observing the waveform at the grid and plate of each i-f amplifier stage can be used to check the gain of each stage. Usually the exact amplitude is not important. If the stage is amplifying, the signal at the plate will be larger than that obtained at the grid. When examining these waveforms, adjust fine tuning to obtain a clean, maximum amplitude signal. As you work back toward the input to the i-f, you will need all the signal available to get a usable indication on the scope.

If your tests indicate that the video detector is not operating, test it by substitution. The crystal detector is sometimes located within the last i-f amplifier transformer shield. You will have to remove the shield to get to the detector. The substitution detector need not be the exact type for the test. Any known good, high quality diode detector can be substituted temporarily. Be sure to observe the correct polarity of the detector. If a substitution detector improves the picture obtained, the detector should be replaced. Test the filter section of the video detector with an ohmmeter to locate open coils or shorted capacitors.

A confusing defect that sometimes develops in the i-f amplifier stage is oscillation. A high-gain i-f amplifier stage can go into oscillation if the output signal of a stage gets back into the input. A defective decoupling network in the plate or screen circuit can provide the feedback path. Or, moving a part in the circuit may cause oscillation. The trouble may show up as a blank screen. For example, suppose the second i-f in Fig. 10 goes into oscillation. The high amplitude oscillations will be rectified by the video detector and produce a large negative dc voltage on the grid of the video amplifier. In some receivers, the large negative dc signal out of the detector will produce sufficient agc voltage to cut off the first i-f amplifier. Therefore no signals get through the stages.

The large negative agc voltage may lead you to think the agc circuit is defective. Use a bias box to clamp the agc voltage to a reasonable value. Isolate the stage that is oscillating by shunting the grids of each stage, one at a time, with a .01 mfd capacitor. Work from the last stage back toward the tuner. Isolate the feedback circuit by shunting decoupling capacitors with test capacitors. Or, try repositioning parts in the oscillating stage. Try a new tube. Check for open grid return circuits. In transistor i-f stages look for open neutralizing capacitors. Perform i-f alignment. If all circuits are peaked at the same frequency, the circuit may have so much overall gain that it oscillates even though nothing is defective in the circuit.

When your tests indicate that an i-f stage is not producing sufficient gain, the screen indication will usually be a weak picture. Test the stage by taking voltage readings. The agc voltage reading is often inconclusive. Try using a bias box to apply various agc voltages to the gain controlled i-f stages. Measure the grid voltages as you change agc to make sure the voltages are actually being applied to the grids. Also notice the change in the picture as you change the agc bias.

When the above tests are inconclusive, an alignment procedure can be effectively used to isolate trouble within the i-f amplifiers. First of all, the circuits may actually be out of alignment and aligning them will bring operation up to normal. Or, as you go through the alignment steps you will locate the defective component. For example, if you find that you cannot peak the waveform with a particular adjustment, it usually indicates that the adjustment coil is defective. Also, if you suspect a component, such as a transformer, your time spent on alignment is not wasted. When you replace a defective transformer, you will have to perform alignment, so you may as well use the alignment procedure to confirm the defect.

Part replacement in the i-f section should be done carefully. Use exact replacement parts if at all possible. Position the new part in exactly the same place as the old one. This is important because of the high frequencies involved, but part replacement is not as critical as in the tuner. Improper placement of parts can cause the circuit to oscillate or it may upset the alignment. Replacing parts other than i-f transformers usually does not require realignment of the circuit. However, almost any older set that has had the i-f section worked on can be improved by alignment. Even changing tubes will affect the response curve to some extent. Don't expect any radical change in picture quality. Improvements usually show up as less smear or more fine detail in the picture.

The problems encountered in the video i-f stage of a color TV receiver are exactly the same as those found in a monochrome receiver. The circuits are essentially the same, except for the separate sound detector in the color receiver and additional traps that may be used to keep the sound signal out of the video amplifier.

VIDEO AMPLIFIER AND PICTURE TUBE

Troubles that have been isolated to the video amplifier and picture tube circuits are usually quite easy to find. The signals in this section are of video frequencies so a direct probe or an isolation probe can be used with the oscilloscope. The schematic diagram in Fig. 11 shows a video amplifier and the picture tube circuits of a receiver. If the video signal is present at test point IV and no picture is present on the screen, the trouble is either a bad picture tube or faulty picture tube circuits. You may want to test the picture tube at this time with a picture tube tester. What tests you perform depend on what is visible on the screen. If the screen is dark (no light at all), measure the voltages at the pins of the picture tube. Determine if high voltage is present on the second anode. Measure cathode voltage and control grid voltage. For example if C166 is shorted, a large positive voltage will appear on the cathode of the picture tube and cut off the beam.

Examine the picture tube socket; the socket may be making poor connections with the pins. If there is any doubt, slide the socket back far enough so you can reach the tube pin with test probes. Take waveforms and measure voltages directly on the tube pins. Meas-
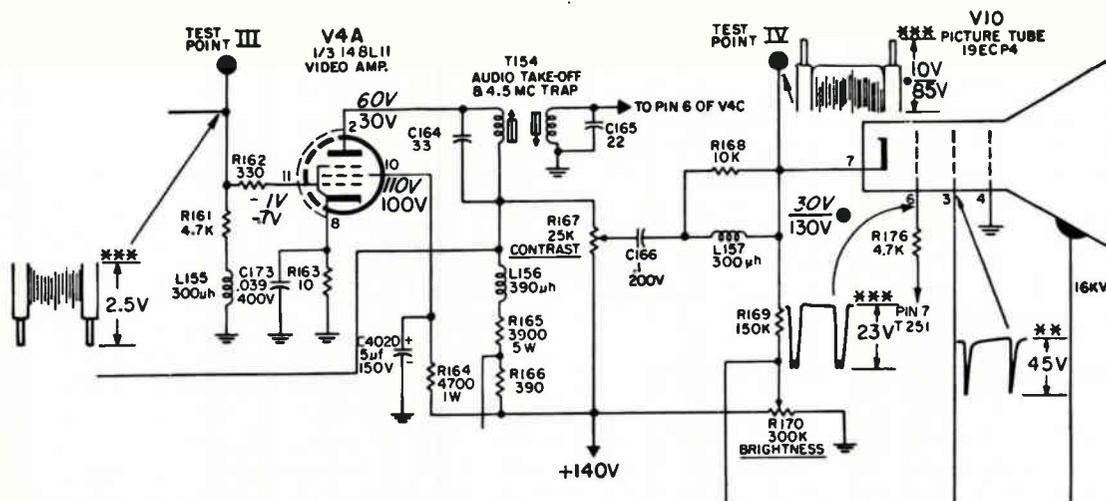
Fig. 11. Video amplifier section of a black-and-white receiver.

ure voltages within the picture tube circuits and/or test individual components to determine why the picture tube pin voltages are incorrect.

If the waveform at test point IV in Fig. 11 is missing or low in amplitude, signal trace back toward the control grid of the video amplifier. Test point IV calls for a peak-to-peak waveform between 10 volts and 85 volts. The amplitude will vary with received signal strength and with the setting of the contrast control. Observe the signal at each component in the picture tube cathode circuit and the video amplifier plate circuit. Signal tracing can pinpoint the defective component. Confirm the defect with ohmmeter readings.

If the video signal is low or missing at the plate of the video amplifier and a correct amplitude signal is present on the grid, test the stage with voltage measurements. Use standard circuit and component test procedures to locate the defective component.

Defects in the video amplifier stage often cause coarse pictures on the screen. For example, a partially shorted video amplifier tube may produce adequate gain but the fine picture detail is lost. Likewise, shorted peaking coils in the plate circuit can cause a loss of the high frequency video signals and produce coarse pictures. Poor low frequency response in the video amplifier causes smearing.

The peaking coils in some video amplifier stages are shunted by a damping resistor that lowers the Q of the coil. If the resistor opens, the circuit will tend to ring when subjected to high frequency signals. This shows up in the picture as multiple edges on objects or bright wiggly edges where signals produce abrupt changes. An ohmmeter test of the coil will not show up the open resistor because the shunt resistance of the coil may be only a few ohms. Test the peaking coil by shorting it while observing the picture. If the momentary short eliminates the ringing, the resistor is probably open.

The video amplifier in Fig. 11 has a sound takeoff transformer in the plate circuit. The transformer also acts as a 4.5-mc trap to remove the sound from the picture signal. If this transformer is improperly adjusted it may affect the picture without noticeable effect on the sound. If the trap is adjusted too low in frequency, it can trap out some of the high frequency,

fine detail picture information. In other cases a misadjusted trap may allow the 4.5-mc sound carrier to get to the picture tube and produce a grain in the picture. You will encounter the same type of defects in transistor receivers as in tube receivers. Often the output video transistor operates from a higher voltage source than the other transistors. As a result, shorts in the output transistors are more common than in those operating from a lower voltage.

In color receivers you have essentially the same circuits in the video amplifiers. You will also have a delay line that may open or short. You will also have provisions for feeding the brightness signal to the three cathodes of the color tube in most receivers. A defect may develop in one cathode circuit that will not affect the other cathode circuits.

SOUND SECTION

The sound section of a TV receiver is very much like an FM radio receiver and troubleshooting procedures are similar. Fig. 12 shows a typical audio system consisting of a sound i-f stage, audio detector stage, audio output stage and speaker. One of the first tests you should make is to determine if the defect is in the audio frequency portion or the i-f and detector portion of the sound section. A quick test is to turn up the volume control to maximum and touch the slider (center) terminal of the volume control with your finger. Since this point connects to the high impedance grid of the audio amplifier, your finger will couple in enough 60-cycle pickup voltage to furnish a sizable signal to the stage. If the audio amplifier and speaker are working a loud 60-cycle hum will be produced.

If the above test indicates that the defect is in the audio amplifier or speaker, determine if the speaker is working. You should be able to hear some sound from the speaker even if the audio stage is dead. Normal power supply variations produce a barely audible sound from the speaker. Another test for the speaker is to momentarily remove the audio tube from the socket. This should produce a loud click or thump from the speaker. If you suspect the quality of the sound produced by the speaker, substitute a test speaker. With the defect isolated to the audio output stage, you can
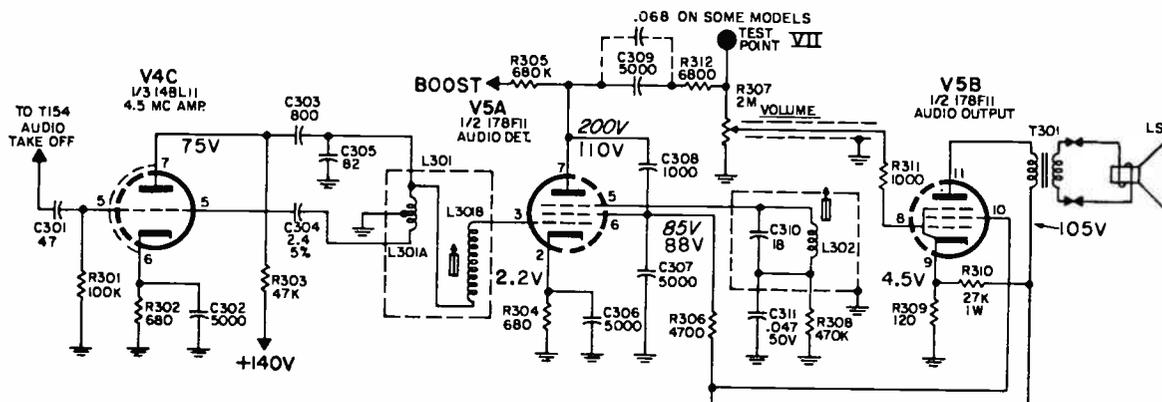
Fig. 12. Audio circuits of a TV receiver.

Fig. 5. Color TV receiver with scope waveforms.
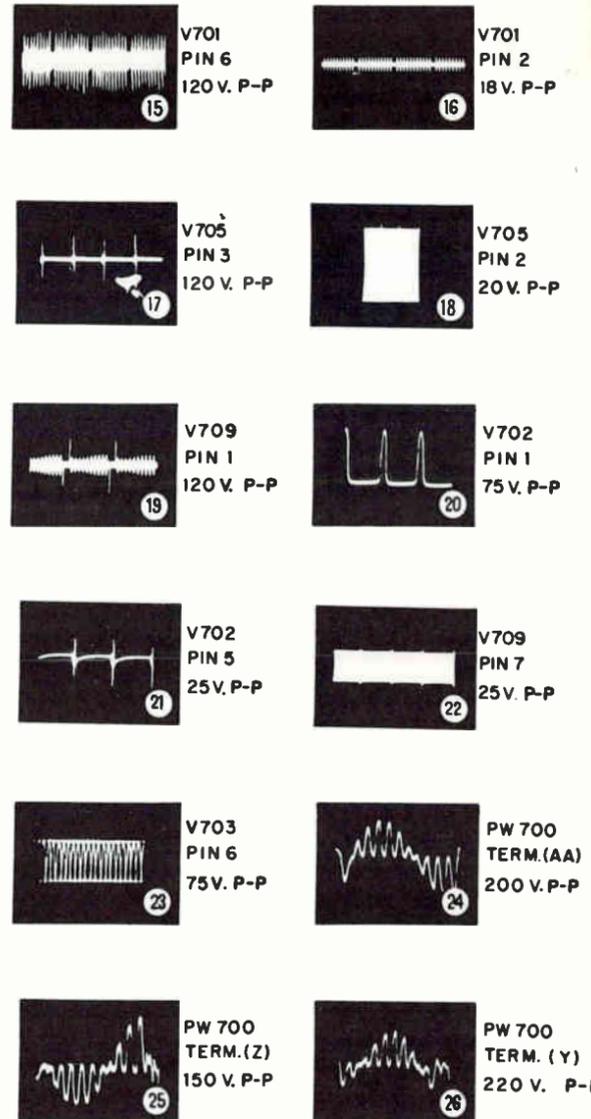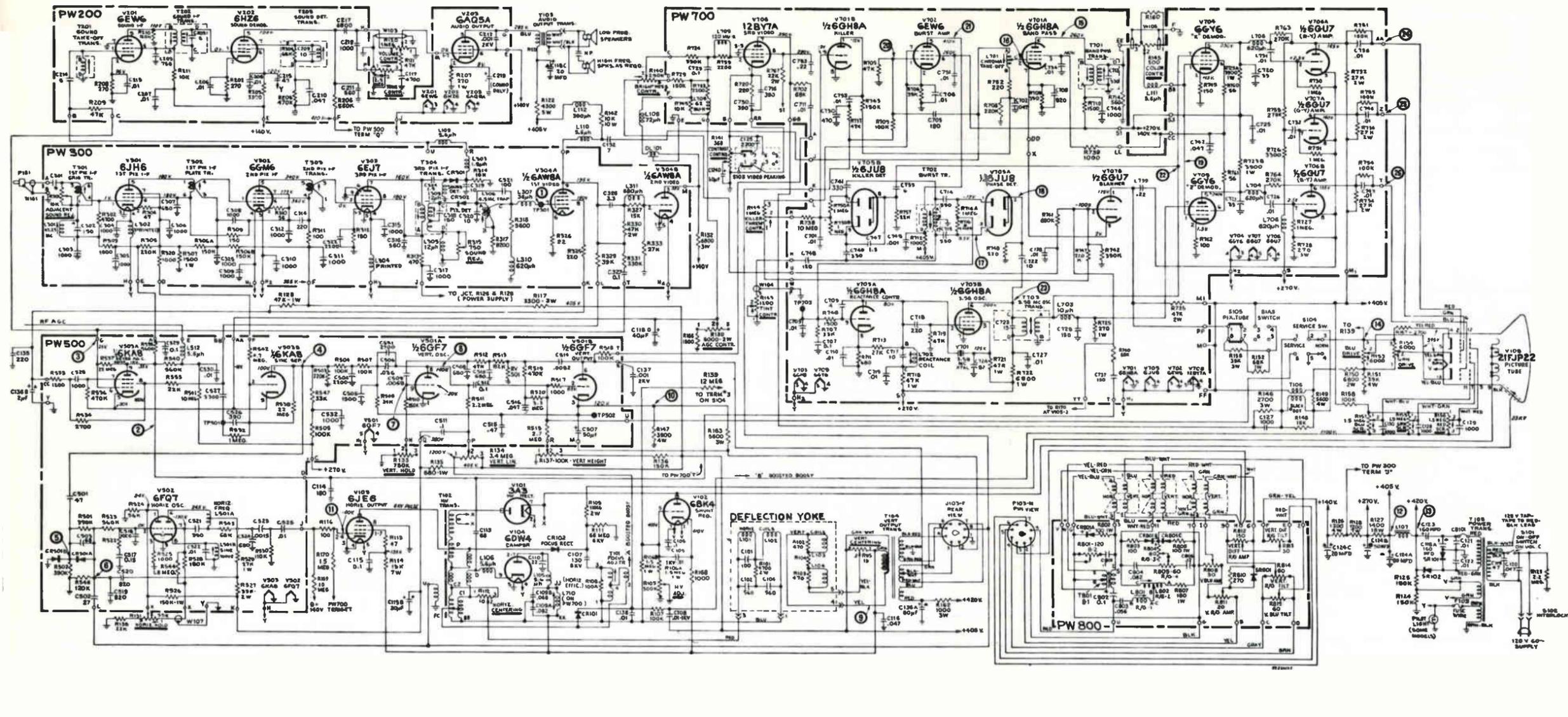
BALLOONS ①,②, ETC.,
SHOWN ON SCHEMATIC
INDICATE POINTS OF
OBSERVATION OF THE
WAVEFORMS.

USE LOW-CAPACITY
PROBE WHEN OBSERVING
WAVEFORMS

enable you to determine if the defect is confined to the agc circuit. Observe sync stability and the quality of the reproduced picture. If you can get a good stable picture at some setting of the bias box, the trouble is probably entirely in the agc circuit.

The video signal to the agc circuit may not contain much fine detail video information. In a keyed agc circuit, the only significant portion of the video is the sync pulse (blanking pulse plus sync pulse). Therefore the video signal may be taken from a place in the plate circuit of the video amplifier where only the sync pulses are well defined. Compare the waveforms given at the input of the agc circuit. It may not call for a high quality video signal. Check the amplitude of the horizontal keying pulse for the agc circuit. Fig. 13 calls for 500 volts.

If the input signals to the agc circuit are of the correct polarity and amplitude, measure dc voltages. Operate the agc controls to see how they affect the voltages. For example, in Fig. 13 the agc control adjusts the grid bias on V5A and therefore adjusts the point at which the tube conducts. When you locate the circuit with defective voltages, find the defective component by taking resistance measurements.

A change in the time constant of the agc filter network can upset agc operation. This may show up as a slow flicker of the displayed picture - similar to the affect of an airplane in the TV signal path. The change in agc voltage may respond either too quickly (time constant too short) or too slowly (time constant too long). Check the value of the resistors and capacitors that make up the agc filter circuit.

The noise inverter circuit in Fig. 13 operates to prevent noise pulses from upsetting the operation of the sync separator. When high amplitude noise pulses get to the grid of the sync separator, they can cause the grid to draw enough current to cut off the sync separator for a period of time during which no sync pulses are recovered. The noise inverter prevents this by applying a negative noise pulse to the junction of C_{44} and R_{37}. This negative noise pulse cancels the positive

noise pulse and prevents overdriving the sync separator grid.

The noise inverter stage, V5B, is normally cut off by a negative bias applied through the sync stabilizer control labeled "Picture Guard". The line labeled 43 returns to the grid circuit of the horizontal output stage where it picks up a negative bias voltage. The control is adjusted to a point where the negative sync tips applied to the cathode circuit do not quite cause the tube to conduct. Noise pulses larger than the sync pulses cause the tube to conduct producing the negative noise pulse in the plate circuit. Loss of the negative bias on the grid of V5B causes the tube to conduct all the time and cancels part of the video signal to the sync separator. This causes poor sync stability.

The dc voltage on the grid of V5C in Fig. 13 is shown as -1.5 volts. This is the voltage for a no signal applied condition. With a signal, the grid of the sync separator will usually develop -15 to -30 volts bias. If video is present in the recovered sync pulses at the output of the sync separator, check the grid circuit. Grid resistors that have decreased in value, or grid capacitors that have decreased in capacitance can cause low grid bias and poor separation of the sync pulses.

Clean sync pulses of the correct amplitude at the output of the sync separator eliminates this section of the receiver as a cause of sync instability. Sync problems can also occur due to defects in the vertical or horizontal sweep circuits. Before you go into those circuits you should assure yourself that good horizontal and vertical sync pulses are being recovered from the received TV signal.

VERTICAL SWEEP

Most vertical sweep circuits consist of two stages, the vertical oscillator and the vertical output stage. These two stages are connected as a multivibrator with a natural frequency near 60 cps. The multivibrator is synchronized to the exact vertical rate by the vertical sync pulses applied through an integrating

test the stage with usual circuit and component test procedures.

If preliminary tests indicate that the defect is in the sound i-f and detector stages, take voltage measurements within these stages. When no sound information is getting through the circuits, the defect is most likely total failure of a part in these circuits and the defect can be located by taking voltage and resistance measurements. On the other hand if sound is distorted, weak, or noisy, the defect may be improper alignment. Some of the sound adjustments are quite critical. Most sound circuits can be aligned by "ear" on a received signal. Consult the manufacturer's instructions for the particular receiver.

With experience you can touch up the sound alignment without reference to service literature. The key to success is to work with as little received signal as possible. Turn the volume control up to maximum. Attenuate the received signal by tuning to a very weak station or remove the antenna connections. Attenuate the received signal until the audio portion of the program is just barely audible. Disregard the picture on the screen. Adjust fine tuning for maximum sound. If necessary, again attenuate the received signal. Identify the adjustments in the sound circuit. Usually they will consist of a sound i-f transformer, a sound discriminator transformer (or ratio detector, or quadrature coil, L302 in Fig. 12), a sound takeoff transformer, and one or more sound traps.

Move an adjustment only a small amount in either direction. Position the adjustment to the point that produces the loudest sound or improves the quality of the sound. Adjust the sound takeoff and sound i-f transformer for maximum volume. Adjust the detector transformer for maximum volume with minimum distortion of the audio. When an adjustment increases the volume, go back and again attenuate the received signal so you make all adjustments with the minimum possible received signal.

If you find an adjustment that does not affect the sound, the transformer for that adjustment may be defective. The 4.5-mc sound i-f subcarrier signal remains on frequency regardless of what adjustments you make in the receiver. The adjustments consist of tuning the circuits to respond to the 4.5-mc signal. If you cannot tune a circuit, either the coil or a frequency determining component connected to the coil is probably defective.

After you align the sound circuit on a weak signal, listen to the sound with a normal picture and sound signal. The sound may have an annoying buzz often called intercarrier buzz. The buzz is caused by the sync pulses driving an audio stage. Some receivers have a buzz control potentiometer that can be adjusted for minimum buzz. If not, check the adjustment of the sound detector transformer or quadrature coil. This adjustment is quite critical. You adjusted it for minimum distortion on a weak signal. Try readjusting it a small amount to get minimum buzz.

On some receivers you may not be able to completely eliminate the intercarrier buzz, particularly during commercials. A station often increases the modulation percentage during commercials making

the buzz more pronounced. Try readjusting the agc. Also careful adjustment of the fine tuning may help minimize buzz.

In some TV receivers a 4.5-mc sound trap is located in the video signal path. This trap may or may not have anything to do with the sound circuits. In Fig. 11 the 4.5-mc trap is part of the sound takeoff transformer and adjusting it affects the amplitude of the sound takeoff signal. Its other function is to remove the 4.5-mc signal from the video that is applied to the picture tube. In receivers where the trap is not part of the sound circuit, the trap is adjusted for minimum 4.5-mc "grain" in the picture.

An occasional sound complaint is that sound is not received when the receiver is tuned for best picture. Check the sound circuit carefully because low gain in the sound circuit or misalignment can cause this complaint. However, the trouble may be due to misalignment in the video i-f or tuner section of the receiver. Make sure that you can fine tune beyond the best picture setting in both directions. If not, reset the oscillator slugs or oscillator adjustments in the tuner. Finally, if this does not correct the trouble realign the video i-f section of the receiver.

SYNC AND AGC

The schematic diagram in Fig. 13 shows separate stages for agc, noise cancellation, and sync separation. Many circuits have two or more of the functions combined in a single tube but separate stages make it easier to discuss troubleshooting. In most receivers the stages are closely related by either common video signals, common dc voltages, or both. When the agc stage is not operating correctly, the sync circuits are often upset.

Signal tracing is an important first step when troubleshooting in this section. If the video signals into the circuit are not correct it is a waste of time to go further. But suppose agc is not operating correctly and therefore the video signal produced by the receiver is deficient. Attach a bias box to the agc line and vary the applied bias to a point that produces a good video signal of the correct amplitude. This will also
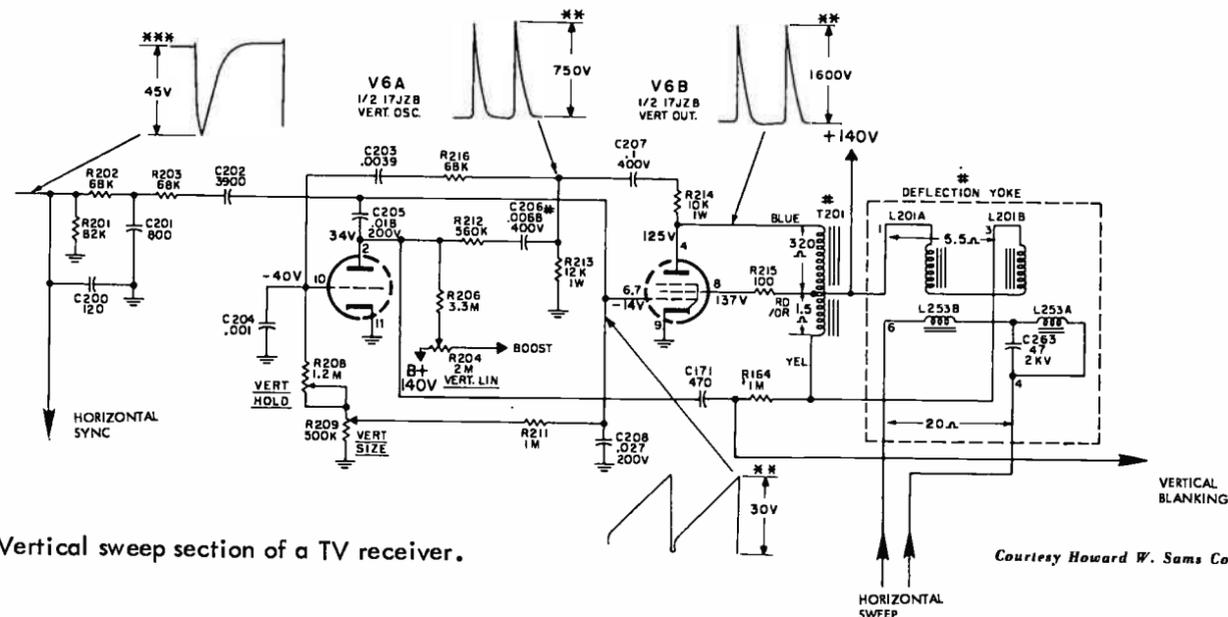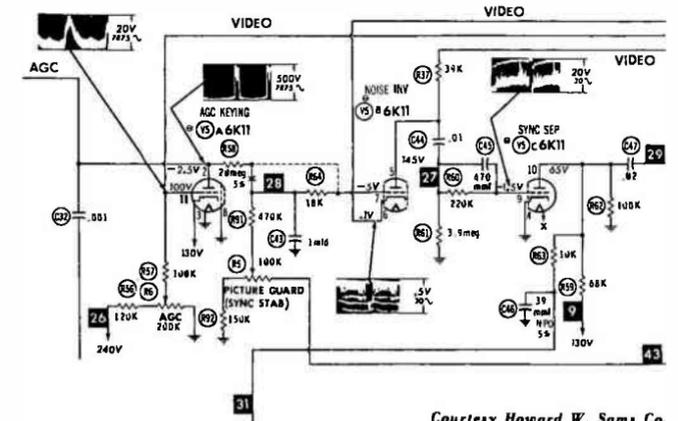
Fig. 13. AGC, noise inverter and sync separator sections of a TV receiver.

Fig. 14. Vertical sweep section of a TV receiver.

network. The output of the multivibrator is coupled through a vertical transformer to the vertical windings of the deflection yoke. Controls in the multivibrator circuit are provided to adjust the natural frequency (hold control), amplitude of the output signal (height), and shape or linearity of the output waveform. Fig. 14 shows a typical vertical circuit.

Defects in the vertical circuit show up as complete loss of vertical deflection, loss of vertical sync, insufficient height of the raster, foldover, or vertical nonlinearity. Observation of the picture isolates the trouble to the vertical section except for sync troubles and the possibility that insufficient dc voltages are being supplied to the circuit. After substituting the vertical tube (or tubes), take voltage measurements of the supply voltages to the circuit. Boost voltage is usually used as a supply voltage for the sawtooth waveforming circuit of the vertical circuit.

In transistor TV receivers, the vertical sweep output transistor must supply considerable power to the yoke. As a result, there is a great deal of heat dissipated in this transistor. The heat often leads to transistor failure. In the event of complete failure of the sweep, check the output transistor.

If the trouble includes poor vertical sync, such as loss of interlace, vertical jitter, or unstable vertical sync, scope the sync waveform at the input to the vertical integrator. Fig. 14 shows a horizontal sync pulse waveform of 45 volts peak-to-peak. When viewed at the vertical rate, the amplitude will be the same or higher. The vertical sync pulse may be masked by the large vertical pulse that feeds back through the integrator network from the vertical circuit. To see if the vertical sync pulse is reaching the multivibrator, adjust vertical hold to position the blanking bar in the center of the screen. Then observe the waveform in the circuit.

In Fig. 14, observe the waveform at the grid of V6B. It calls for a 30-volt peak-to-peak sawtooth. With the blanking bar in the center of the screen, the vertical sync pulse shows up as a small negative notch in the ramp of the waveform as shown in Fig. 15. Adjust vertical hold while observing the waveform and you will see the sync pulse move up or down the ramp. When vertical locks in, the sync pulse merges with the vertical edge of the sawtooth waveform.

The vertical sync pulse integrating network may be separate components as in Fig. 14 (R202, C201, and R203), or the network may be encapsulated in a single unit. If the sync signal is not getting to the multivibra-

VERTICAL SYNC PULSE
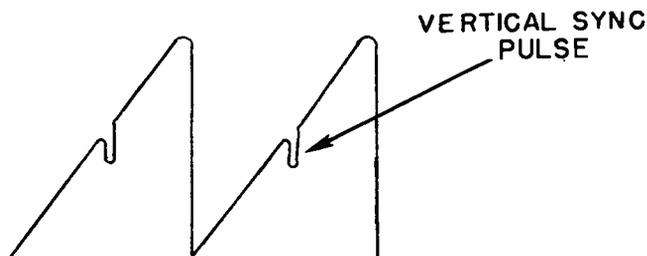
Fig. 15. With the blanking bar in the center of the screen, the vertical sync pulse can be seen as shown above.

tor, check the values of the components in the integrating network. Or substitute the printed wafer if a single unit is used.

If the defect causes complete loss of vertical deflection, determine if the trouble is in the multivibrator or in the output circuit. A quick check is to inject a 60-cycle signal, such as filament voltage, into the grid of the output stage. If this produces any vertical deflection at all on the screen, the output tube is capable of amplifying a signal and the output and yoke circuits are probably good. The defect is probably in the feedback network between the output stage and the oscillator stage. In Fig. 14, the feedback components are R214, C207, R216, and C203. Failure of one of these components is quite common because of the high peak voltages applied to them. Use a test capacitor, such as a .01 mfd, to jumper momentarily each of the feedback components. When you shunt an open component, even if it is a resistor, the vertical circuit will oscillate. When you locate a defective component in this section, check the condition of other components. For example, a burned resistor, R214, may have allowed the large pulses to damage C207 before the resistor failed completely. When you replace parts in this section be sure to use exact replacements with adequate voltage ratings.

Vertical nonlinearity and foldover are often caused by parts changing value or by a leaky capacitor in the vertical circuits. The high value resistors, often several megohms, may increase or decrease in value with age. This can be determined with an ohmmeter. Coupling capacitors such as C202, C205, and C206 in Fig. 14 may change value or develop leakage. The high peak pulses in the circuit may break them down only on peaks so the leakage cannot be detected with an ohmmeter. Part substitution may be necessary.

Many vertical circuits have an electrolytic capacitor in the cathode circuit of the vertical output stage. If this capacitor decreases in capacitance, it can produce loss of sufficient height and poor linearity or both.

When the yoke is suspected of being defective, check to see if the yoke uses a resistor-capacitor compensating network across the yoke windings. A defect in these components may cause vertical troubles. The components can be checked and replaced without replacing the yoke. One precaution: do not operate the vertical circuit with the yoke removed from the circuit. Removing the electrical load of the yoke may cause the circuit to produce excessive voltage peaks that can break down the insulation on the output transformer.

HORIZONTAL SWEEP AND HV

Defects in the horizontal sweep section of a TV receiver affect the raster and/or the high voltage of the picture tube. A blank screen caused by loss of high voltage is the most common symptom that leads you to troubleshoot the horizontal section. Loss of horizontal sync is another common symptom that indicates trouble in the horizontal section. Distortions in the raster, including poor horizontal linearity, usually places the trouble in the horizontal section. It is
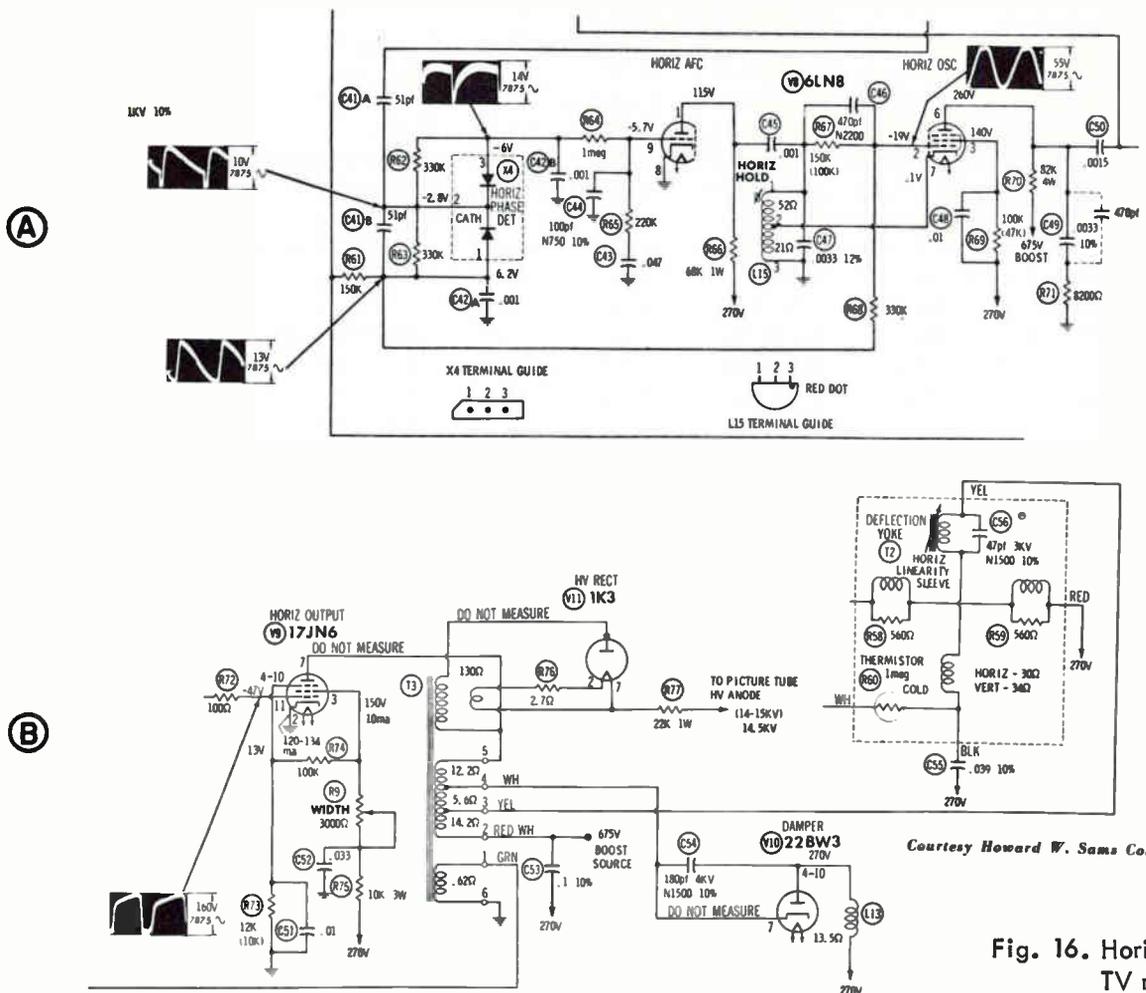
Fig. 16. Horizontal section of a TV receiver.

important to determine if the raster distortions are still present when the video is removed from the screen. Observe the distortion as you decrease the contrast to a minimum. If the distortion decreases, the trouble is probably in the signal path of the receiver. If the distortions are present in the raster when turned to a blank station, the defect is almost sure to be in the sweep section of the receiver.

Fig. 16 shows the horizontal section of a TV receiver. Fig. 16A shows the horizontal afc and oscillator sections while Fig. 16B shows the horizontal output, high voltage, and yoke sections for the same receiver. When you have horizontal trouble, the first step is to isolate the defect to one of these stages within the horizontal section. Of course you will have already tried tube substitution and the circuit adjustments.

The first check should be made at the grid of the horizontal output stage. Measure the dc grid voltage. A large negative grid voltage indicates that drive is being applied to the horizontal output stage so the defect must be in the horizontal output stage plate circuit, flyback transformer circuit or yoke. This test is not conclusive. The horizontal drive signal may be so far off frequency (low) that the circuit produces very little high voltage. Or the waveform may have the wrong shape and still produce grid bias.

A better check is to observe the shape and amplitude of the grid waveform with a scope. The frequency

calibration on service scopes is often inaccurate so set the scope up by observing the video signal. Adjust the horizontal sweep rate of your scope to observe two horizontal lines of video. Then without moving the scope controls, observe the horizontal output grid waveform. If the horizontal oscillator frequency is correct your scope will display two sweep waveforms. Compare the shape and amplitude of the waveform with that given in the service literature. From this you can tell for sure if your circuits are good up to the output stage.

If your tests indicate trouble in the oscillator or afc section, isolate the defect to one of these stages. A quick check is to ground the grid of the horizontal afc stage (V8A in Fig. 16A). Then adjust the horizontal oscillator to see if you can get it to produce a picture that floats slowly across the screen. If you can, the oscillator circuit is probably good and the defect lies in the afc circuit. In some horizontal circuits the grid voltage of the afc control tube is designed to run at a voltage other than zero so the oscillator has to be readjusted when it locks into the sync signal. However, if the oscillator cannot be adjusted to run at the correct frequency with the grid of the control tube grounded, the oscillator is almost definitely defective.

Horizontal AFC.

If your tests indicate a defect in the afc circuit observe the waveforms in the circuit. All afc circuits have two input signals, the horizontal sync pulse and

a waveform fed back from the horizontal oscillator or horizontal output circuit. In Fig. 16A the horizontal sync pulses are coupled to the circuit through C41A, a 51 pf capacitor. The horizontal waveform originates from terminal 1 on the flyback transformer (in Fig. 16B). This flyback pulse is shaped into a sawtooth waveform by resistor R61 and capacitor C42A. These two pulses are compared in the phase detector diodes where they produce a dc voltage proportional to the phase difference of the two signals. The dc voltage is applied to the grid of the afc control tube. In response to the dc voltage, the control tube corrects the frequency of the oscillator to hold it in step with the sync signals.

Observe the sync input carefully at both the horizontal rate and the vertical rate. Look for video signals in the sync caused by poor sync clipping or by sync compression (sync signal less than 25% of the total video waveform). Look for hum or other interferring signals that distort the sync signals. For example a defect in the vertical integrator can allow large (broad) vertical pulses to get back into the sync signal. These can distort the horizontal pulses and cause raster distortion such as a hook at the top of the screen.

The waveform at the cathode of the afc phase detector diode in Fig. 16A shows the combination of the sawtooth waveform and the sync pulses. If either of the pulses appear to be missing here, remove the other waveform input and again observe the waveform. If both signals are present, check the components in the circuit with an ohmmeter. Check the diodes by substitution or measure the front to back resistance ratio with an ohmmeter. If the diodes are unbalanced they will not function correctly. As a last resort check the values of the capacitor in the grid circuit filter network or check the capacitors by substitution.

Horizontal Oscillator.

This circuit generates the horizontal waveform and shapes the drive signal for the grid of the horizontal output stage. Many circuit variations are in common use. Usually two stages are connected as a multivibrator circuit with the second stage acting as a discharge tube to discharge the sawtooth waveforming network at the end of each sweep. The resistor and the capacitor network in these circuits are chosen so the multivibrator oscillates at the horizontal frequency. The ringing coil in these circuits acts as a stabilizing device that prevents noise from triggering the multivibrator early on some cycles. You should be able to short out the ringing coil and still get the circuit to oscillate at the correct frequency. If shorting out the ringing coil enables you to get the circuit to oscillate at the correct frequency, the trouble is probably in the ringing coil. Try a new capacitor across it and/or replace the coil. Also an unstable multivibrator can be caused by a shorted coil. Observe the waveform at the coil and look for the characteristic sine wave indicating that the coil is ringing.

Measure resistance values carefully in a multivibrator type horizontal circuit when it will not oscillate at the correct frequency. Resistors often have a 5% tolerance and a small change in value can upset the operation. A potentiometer in a grid circuit may be used as the hold control. Check resistance values carefully with an ohmmeter. Dirty slider contacts on the pot can cause random variations in resistance and erratic operation of the multivibrator. Use spray cleaner on the pot or replace it. If you replace capacitors in this circuit, use exact or recommended replacements. The capacitors are often silver-mica and have very small temperature coefficient tolerances.

The circuit in Fig. 16A uses a Hartley-type oscillator for the horizontal oscillator. The hold control adjusts the inductance of the coil part of the resonant circuit. If this circuit runs off frequency and cannot be adjusted by moving the coil slug, capacitor C_{47} is probably defective. Also check the value of the grid lead resistor R_{67}. If this resistor increases, the circuit may run at half the line frequency producing two pictures on the screen with a blanking bar in the center. The high grid resistance blocks the grid for one cycle and the tube conducts only on every other cycle.

Almost every horizontal oscillator circuit is influenced by supply voltage changes. Off frequency conditions can be caused by low B+ voltage. Also poor filtering in the B supply may cause erratic operation or cause a bend or ripple in the raster. Check the supply voltages with a scope. If excessive ripple is present check the filter components in the power supply.

Output Circuit.

The horizontal output stage, damper stage, high voltage rectifier and the horizontal yoke windings are all closely related. The flyback transformer and its associated circuitry is tuned to a resonant frequency (around 70 kc) so a defect anywhere in the circuitry tends to affect the whole circuit. For example, a short in the yoke winding will load down the circuit so insufficient high voltage is produced. For these reasons you must consider the entire circuit when troubleshooting in this section. Also signal tracing with a scope beyond the grid of the output stage is not very practical because of the high voltages involved. Successful troubleshooting in this section requires isolation procedures that will pinpoint the trouble to a particular component. Defects in this section show up as insufficient high voltage, insufficient width, poor horizontal linearity, or other raster imperfections such as ringing, streaks, etc. Let's examine troubleshooting procedures for each of these.

The first test for loss of high voltage or insufficient high voltage is to eliminate the high voltage rectifier stage. Look to see if there is a glow at the base of the high voltage rectifier tube indicating that the filament circuit is all right. Measure the high voltage with a high voltage probe on your vtvm. If the voltage is low, the trouble may be in the rectifier circuit. You will have already tested the tube by substitution so measure the resistance to ground on the high voltage circuit. Ground the circuit to discharge any circuit capacitance before you attach the ohmmeter. The circuit should read infinity. Also measure the value of any resistors in the circuit.

Measure the voltage on the screen and cathode of the output stage. Resistors in these circuits pass considerable current and they sometimes change in value or open up. If voltages are incorrect, test with an ohmmeter. Turn off the receiver and check for continuity in the plate circuit of the horizontal output transformer. There is a possibility that the primary winding on the flyback transformer is open.

Measure the dc voltages on the plate and the boosted B+ voltage at the output of the damper stage. The large ac pulses normally present on the cathode of the damper makes it inadvisable to measure the voltage at this point. However, the boosted B+ voltage will give you a good indication of the voltage at the cathode of the damper. If the output stage and damper are operating even partially, boost voltage should be higher than B+ voltage. If not, check the damper circuit.

When you suspect a defective flyback transformer, isolate it by removing parts, one at a time, that are connected to it. A defective part such as a yoke, width coil, or linearity coil may be loading down the circuit. Each time you disconnect a part, draw an arc from the HV rectifier plate cap. If the arc increases when you remove the part, that part is probably defective. In Fig. 16, you would remove the HV plate cap, unplug the HV rectifier tube, and disconnect terminals 1, 2 and 3 on the flyback transformer. The circuit now has B+ supplied through the damper tube, to terminal 4 on the flyback and from terminal 5 to the plate of the horizontal output tube. With correct drive signal to the grid and proper tube voltages, you should be able to draw an arc from the HV cap. If you cannot, the flyback transformer is probably defective. You can check it further with an ohmmeter but shorted turns are hard to detect this way. Or you can check it using a tester that checks the "Q" of a circuit.

The yoke circuit can be checked when you reconnect it to the flyback circuit. When you connect the yoke to the flyback, the amplitude of the flyback swing should increase. The yoke should increase the efficiency of the circuit by "tuning" the circuit closer to the resonant frequency. Therefore when you connect the yoke to the circuit if the arc you draw is smaller, check the yoke circuit. Open the yoke cover to expose the yoke winding connections. Check the components that are connected across the horizontal windings. You will have to remove the component to test it because the parallel resistance of the yoke is low. Try operating the circuit with the suspected capacitors removed. If the capacitor was shorted the high voltage will come up, but the linearity may be off. Then replace the capacitor with an exact replacement. Ohmmeter readings on the yoke windings are usually inconclusive. Check it with a "Q" tester or by substitution.

Width troubles may be associated with insufficient high voltage. Or after you bring up the high voltage, there may not be quite enough width. Increased high voltage requires more sweep to fill the screen. Measure B+ and boost voltage. Excessive load on the boost line can affect width. Check for adequate drive, correct screen voltage, a good output tube, good damper and properly centered picture. Make sure the yoke is up against the bell of the picture tube. Depending on the circuit, several capacitors have a large effect on width. In Fig. 16B, C_{54}, C_{55}, and C_{56} will affect width and linearity. Also the screen decoupling capacitor, C_{52}, will affect width. When replacing capacitors in this section use exact replacements.

Vertical lines on the screen, including horizontal foldover, are associated with defects in the horizontal section. Vertical lines are usually caused by signals from the horizontal section that are radiated into the tuner. Thus they show up as intensity modulation of the beam. Since they occur at the same time in each horizontal sweep, they produce a vertical line on the screen. Lines that appear to the left of center are usually associated with the damper tube circuit. Arcing in the high-voltage rectifier tube can produce lines anywhere on the screen. The lines are likely to have a speckled appearance similar to interference caused by high voltage arcing or corona discharge. Signals radiated into the tuner are most noticeable when tuned to weak stations or when tuned to a blank channel.

If the interfering lines are not too strong they can usually be eliminated by dressing the antenna lead-in away from the horizontal section; or an ion trap magnet placed around the horizontal output tube will eliminate signal originating in that stage. New tubes in the horizontal section should be tried but it is not always a permanent solution. Some receivers apply a suppressor grid voltage to minimize ragged vertical lines called "snivets" that are caused by interference originating in the horizontal output stage. In Fig. 16B, voltage divider network R_{73} and R_{74} provide this voltage. In other cases, vertical lines are caused by defects in the flyback transformer or yoke and can only be located and corrected by part substitution.

High voltage arcing and corona discharge can be a problem, especially during damp or humid weather. Corona discharge is likely to occur at sharp pointed solder connections in the flyback and rectifier circuits. Take special care to round off any solder connections in this area. The high-voltage anode lead and rectifier plate cap lead should be routed away from metal parts that could provide leakage paths. High voltage leakage around the flyback can sometimes be prevented by spraying the surfaces with insulating varnish. Be sure areas are very clean. Dust and grime can produce a high voltage conducting path on an otherwise good insulating surface.

CHROMINANCE SECTION

Defects in the chrominance section will usually be isolated to that section by simply observing the picture on the screen. Always make sure that the black-and-white picture is up to standard before you start troubleshooting in the color section. Evaluate the black-and-white picture for good detail and proper rendition of the gray scale. If the set meets these requirements, you can be pretty sure that the signal path circuitry is good up to the color section and the picture tube is operating correctly. Then the trouble must lie in the chrominance section. Symptoms of defects in the color section can be broadly divided into two types -- loss of color, including insufficient
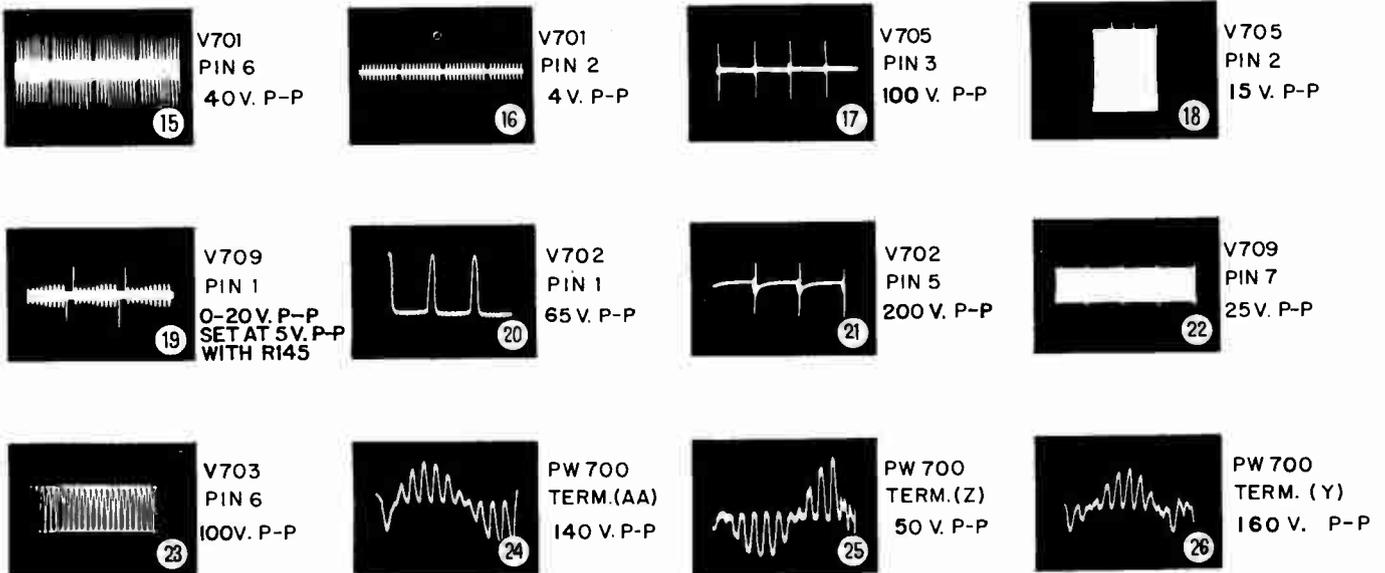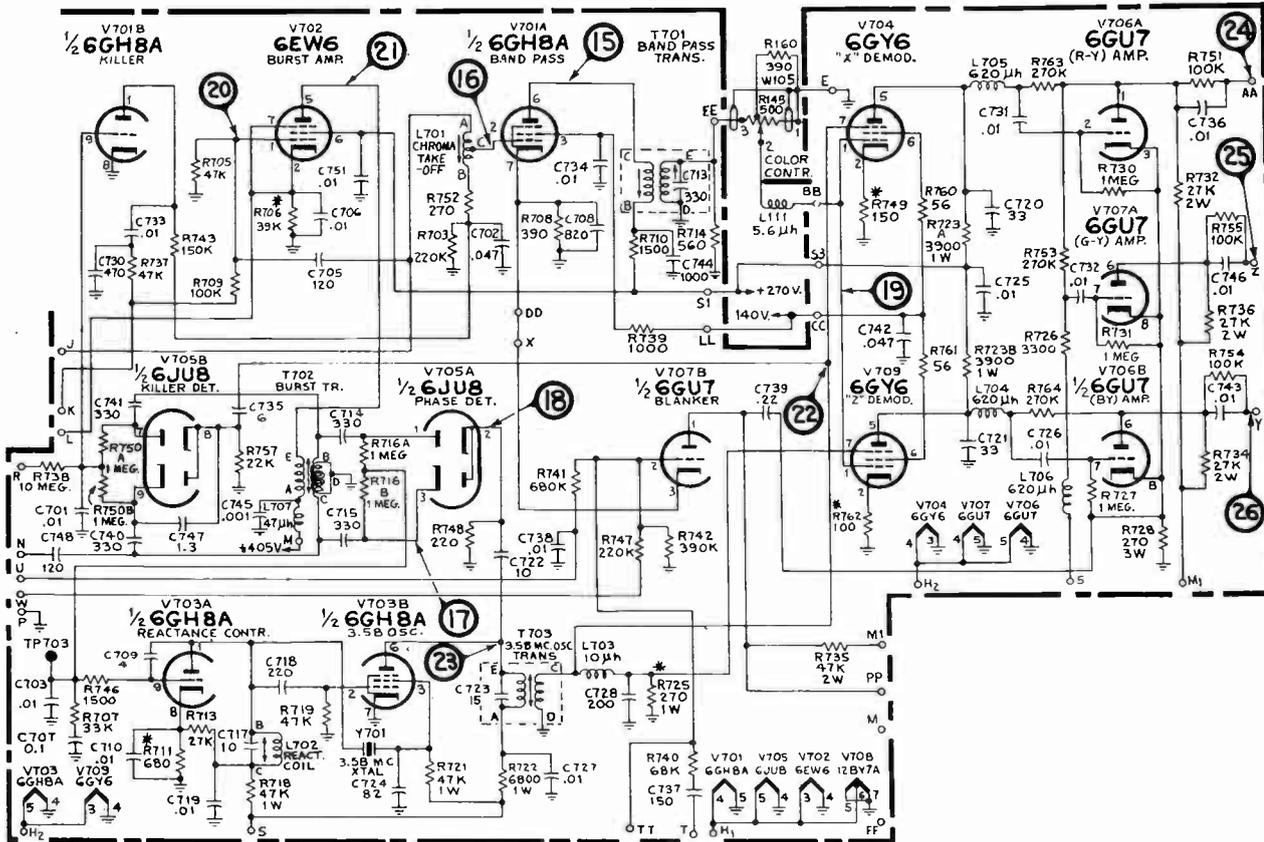
Fig. 17. Chrominance section of a color TV receiver.

Courtesy RCA

color, and improper hues, including color sync problems.

When you substitute tubes in the color section, you must consider whether a replacement tube requires an adjustment to the circuit. Refer to the color section of a receiver shown in Fig. 17. Suppose your screen shows a complete loss of green color in the reproduced picture. You suspect the G - Y amplifier so you replace V707. Now your picture has a green-

ish cast indicating too much green in the picture. You have replaced the defective tube but now you must check the color temperature adjustment and readjust the blue and green drive controls for proper black-and-white tracking. Likewise, when you replace tubes in the color sync section you will usually have to go through the color afpc adjustment.

A complete loss of color leads you to suspect the bandpass amplifier or the circuits that control the

bias on the bandpass amplifier. With color turned up full and the bandpass amplifier operating, you should get something through the color channel. However, if the 3.58-mc oscillator is not operating or if the color killer circuit is defective, the bandpass amplifier may be cut off by a large negative bias on its grid.

Loss of color sync should lead you to suspect the color phase detector stage or the reactance control stage. Depending on the exact circuitry, the trouble could also be in the burst amplifier. In the circuit in Fig. 17, a defective burst amplifier removes the burst signal from the killer detector. Therefore, the killer detector would not bias off the killer stage and the bandpass amplifier would be cut off. In this case you would not see the loss of color sync because the color would not be displayed. In many sets, you can disable the color killer and observe the received signal whether the burst amplifier is working or not.

The most rapid and accurate method of completely checking a color section is to use the signal tracing procedure. Apply a color bar generator signal to the receiver. You can apply an rf signal to the antenna terminals or a video signal to the input of the video amplifier. If possible, use the same pattern that is shown on the service literature. The waveforms in Fig. 17 are from a keyed rainbow generator. If you use a different type you will have to evaluate the waveforms in terms of what each circuit should do to the signal.

Adjust the receiver and the signal generator to get the same waveforms shown on the service literature. When signal tracing a defective receiver, always adjust fine tuning and the signal generator output to try to duplicate the waveforms. This is necessary when you do not have a satisfactory display on the receiver to evaluate the receiver and generator settings.

In Fig. 17, you should observe waveform 19 at the control grid of the "X" and "Z" demodulators. Adjust the color control for a 5-volt peak-to-peak waveform. If you can get this waveform correctly you can be pretty sure that the signal path for the chrominance signal through the bandpass amplifier is all right. Then check waveform 22 at the suppressor grids. With these two signals present, the color demodulator should produce color difference signals. However, the colors could be out of sync. If waveforms 24, 25, or 26 are missing, signal trace within the demodulator and color difference amplifier circuits. If these three waveforms are present but are of the wrong shape, the reproduced bars will be of the wrong hue and the trouble is probably in the color sync section.

Signal trace the waveforms in the color sync section. A correct burst, waveform 21 at the plate of the burst amplifier, indicates that the burst signal is being properly processed. Waveforms 17 and 18 check the inputs to the color phase detector. A waveform similar to waveform 17 should be present at pin 1 of the phase detector. You can take waveforms on the pin terminals of the killer detector to check for the burst signal and 3.58-mc oscillator signal inputs to this circuit.

After you isolate a defect to a single stage in the color section, use circuit tests and component tests to find the defective component. Many parts in the color section must be replaced with exact replacement parts. The location of parts and lead dress is not very critical in this section. However, you can expect to have to make alignment adjustments to the circuit after replacing parts.

CONVERGENCE CIRCUITS

You will rarely find it necessary to troubleshoot the convergence circuits of a color TV. The circuit is made up mostly of passive components that seldom fail. Most troubles will consist of mechanical damage to the leads or controls. Troubles of this sort can usually be located by a careful inspection of the convergence board, the controls located on the board, the convergence yoke assembly, and the wires connecting the various parts of the circuit.

Defects in the convergence circuit show up when you find that you cannot perform a convergence adjustment (one or more of the convergence controls produce no change in the convergence pattern). Before you conclude that the convergence circuits are defective, recheck the adjustment procedure. For example, if you have an amplitude control turned to minimum you will get little or no effect from adjusting its associated tilt control. If you determine for sure that the controls are not affecting the convergence, check some simple things first. Some convergence controls use plastic knobs that fit in metal slots of the control. If these knobs have been forced beyond the control stop, the plastic may turn in the slot and not move the control slider. Check for broken leads to the coils of the convergence yoke. Examine the convergence board for evidence of cracks in the circuit board.

Check for the presence of the horizontal and vertical input waveforms to the convergence board. Compare the waveforms present with those shown in the manufacturer's service information. Usually vertical signals will be taken from the cathode of the vertical output stage and from the vertical output transformer. Horizontal signals will be supplied by the horizontal output transformer. Make sure all these signals actually reach the convergence board. Often a broken lead or a poor contact in a plug or socket can upset the operation of the convergence circuits.

After assuring yourself that the input waveforms to the convergence board are present, test the board circuitry and components with an ohmmeter. Use the ohmmeter to make a point-to-point circuit check of the suspected circuit and control. Test the diodes in the circuit by measuring their front to back resistance ratio or test the suspected part by substitution.

SELF-TEST QUESTIONS

(x) What kind of tests are most useful for troubleshooting a low voltage power supply?

(y) What type of defect is indicated if the receiver blows house fuses as soon as it is turned on?

(z) When using an ohmmeter to check for a short circuit in a power supply, what reading do you look for between the B+ circuit and chassis?

(aa) What is the usual cause of an audible hum from a choke or power transformer?

(ab) What defect should you look for in a tuner if the tuner does not work after replacing a shorted tube?

(ac) What kind of defective condition in the i-f amplifiers can produce excessive agc voltage?

(ad) What precautions should you take concerning parts placement when working in the i-f amplifier section?

(ae) What kind of defect in the video amplifier is indicated by loss of fine detail in the picture?

(af) What defect in the video amplifier could cause smearing of the picture?

(ag) What is one likely cause of ringing in the video amplifier?

(ah) What is a quick test of the audio frequency portion of the sound section of a receiver?

(ai) What two defects are the most likely cause of distorted sound in a TV receiver?

(aj) Why is it important to clamp the agc line with a bias box when troubleshooting in the agc circuits?

(ak) What is a quick way to check the vertical output stage and yoke of a receiver that shows no vertical deflection?

(al) What can you do to see the vertical sync pulse on the vertical sweep waveform when viewing it with a scope?

(am) Where is a good "first test point" for isolating trouble within the horizontal section of a receiver?

(an) Should you be able to sync the picture horizontally when the grid of the afc control tube is shorted to ground?

(ao) Why is it important to use exact replacement capacitors in the horizontal oscillator circuit?

(ap) Why is it impractical to signal trace the waveforms in the output circuit of the horizontal sweep circuit?

(aq) Which of the following stages would you suspect if a color receiver produces no color, not even colored snow: color demodulator, 3.58-mc oscillator, bandpass amplifier, burst amplifier, or color killer?

(ar) Why will you not see an out-of-color-sync condition on some color receivers?

(as) What is the most likely cause of defects in the convergence circuits?

(at) Why can a defective color amplifier tube make it impossible to properly adjust the color drive controls?

Picture Indications of Defects

Every defect in a TV receiver gives a telltale indication in the picture or sound. Learning to relate these indications to the probable trouble area in the receiver is an important part of TV servicing. The experienced service technician sees more in the defective picture indication than, for example, the customer. Also the things he sees have more meaning. He knows where each of the visible signals originate and what circuitry they pass through before they are displayed on the TV screen. The TV screen shows the end product of the various functions performed by the receiver circuitry. If a defect in one circuit prevents the function from being properly performed it shows up in this end product.

A careful study of the signals on the TV screen pays rich troubleshooting dividends. Learn to identify each signal in terms of both the voltage waveform in the circuit and the light intensity change produced by that signal on the screen. For example, can you see any indication of the horizontal sync pulse on the screen? No, not directly because the horizontal sync pulse occurs during horizontal retrace time when the picture tube is blanked. Just when does the sync pulse occur? At the start of the horizontal sweep? At the end of the horizontal sweep? Think of the horizontal sweep circuit. The manner in which the sync pulse controls the sweep varies for different circuits. Theoretically, the sync pulse terminates the sweep and initiates the flyback pulse. In practice, the adjustment of the horizontal circuit affects the time of occurrence of the sweep in relation to the sync pulse. With careful adjustment on some receivers you can see a portion of the horizontal blanking bar at the edges of the screen. Knowing intimate details about signals is a big help in rapid troubleshooting. You learn these details by careful observation and by thinking through the formation and display of the signals.

In this section we will confine our discussion to those sections of the TV receiver found both in black-and-white receivers and color receivers. Therefore all this information applies equally to both color receivers and monochrome receivers. Then in a separate section we discuss the additional picture indication that applies strictly to color receivers.

PICTURE SIGNALS

When you examine a defective receiver you look for the presence of all the normal signals on the face of the screen. By observing these signals on a properly operating receiver, you know what is normal. You mentally compare the defective indications with what you know to be normal. Then you apply effect-to-cause reasoning to account for the defective indications.

The screen displays four different signal areas that you can observe for clues to defects in the receiver. These include the raster, vertical blanking, horizontal blanking, and video information. In some cases you must move secondary adjustments to observe these signal areas. Let's examine each of the signals so we know what to look for.

Raster.

As you know, 525 horizontal lines make up one raster frame on the screen. 262-1/2 lines form the first field while the next 262-1/2 lines are interlaced between the lines of the first field to form the second field of the frame. Approximately 21 lines are used up in the vertical blanking period. A normal raster fills the screen both vertically and horizontally; it has adequate brightness; the sweeps are synchronized with the sync pulses; and the fields are interlaced. The raster will not be in sync and will not be interlaced unless a received signal is applied but it is still considered to be a "normal" raster under these conditions. It is important to recognize that when we speak of the raster we are excluding any intensity modulation produced by the picture information signals.

A receiver with the normal raster tells us a great deal about the receiver circuitry. The low voltage and high voltage power supplies are good. Both the vertical and horizontal sweep circuits are operating. If the raster is synchronized with an incoming signal, the sync section of the receiver is operating and the receiver is receiving and processing, at least partially, a signal from a TV station. Thus a normal raster eliminates large portions of the receiver as possible defective sections.

Defects in the raster point toward trouble in the high voltage, sweep, sync or power supply sections of the receiver. A standard test is to remove the video signals while observing the raster. If the raster defect is still present with no video, the trouble is almost certainly not in the signal path sections of the receiver.

Vertical Blanking Bar.

Adjust vertical hold to position the blanking bar in the center of the screen as shown in Fig. 18. The vertical blanking period shows up as a dark band about

Fig. 18. Vertical blanking bar showing signals present during the vertical blanking period.

21 horizontal lines wide. The darkness of the blanking bar can be adjusted with contrast control. Actually the blanking level should just cut off the picture tube thereby reproducing a dark area. In practice, contrast is usually adjusted so that the blanking bar is not perfectly black. The dark area in the center of the blanking bar is sometimes called a "hammer head". This pattern is formed by the equalizing pulses and serrations in the vertical sync pulse. The sync pulses produce about six darker lines in the blanking bar.

The presence of the sync information in the blanking bar indicates that the receiver is processing the sync signals. When you can see the center-line indications of the equalizing pulses, you know that the receiver is also processing the horizontal sync pulses at least through the video amplifier. Therefore sync troubles must be confined to the sync separator or sweep sections of the receiver. On the other hand, if the sync information is missing in the blanking bar, look for trouble in the video amplifier or video i-f; it is unlikely that the sync trouble is in the sync separator or sweep circuits.

WHITE
FLAG
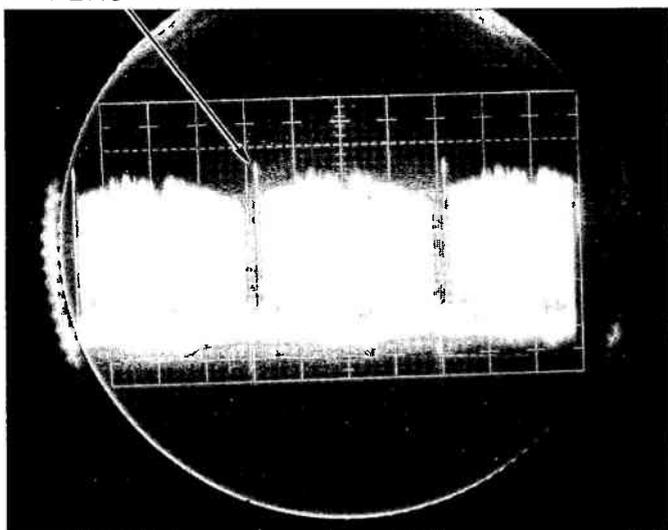
Fig. 19. Scope pattern of video signal with "white flag" indicating the white level of the signal.

TV station test signals are sometimes present in the vertical blanking bar. FCC transmission standards reserve lines 17 through 20 of the vertical blanking interval for these test signals. They are used by the TV stations for evaluating the performance of the transmission system and for cue and control signals. Some of the signals are useful for evaluating the performance of receivers. For example, the "white flag" or white peak signal establishes the amplitude of the white level signal in the video signal. As shown in Fig. 19, the white level signal appears as a sharp pulse in the vertical blanking period. It extends in the opposite direction from the vertical sync pulse. It can be used as a reference to evaluate the relative amplitude of portions of the video signal.

The multiple dot pattern that appears during the blanking pulse in Fig. 18 can be used as a rough indi-
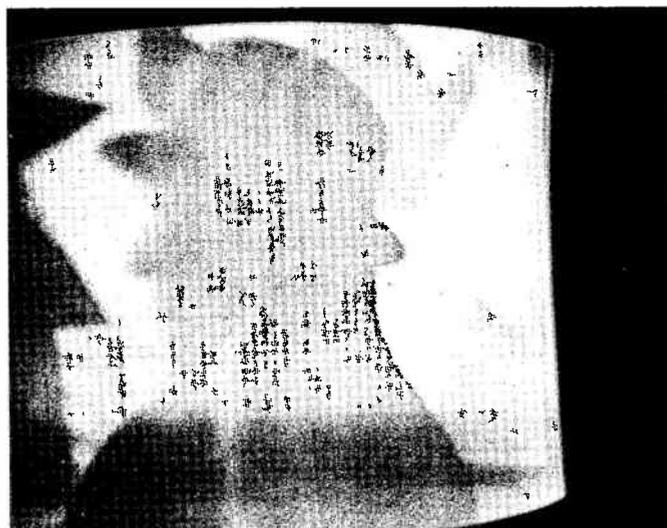
Fig. 20. Horizontal hold has been misadjusted so the horizontal blanking bar is visible at the right edge of the raster.

cation of the frequency response of a receiver. The ability of the receiver to display the fine dots is a measure of the high frequency detail that the receiver can reproduce. Since there is no standard set of signals, you cannot be sure what signals a station will transmit or that it will transmit any test signals during the vertical blanking period.

Horizontal Blanking Bar.

The horizontal blanking period normally starts after the sweep has completed the travel across the visible portion of the screen. Likewise, the period ends before the sweep becomes visible on the left side of the screen. You may want to move the picture off center to view the edges of the raster. This will show any raggedness of the starting or ending of the sweep that can be caused by noise getting into the sync signals. Also observing the edges of the sweep may give clues to the cause of raster bending. By moving the contrast control you can determine if the raster edge distortions are caused by video in the sync signals.

You can see the horizontal blanking bar in most receivers by moving horizontal hold while observing the raster edge. As shown in Fig. 20, a narrow bar along the right edge contains no video information. Contrast has been misadjusted so that the edge of the raster is visible as well as the limits of the video information. This test is useful for observing the effect of the video on the raster.

Video Information.

That part of the video signal that delineates the picture on the screen is referred to as the video information. Or you can think of it as the intensity modulation applied to the electron beam during each horizontal sweep line. You observe the quality of this signal in terms of how well the receiver reproduces the picture. Loss of fine detail in the picture implies poor high frequency response, probably in the video amplifier. Likewise, smearing along the edge of the large picture areas implies poor low frequency response. A weak picture with poor contrast suggests insuffici-

ent gain in the video section of the receiver. If the weak picture is accompanied by snow, the insufficient gain is probably in the tuner section of the receiver. Picture distortions may be caused by trouble in the signal path or a defective signal in the sync section may be distorting the raster. You can usually determine if the picture distortions are caused by a distorted raster by careful observation of the raster with the video information removed.

How carefully you examine the visible signals on the screen is determined by the type of trouble that the receiver exhibits. Usually a glance at the screen is all that is needed to confirm gross defects such as a loss of vertical sweep. However, when a defect is marginal, you may want to observe the screen carefully. For example with the sync problem, careful observation of the picture may enable you to isolate the defect to the sweep circuit, sync separator or the video i-f section. It is important to form the habit of observing the signals on properly operating receivers. Then you can quickly spot signals that are not correct on defective receivers.

VIDEO DEFECTS

Defects that show up in the displayed video are limited to the signal path sections of the receiver. As you know, the signal path includes the antenna, tuner, i-f amplifier, video detector, video amplifier and picture tube. In observing a defective picture, you first determine for sure that the defect shows up as improperly displayed video. Then from the indications you try to isolate the defect to one of the signal path sections.

Blank Raster.

A completely blank raster means that the signal path is broken. Since not even snow is present, it means the defect probably lies between the i-f amplifier and the picture tube. Rotate agc through its full range. Some misadjusted agc circuits can cut off the i-f amplifiers and produce a blank raster. Check the setting of the contrast control. Rotate the brightness control. No control of brightness may indicate an open cathode in the picture tube. Adjust the vertical hold and try to determine if the blank raster is synced to the station signal. If it is, the trouble must lie in the video amplifier or picture tube circuits. Look for a dead tube in the i-f amplifier or video amplifier section. Substitute tubes in the video amplifier and then in the i-f amplifier. Use signal tracing or signal injection procedures to isolate the defective stage.

Snow.

The presence of "snow" on the raster indicates that noise is being amplified and displayed on the screen. It usually indicates that the i-f amplifier is running wide open with maximum gain and the noise originates in the tuner. Tuning a good receiver to a blank channel usually produces snow. Try different channels. If snow is worse on high channels (weak picture with snow) the oscillator tube in the tuner is probably defective. A weak or dead tuner rf stage can result in snow with a weak or missing picture. Likewise, a defective antenna or lead-in can produce a weak signal with accompanying snow.

Weak Picture-No Snow.

Insufficient video signal without snow usually eliminates the tuner and antenna as the cause of trouble. If the picture has good quality but is just weak, it indicates that normal agc is probably being developed and the i-f stages are operating with normal bias. Check the contrast control and brightness control. An open cathode in the picture tube can produce a weak picture. Check the action of the agc control. Substitute the video amplifier tube and the video i-f tubes. A defective video detector can also produce a weak picture. Signal trace the circuit to locate the weak stage.

Coarse Picture.

A coarse picture with little or no fine detail almost always places the trouble in the video section of the receiver. Substitute the video amplifier tube. Test the picture tube for shorts. Grid to cathode leakage in the picture tube can produce a coarse picture. Look for a clean signal at the output of the video detector. Look for a defective video detector or shorted components in the detector filter. Check for shorted peaking coils in the plate circuit of the video amplifier. Burned plate or screen resistors in the video amplifier can likewise produce a coarse picture.

Poor Detail-Smear.

Sometimes a defective picture will have poor detail but it will not be accompanied by the harsh coarseness that is so characteristic of video amplifier troubles. The picture usually shows severe smearing indicating that some frequencies of the video signals are phase shifted. Fig. 21 shows an example of this condition. Look for evidence of overloading in the i-f amplifiers and check operation of the agc. Excessive capacitance-to-ground anywhere in the video circuit can cause this condition. A defective plate load resistor in the video amplifier can also cause this trouble. If it increases in value, the stage provides more gain for some frequencies while increasing the effect of the normal distributed circuit capacitance. The resultant picture resembles an i-f overload condition.

Fig. 21. Smeared video and loss of fine detail produced by shunt capacitance in the video amplifier.
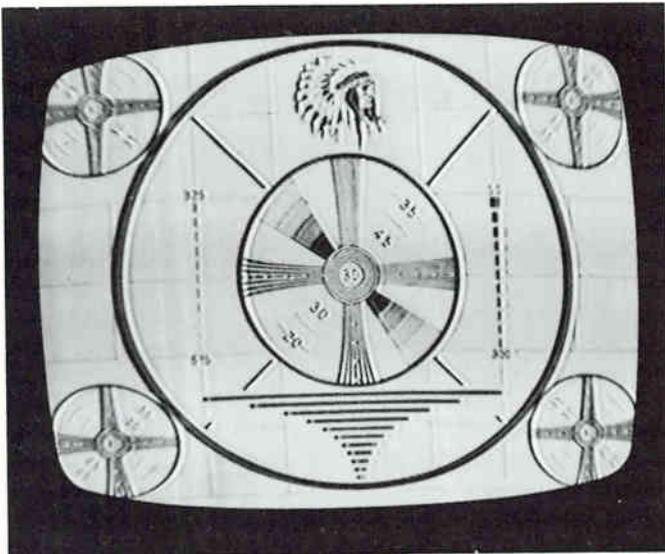
Fig. 22. Appearance of ringing produced by an open damping resistor across a peaking coil in the video amplifier.

If the sync signals are not affected, the defect is probably in the video amplifier beyond the sync take-off point. If the overload also affects the sync, look for the defect in the video detector or i-f stages.

Ringing-Ghosts.

Multiple pictures similar to ghosts can be caused by a video amplifier circuit that produces damped oscillations when driven by an abrupt signal change. As shown in Fig. 22, the edges of objects are followed by several weaker edges. Determine for sure that the condition is not caused by reflections in the antenna lead-in or by multi-path ghosts. If not, it is probably caused by an open damper resistor that is shunted across a peaking coil. Test the various peaking coils by momentarily shorting them and observing the effect on the picture. In some cases other resistors in the circuit can change value and produce similar results.

In a color receiver, evenly spaced ghosts or reflections can be caused by an improperly terminated delay line. An ungrounded shield on the delay line or an improper impedance match at the output of the delay line can be the cause of this. Energy in the video signal is reflected from the termination producing multiple delayed signals.

Hum.

Hum bars in the picture, such as is shown in Fig. 23, are caused by 60 or 120-cycle voltage getting into the video signal. A 60-cycle hum produces one wide dark (or one light) bar on the screen while 120-cycle hum produces two narrower bars. The example in Fig. 23 is 120-cycle hum; the second dark bar occurred during the vertical retrace interval so part of it appears at the top of the picture and part at the bottom. In cases such as this, the hum may look like 60-cycle hum, but 60-cycle hum would produce a wider bar than the one in the figure.

If the power supply uses a full-wave rectifier, the ripple voltage is 120 cycles so that the hum is getting into the video from the power supply. If the set uses full-wave rectification and it shows a 60-cycle hum bar, the hum voltage is probably due to heater to cathode short (or leakage) in one of the tubes (including the picture tube) in the signal path. If the hum bar does not affect the sync, the leakage is probably in a tube beyond the sync takeoff point in the circuit.

Interfering Signals.

Sometimes interfering signals may produce patterns on the screen that lead you to believe a defect is present in the receiver. Multi-path ghosts, amateur radio signals, FM radio broadcast, automobile ignition, and industrial equipment can interfere with the proper operation of a TV receiver. It is usually not too difficult to determine if interference originates in the set or outside. For example, corona discharge in the receiver may cause interference similar to auto ignition noise. Remove the antenna lead-in and short the antenna terminals together and then to the chassis. If the interference is still present it probably originates in the receiver. In other cases you can identify the external interference signal by the pattern it produces on the screen.

RASTER DEFECTS

Imperfections in the raster are limited to defects in the sweep circuits and power supply. It is possible for the raster to be distorted by video signals or improper sync. In these cases the raster will be normal when you remove the video signal. In this section we will consider those indications of raster defects that are associated with the sweep and power supply.

Size.

When the raster fails to fill the screen either horizontally or vertically, suspect the low voltage power supply. However, it may be easier to try a new vertical and horizontal output tube if the receiver uses a silicon diode type low-voltage power supply. If B+ is low you can usually get enough height by adjusting
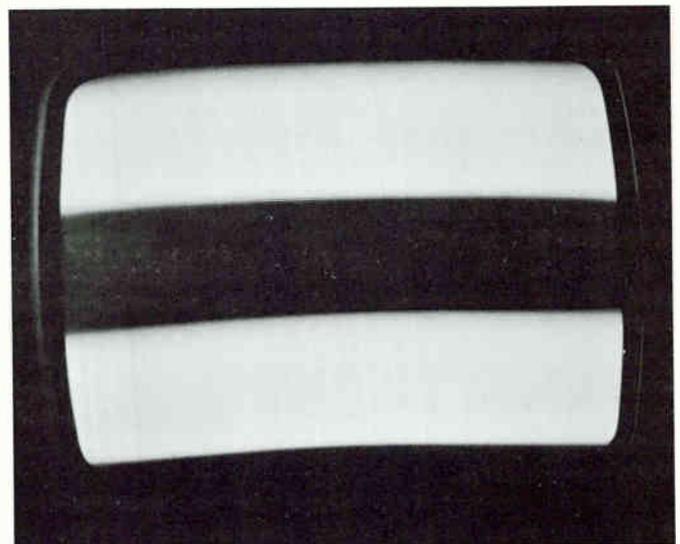
Fig. 23. Hum bar produced by a 120 cycle signal from a full-wave rectifier power supply getting into the video signal.
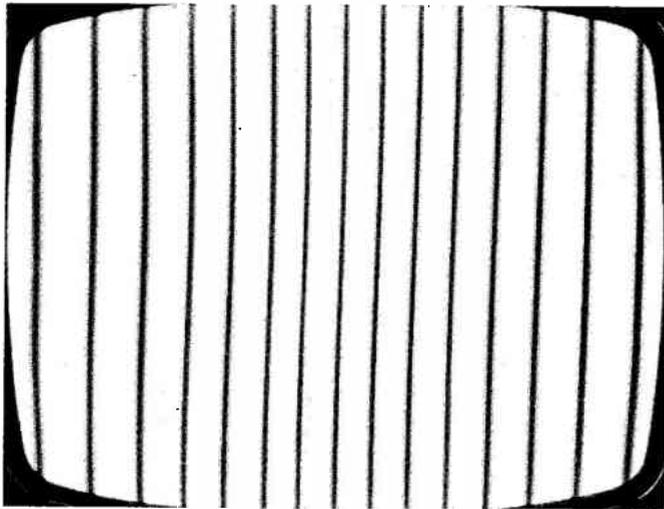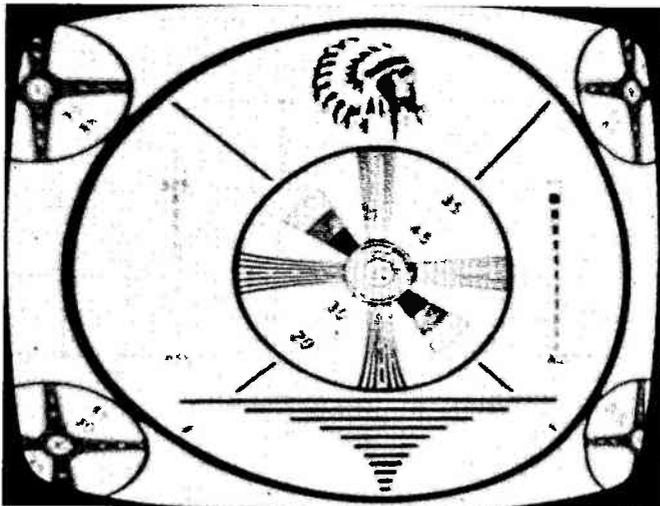
Fig. 24. Horizontal nonlinearity. The vertical bars are squeezed together in the center and spread apart at the edges (A). At (B) the pattern is spread out on the left half of the picture.

height and vertical linearity. Many inexpensive receivers have no width control. Also try the damper tube and the horizontal oscillator since these tubes can affect width.

If B+ is normal, examine the drive waveform on the grid of the horizontal output stage. Measure boost voltage. Since boost voltage is often used in the sawtooth forming network of the vertical circuit, a low boost voltage can affect both width and height. Except for low B+, defects that affect size are limited to the vertical and horizontal sweep circuits.

Nonlinearity.

When the picture is stretched out or squeezed together in some areas of the screen, the picture is said to be nonlinear. This condition may exist vertically or horizontally. Fig. 24 shows two extreme examples of horizontal nonlinearity. The condition is caused by the beam sweeping across the screen at

different speeds in different areas. The defect is limited to the sweep circuits of the receiver.

Vertical nonlinearity is often caused by improper adjustment of the secondary controls. On some receivers, height, vertical linearity and vertical hold interact badly. If these three controls have been misadjusted, you may have to use trial and error to find a setting for each that will enable you to correct the separate controls. Try setting height and linearity in the mid-position. Then adjust hold to lock the picture. Carefully move height only a small amount and observe the effect on both height and linearity. You may find that the linearity control has the greatest effect on the height of the raster while height greatly affects linearity. In many vertical circuits, the hold control may have quite a bit of effect on linearity. This is especially noticeable when you are setting up the picture.

Many inexpensive receivers have rather poor horizontal linearity and no horizontal linearity adjustment is provided. The condition may appear to be quite bad when a crosshatch pattern is displayed but will not be noticeable to the customer viewing the picture. When you check the circuit you may find all part values within tolerance. Try varying the size of the components that affect linearity. Refer to the section on horizontal sweep in this lesson.

Pincushion-barreling.

This condition is the result of the geometry of wide angle deflection tubes. The distance from the deflection center to the screen changes for various points during the sweep. Therefore the beam describes an arc on the screen. Fig. 25 shows pronounced pincushioning. When the lines are bent in the opposite direction it is called "barreling". In most black-and white receivers the condition is corrected by small magnets placed on the rim of the yoke. The field of the magnet bends the beam enough to straighten out the raster. If the magnet becomes unglued and is mis-
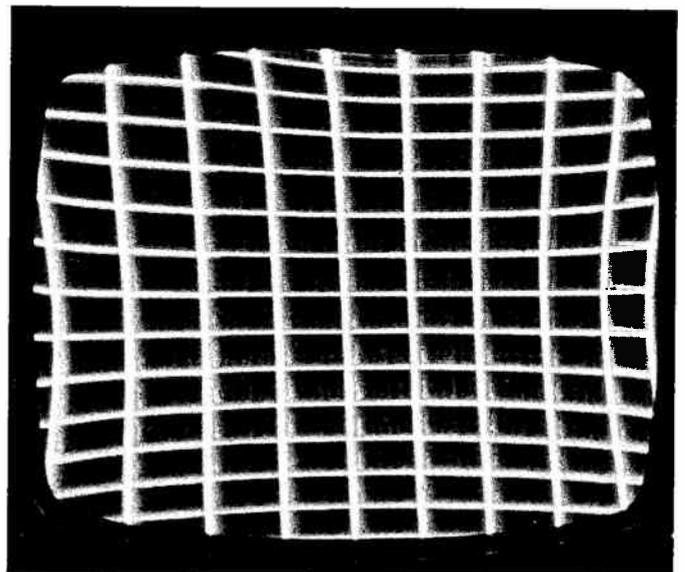
Fig. 25. Pincushion. This exaggerated example was produced by reversing the polarity of the pincushion correction magnets on the yoke.
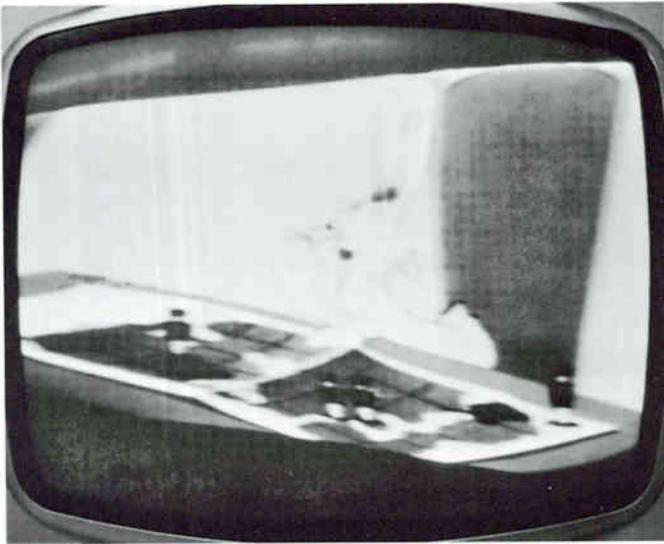
Fig. 26. Trapezoidal raster resulting from a shorted section of the vertical yoke windings.

sing, the condition may show up. Some color receivers have a pincushion correction circuit since magnets are impractical for a three-gun color tube.

Trapezoid.

When the raster presents a pattern with nonparallel sides (or top and bottom) the defect is known as trapezoid. This condition is limited to defects in the sweep circuits and is usually caused by a partially shorted yoke. Fig. 26 shows a trapezoidal raster caused by a shorted component across one-half of the vertical deflection yoke winding.

Bending.

Irregular distortions of the raster are described as S-ing, hooking, or bending. When these troubles are coming in through the sync circuits they may be caused by defects in the sync, video, or i-f circuits. This can be determined by removing the video and observing the bare raster. If the defect is still present, it is probably caused by poor filtering in either the power supply, boosted B+ or by defects in the sweep circuits. Heater-to-cathode leakage in the tubes in the horizontal section can cause bending. Excessive 60 or 120-cycle ripple in the power supply is another frequent cause. The condition may or may not be accompanied by a hum bar depending on whether the ripple is getting into the video signal path.

Foldover.

Vertical foldover such as shown in Fig. 27 usually occurs at the bottom of the picture. A gassy vertical output tube or a leaky coupling capacitor to the grid of the vertical output tube is the most usual cause. A change of resistance values in the sawtooth forming network can also cause vertical foldover. The defects are limited to the vertical sweep circuit or to low boost voltage.

Horizontal foldover points to defects in the horizontal sweep section. Defects in the sweep forming network at the grid of the horizontal output stage usually causes foldover in the center or right half of the screen. Foldover or distortion in the left half of the screen is usually associated with the damper or yoke circuit.

Blooming.

A picture that gets bigger as brightness is turned up is said to "bloom". This is usually accompanied by decreased brightness and loss of focus. The cause is poor regulation of high voltage. As you turn up brightness and draw additional beam current, the second anode voltage drops to a lower value. With reduced high voltage, the beam is overswept making the picture occupy a larger area. The usual defect is low emission of the high voltage rectifier tube but other things can cause it. Insufficient filament voltage to the high voltage rectifier tube can cause the low emission. Measure the resistance of any series resistor in the filament circuit. High voltage leakage may put a constant drain on the high voltage supply. This condition is rare because leakage usually shows other more noticeable symptoms than blooming.

Increasing brightness increases the load on the horizontal circuit which in turn can reduce the output. Thus, any marginal defect in the horizontal circuit can produce blooming. This includes a weak horizontal output tube, weak damper tube, or low B+.

OUT OF SYNC CONDITIONS

A properly synchronized raster maintains a stationary position on the screen of the receiver. The beginning and end of the horizontal lines form straight edges along either side of the raster. The odd-line field stays interlaced with the even-line field. Each succeeding field of the raster is laid down in exact synchronism with the sync pulses in the received signal. Any variation of these conditions shows up instantaneously as a flaw in the presentation of the video information.

Sync defects produce symptoms that range from a slight unsteadiness of the picture to a complete loss of either horizontal or vertical sync or both. Thus,

Fig. 27. Vertical foldover due to a leaky coupling capacitor on the grid of the vertical output stage. Notice the inverted lettering on the bright foldover at the bottom of the picture.

stray noise pulses may only occasionally change the time of occurrence of a single horizontal sweep line and the fault will go practically unnoticed. Or the vertical hold may be slightly misadjusted resulting in loss of interlace that produces a coarse picture. The fault may go unnoticed by the customer. Of course when sync is lost completely, either horizontally or vertically, the picture can no longer be watched.

The vertical and horizontal sync pulses are recovered by the same circuit so if one set of sync pulses is lost, the others are also lost. In practice, when the recovered sync pulses deteriorate, the vertical circuit is usually affected first. Thus the defect may be affecting both horizontal and vertical sync pulses but the symptom will show up only as instability of one of the sweeps. In other words, just because horizontal sync is rock solid, don't assume that poor vertical sync places the trouble definitely in the vertical sweep circuit.

When using tube substitution to locate sync troubles, try to determine if the signal is good to the sync separator. Observe the blanking bar as shown in Fig. 18 and look for the sync information. Notice how the set responds to the agc. If a video i-f amplifier tube is gassy, it may be compressing the video signal and thereby reducing the amplitude of the sync pulses.

Vertical Sync.

Fig. 28 shows an out of vertical sync condition. If the rolling cannot be stopped by adjustment, a defect probably exists in the vertical multivibrator circuit. Or perhaps you will be able to nearly stop the roll with the hold control tuned to the maximum in one direction or the other. A resistor in the hold control circuit has probably changed value. Or a capacitor in the same circuit has developed leakage.

The vertical circuit should exhibit a definite "snap" when the picture is rolled slowly down. The blanking bar should move down slowly about 3/4 of the screen and then "snap" into sync. This is an indication that the vertical multivibrator is being synchronized by the
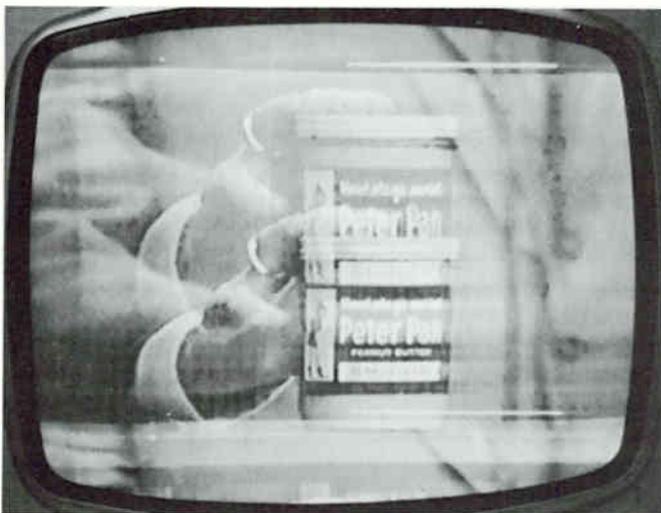
Fig. 28. Vertical roll produces multiple images displayed vertically on the screen.
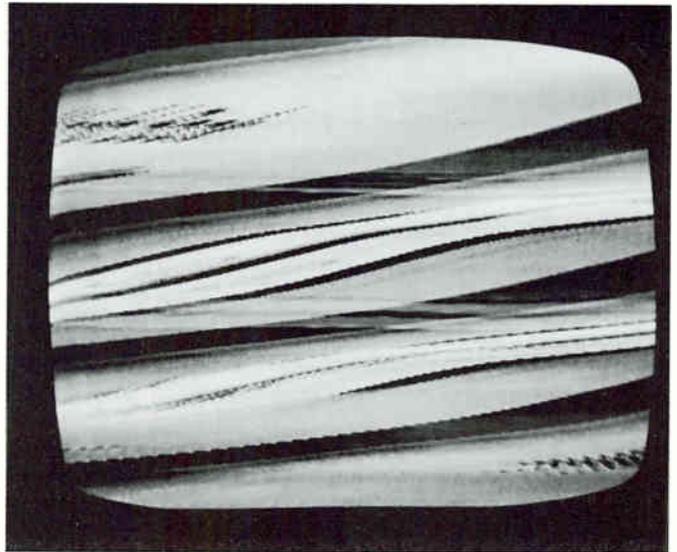
Fig. 29. Loss of horizontal sync produces slanting bars across the screen.

vertical sync pulses. Also, move the hold control with picture in sync and look for good interlace.

Vertical "jitter" or unsteadiness may be present in a picture that is firmly locked in vertical sync. If the natural frequency of the vertical oscillator is off frequency, the sync pulses have to constantly "pull" the oscillator into the locked condition. This results in slight vertical movements. It is often accompanied by "pairing" of the scanning lines that produces a coarse picture. Under these conditions the picture may roll one full frame (or more) each time the signal is momentarily lost, or when the station changes camera. Another cause of "jitter" is noise pulses coming through with the sync signals. In some cases, poor filtering in the vertical integrator circuit makes the vertical oscillator excessively sensitive to normal noise in the circuit. Another possibility is a defective capacitor that generates the equivalent of noise pulses within the vertical circuit.

Horizontal Sync.

Fig. 29 shows a picture out of horizontal sync. The number of bars present is a measure of how far out of sync the oscillator is running. A large number of bars indicates that the oscillator is far out of sync. As you rotate hold, the picture should lock into sync from not less than 2-1/2 bars. This will vary for different circuits and is usually spelled out in the adjustment procedure for a particular receiver.

Loss of horizontal sync usually results from a defect in the horizontal oscillator, horizontal afc circuit, or sync separator. If tube substitution and adjustment does not correct the fault, follow the troubleshooting procedures outlined for the horizontal section.

Horizontal instability is often caused by noise getting into the sync circuit. The receiver will not drop out of sync but succeeding horizontal sweep lines start at slightly different times producing a ragged picture. The common cause is high voltage arcing or corona discharge. If the arcing is getting into the signal path,

it will show up as streaks in the picture. Or the arcing may get directly into the sync or afc circuit. Poor filtering in the afc circuit at the grid of the reactance control tube may make the circuit sensitive to normal signal noise. Also check for the presence of a noise rejection control on the receiver. If this control is improperly set, it can cause the appearance of overloading or sync compression. The noise rejection circuit is effective when the receiver is operating in noisy (electrical noise) locations. It prevents the set from losing sync. However, don't expect the circuit to keep noise from showing up on the reproduced picture.

Many types of picture distortion are produced by sync problems. The most common is the presence of video information in the sync signal. These video signals distort the raster causing the picture to bend and tear. Often you can detect a correlation between the picture distortion and the picture content. This condition is most often associated with overloading indicating trouble in the i-f or video amplifier section of the receiver. If overloading is not present, the defect is more likely to be in the sync separator section of the receiver.

SELF-TEST QUESTIONS

(au) What secondary control(s) would you adjust to observe proper interlace on a TV raster?

(av) If a receiver displays a normal raster, what sections of the receiver can be eliminated as sources of trouble?

(aw) If a raster defect is present both with and without displayed video, what sections of the receiver can be eliminated as probable areas of the defect?

(ax) What important information about sync can you observe by viewing the vertical blanking bar?

(ay) In what section of the receiver would you look for trouble if you can change the amount of raster bending by changing the contrast control setting?

(az) The appearance of snow in the picture points to trouble in what section of the receiver?

(ba) In what section of the receiver would you look for trouble causing a weak picture without snow?

(bb) Would you expect a broken antenna lead-in to cause a picture with snow?

(bc) What defect in a color receiver can cause evenly spaced reflections in the displayed video?

(bd) What section of the receiver would you suspect if the picture has insufficient height and width?

(be) In what part of the horizontal section would you look for a defect causing horizontal foldover in the center of the screen?

(bf) Will horizontal or vertical sync be more affected by a deterioration of the sync signals to the sync separator?

Picture Indications of Color Defects

Careful observation of picture indications can often pinpoint color defects to one stage of the color section of a receiver. Each stage of the color section performs a specialized function so if that function is not being performed, it gives a definite indication in the picture. Here again, you use effect-to-cause reasoning to isolate defects. You observe the color defect and think through the circuit function to determine what circuit defects could cause the observed effect. From this reasoning you decide what tests to make to further isolate the trouble.

The first isolation step with a color defect is to determine if the defect is in the chrominance section or in another part of the receiver. No color or weak color can be caused by a weak received signal or defect in the signal path prior to the color section. Most other color defects are almost always located in the color section. A defective antenna or transmission line can "suck out" the color information from the received signal. Likewise, improper tuner or i-f alignment can attenuate the color portion of the received signal. Observe the picture for adequate signal and good fine detail. If these are present, the color information is probably getting to the color section of the receiver. If possible, try the receiver on more than one station transmitting a color program. This should help determine if the received signal has adequate strength and detail.

Check the operation of the receiver on an inactive channel to display "snow" on the screen. Turn the threshold control fully counterclockwise (clockwise on some receivers) to disable the color killer. Advance the color control fully clockwise. If the receiver displays colored snow, the color circuits are capable of producing color. The reproduced color may have sync problems (wrong hues) but the fact that the color circuits are processing noise and thereby producing colored snow indicates that a signal is getting through the color channel to the grids of the picture tube. If the snow remains black and white, the trouble is defi-
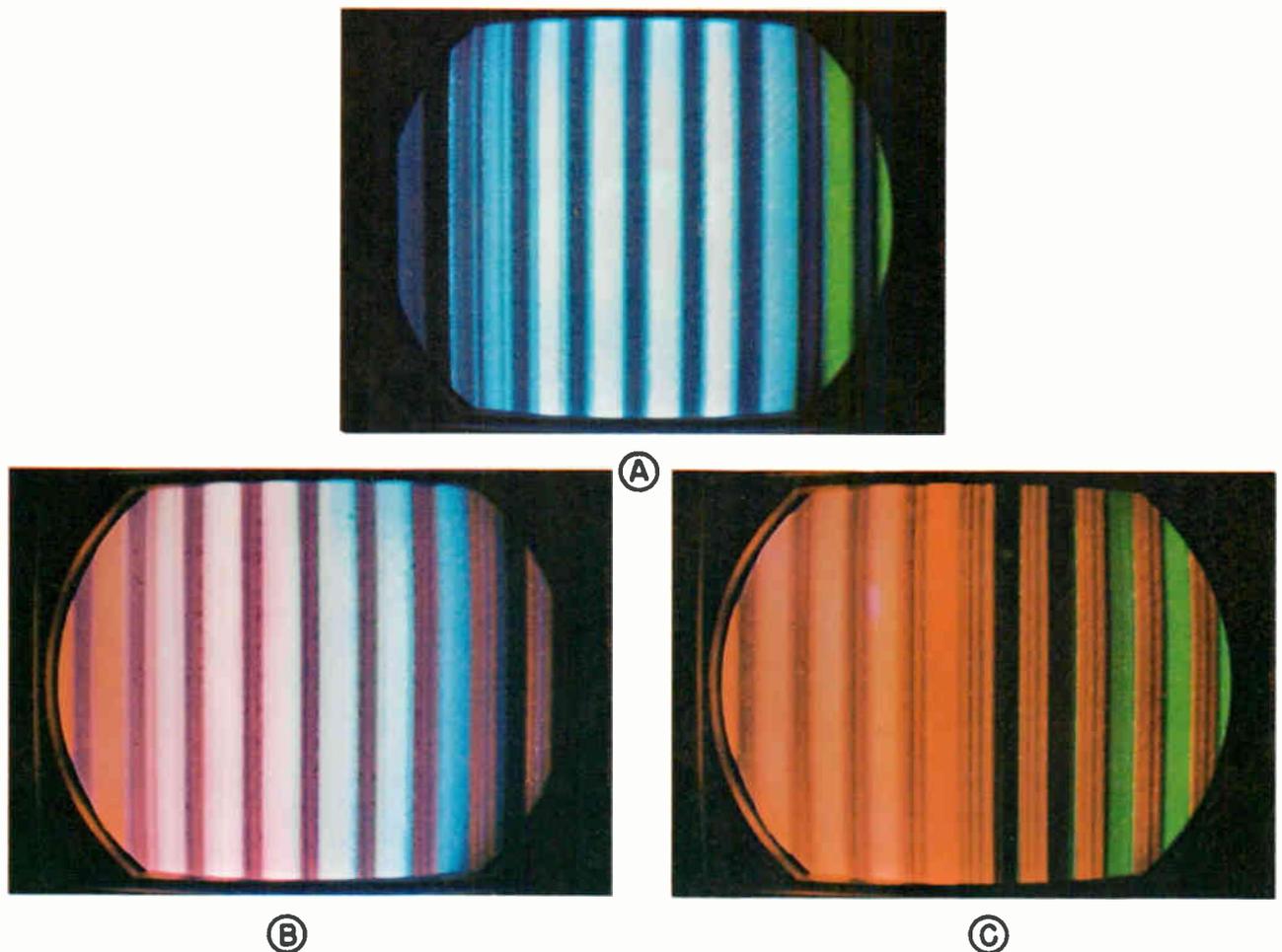
Fig. 30. When one of the primary colors is missing the picture takes on a yellow, magenta or cyan cast. (A) shows red missing, (B) green missing and (C) blue missing.

nitely in the chrominance section of the receiver.

A color bar generator is helpful at all stages for isolating color defects. You work with a known signal and you know how a receiver should respond to the signal. Also, defects that cause missing colors or incorrect hues can be quickly recognized by observing the bars of the pattern. On a color program these indications may not be as readily identified.

MISSING PRIMARY COLORS

When one of the three primary colors is missing, the picture takes on a yellow, magenta, or cyan cast. Thus, when blue is missing, the overall appearance of the picture is yellowish, being made up of only red and green. When green is missing, the red and blue colors give an overall magenta appearance. When red is missing, the green and blue colors produce an over-all cyan appearing picture. Fig. 30 shows the three conditions when the receiver is displaying a color bar pattern. You can duplicate these conditions by biasing off the appropriate gun with a grid shunt switch.

The loss of only one color indicates a defect in that color difference amplifier stage. In receivers with three demodulators (one for each color difference signal), the defect could be in a demodulator. A defective color difference amplifier stage usually upsets the dc operating voltage of that stage, in which case, the picture would also show a loss of color balance. That is, it would not reproduce a balanced black-and-white picture. Or, the defect could be in the picture tube circuits. Check the color temperature adjustments (black-and-white tracking). Look for correct amplitude color difference signals to the picture tube grid. Check dc operating voltages at the picture tube grid and cathode.

MISSING "X" OR "Z" DEMODULATOR OUTPUTS

When one of the demodulators is inoperative, the colors are not present in their correct amounts but all colors are present. On a live program it is difficult to determine just which colors are inadequate. You tend to adjust the hue and color controls to overcome the deficiencies so the picture may look fairly good on some program material. If the "X" demodulator is inoperative, the picture will be deficient in red and green. An inoperative "Z" demodulator produces a grayish picture that is deficient in blue and green.

When a color bar pattern is viewed on a receiver with a defective X or Z demodulator, the color deficiencies are more apparent. Fig. 31A shows a color bar pattern with an inoperative X demodulator. Notice that some of the normally red bars have some orange-red color. If you put a scope on the red-gun grid, you will find a signal present but of the wrong shape and with reduced amplitude. Likewise, in Fig. 31B, the color bar pattern produced with an inoperative Z demodulator produces color in all bars. Notice that the
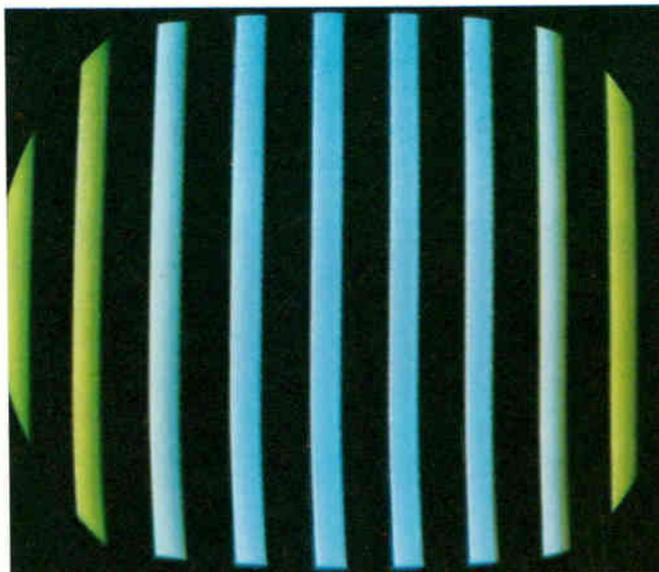
Fig. 31A. Color bar pattern showing the effect of an inoperative X demodulator.
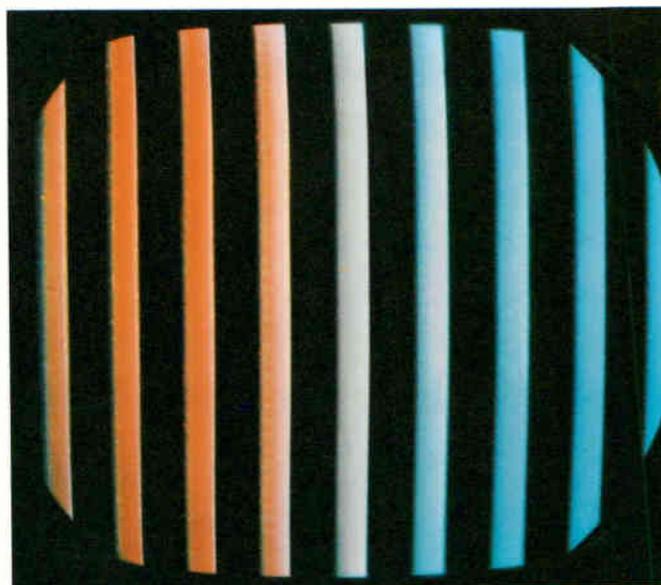
Fig. 31B. Color bar pattern showing the effect of an inoperative Z demodulator.

red appearance extends way over to the sixth bar while the deficiency in the green makes the normally cyan eighth bar look blue. As with a defective X demodulator, a color difference signal will be present on all three grids of the picture tube.

Varying degrees of the conditions described above can result from a defective demodulator that produces a reduced output. You may mistake the condition for an error in hue. When you try to correct the hue of one bar in the pattern by moving the hue control, other bars produce incorrect hues. The condition can be pinpointed by observing the amplitude of the color difference signals at the grids of the picture tube. In Fig. 32 we have shown the normal waveforms at the grids of the picture tube and also the waveforms with the color difference signals missing. Compare the am-

RED GUN　　　　　　　　　BLUE GUN　　　　　　　　GREEN GUN
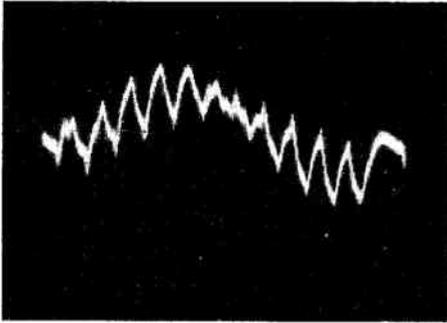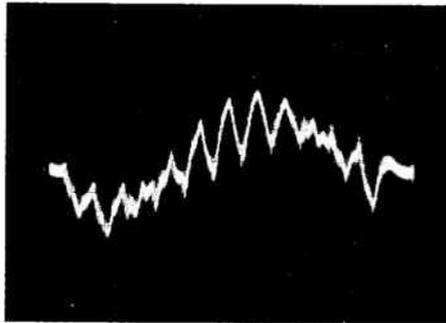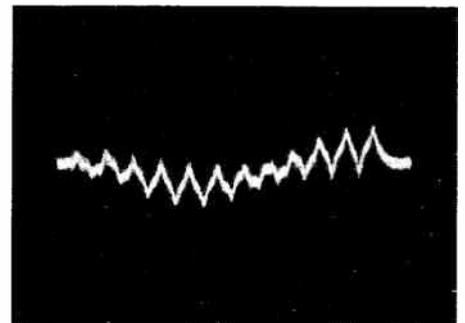
NORMAL　　　　　　　　　NORMAL　　　　　　　　　NORMAL
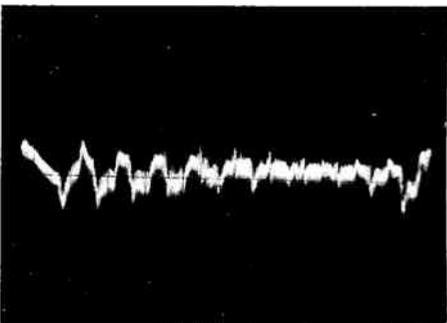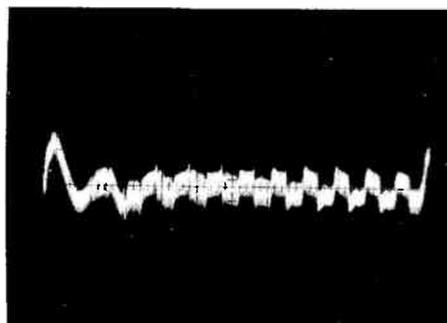
R-Y MISSING　　　　　　　B-Y MISSING　　　　　　　G-Y MISSING
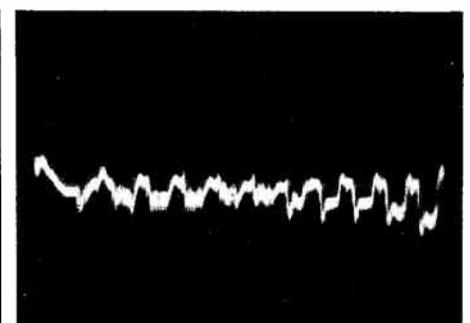
Fig. 32. Waveforms on the grids of a tricolor tube.

plitude and shape of the observed waveforms with the examples given in the service literature for the particular receiver you are working on. Also, the shape of the waveform will tell you if the hue setting is correct.

LOSS OF COLOR BALANCE

The color receiver produces a balanced black-and-white picture when the proper amounts of each color add together to produce white light. This condition is attained by making the color temperature adjustment and black-and-white tracking adjustments. While the adjustments for different receivers differ, the results are the same. A circuit defect that upsets this balance produces a black-and-white picture with a colored cast. The situation is similar to a picture with a missing color but the effect is not nearly so pronounced. The black-and-white picture may simply have a warm rosy tint or it may appear a cool blue-green. When normal adjustments do not correct the condition, look for a defect in the picture tube circuit or in the color difference amplifier stages. Any defect that changes the dc operating level of the color difference amplifiers can produce this condition. For example, grid to cathode leakage in the G - Y color difference amplifier

tube will cause its plate voltage to run low. Since dc coupling is used, the low dc voltage will be felt on the green grid of the picture tube. The result will be a picture with insufficient green and an overall purple cast. This kind of trouble can be located by taking voltage measurements in the circuit if tube substitution and adjustment does not correct the condition.

WEAK COLOR SIGNAL

You should always be able to turn up the color control and produce saturated colors with any color TV transmission that produces a usable picture. When the receiver is properly tuned, the color section normally has enough reserve gain to oversaturate the colors. If the colors show up only as pale tints, the color signal is not getting enough amplification. This condition is similar to a no-color condition except that the signal has low amplitude instead of being completely missing. Since some color signal is getting through, you know that the killer circuit is all right. The defect must be in the signal path before the demodulators because all colors are affected the same. Try tube substitution in the color i-f amplifier. The best method of locating the weak stage or defective component is by signal tracing in the chrominance section.

The amplitude of the 3.58-mc reinsertion signal to the demodulators can affect the saturation of the displayed colors. A defect that appreciably lowers the 3.58-mc oscillator signal will usually also affect the phase of the signal and the hue of the displayed colors. Likewise, the effect of reduced reference signal amplitude varies for different types of demodulators. Waveform 22 in Fig. 17 shows the correct amplitude for the reference signal to the X demodulator in that circuit. Since this is a rather high frequency signal, you must take into consideration the frequency response of your scope when measuring it.

IMPROPER HUES

Large phase errors in the 3.58-mc reference signal to the demodulator produces constant errors in the demodulated colors. The receiver produces good saturated colors that are of the wrong hue. Correct hues cannot be obtained by adjusting the hue control.
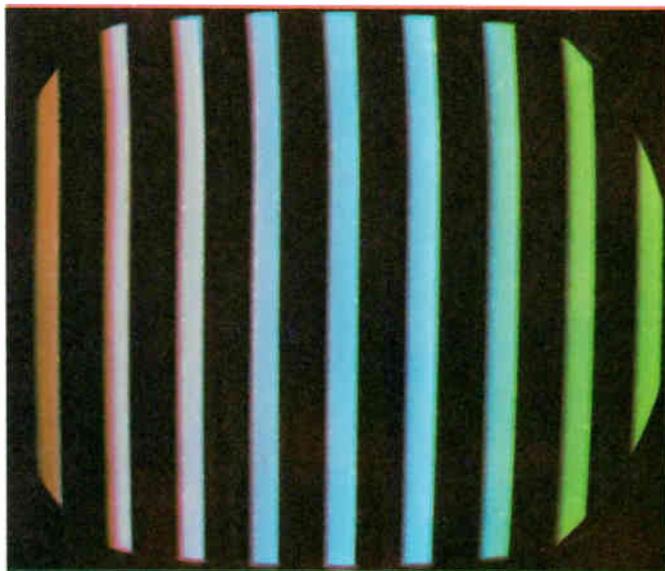
Fig. 33. Color bar pattern showing large phase error.

This condition may appear similar to that produced by missing colors but careful examination will show that all colors are present. The condition can be recognized by viewing a color bar pattern. Observing the pattern will also enable you to tell if the defect is an inoperative demodulator. This condition was discussed previously. As you recall, an inoperative demodulator results in incorrect amounts of some of the colors whereas large phase errors produce the correct amounts of each color. On the bar pattern the correct color bars are simply shifted to the wrong position in the pattern. Fig. 33 shows a bar pattern having a large phase error. Notice that bar 3 which should be red is reddish-blue. Also bars 8, 9, and 10 are green. This condition definitely places the defect in the chrominance section of the receiver.

A defect producing large phase errors can be located by performing the alignment procedure (afpc

adjustments) in the color sync section of the receiver. Before attempting the adjustment, check the related tubes by substitution. As you perform each adjustment, look for an abnormal response to the adjustment. A defect in the circuit, such as an open capacitor, will affect the adjustment. When you find an adjustment that cannot be made properly or has insufficient adjustment range, check the components in the associated circuitry.

For example, in Fig. 17, suppose the 330-pf coupling capacitor, C714, to pin 1 of the phase detector, decreases in value. The receiver produces color but the hues are off. Rotation of the hue control does not quite produce the correct colors. You perform the phase adjustment with the hue control centered and you are able to get the correct hues. However, now, when you rotate the hue control in one direction, the set drops out of color sync. (To see the out of sync color you must disable the color killer.) Voltage measurements and component tests are necessary to locate the defective component. Incidentally, the same condition can develop if resistor R17A or R17B change in value.

LOSS OF COLOR SYNC

When the 3.58-mc oscillator is not locked in frequency and phase with the color burst, the colors in the picture break up into bands of color. A small frequency error produces a few broad bands of color while a large frequency error produces many small bands of color. Also the color bands may hold still, move slowly, or move rapidly. Fig. 34 shows a color bar pattern with the color out of sync. The pattern holds still because the off frequency oscillator is held there by the sync circuit. When the oscillator is free-running, the color bars move up or down as the oscillator drifts. In any case, defects causing the loss of color sync are confined to the color section of the receiver.
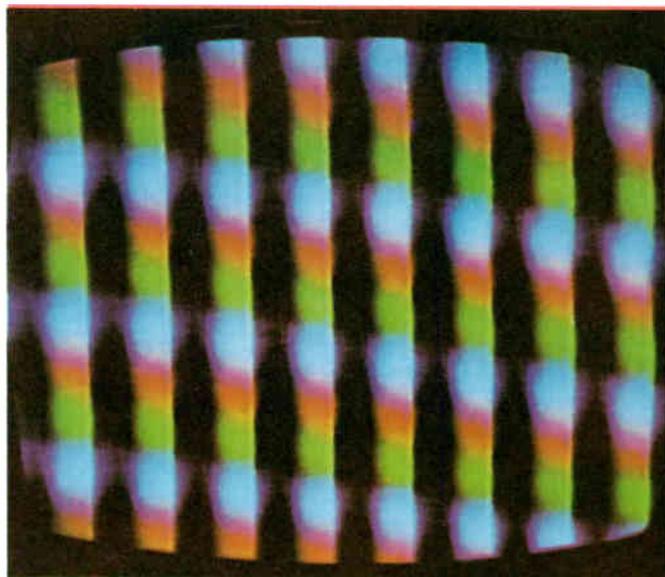
Fig. 34. Color bar pattern showing loss of color sync.

The stages that affect color sync are the 3.58-mc oscillator, the reactance control stage, the phase detector and the burst amplifier. The stages vary somewhat depending on the exact circuitry of a particular receiver. You can isolate the trouble by grounding the grid circuit of the reactance control stage. In Fig. 17, the grid circuit is brought out to test point TP703. Ground this point and adjust L702 in the plate circuit of the reactance control stage. You should be able to find an adjustment point that momentarily produces a correctly colored bar pattern. This indicates that the oscillator is capable of producing the correct frequency and the defect must lie in the phase detector or burst amplifier section. Signal tracing in the sync circuit section can be used to determine if the color burst signal and 3.58-mc oscillator are being applied to the phase detector stage.

MISREGISTERED COLORS

When the color information does not fit into the correct places in the picture, it is said to be out of register. Fig. 35 shows an example of misregistered color information produced by shorting the delay line.
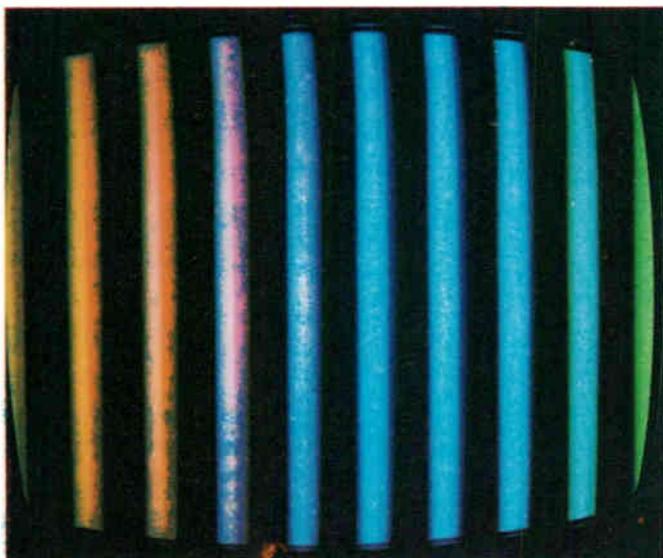
Fig. 35. Misregistered color information produced by shorting the delay line.

In this case, the shorted delay line is producing reflections that show up as multiple images of the brightness signal. Defects in the delay line or delay line circuit usually produce reflections in addition to the shift of the color information in relation to the brightness information.

Misregistered colors can also be caused by a misaligned bandpass amplifier circuit. The misalignment changes the bandwidth and therefore the time delay in the chrominance channel. The circuit must be badly misaligned to produce a noticeable misregister of color. Also the condition will produce other more noticeable symptoms. The picture will show poor color resolution with small areas not reproduced in color.

Also the picture will tend to have incorrect colors along the vertical edges of objects in the picture.

Do not assume that the set is improperly aligned from a casual observation of the color picture. The color definition will vary widely with program material. Live programs usually produce better definition than taped or filmed programs. But in some cases it will be the other way around. You must practice observing different color programs on various receivers before you can judge if poor definition and color distortion can be improved by alignment.

SELF-TEST QUESTIONS

(bg) What is indicated if a color receiver can be made to produce colored snow on an inactive channel?

(bh) What color is missing when a picture produces an overall yellowish appearance?

(bi) What piece of test equipment is most useful for troubleshooting in the color section of a receiver?

(bj) What symptoms appear in the displayed picture when a defect upsets the dc operating voltages of the picture tube circuits?

(bk) Will a defect that causes a large phase error produce saturated hues?

(bl) What is indicated when the reproduced color breaks up into bands of color?

(bm) Under what conditions will loss of color sync appear as a no-color condition?

(bn) What are two conditions (defects) that can produce misregistered color on a receiver?

ANSWERS TO
SELF-TEST QUESTIONS

(a) Soldering, use of hand tools, operation of test equipment.

(b) Your knowledge and understanding of the TV system.

(c) Many of the basic servicing skills are the same for radio and for TV servicing.

(d) Because the presence or absence of particular signals in the displayed picture indicate whether or not certain circuits in the receiver are operating correctly.

(e) It assures a logical approach to locating the trouble. It eliminates much guess work, prevents spending too much time locating simple defects, prevents overlooking possible causes of trouble, and assures finding the trouble in a minimum of time.

(f) The customer's description of the complaint may not fit the defect. Other defects may be causing the complaint that the customer describes.

(g) Block diagram.

(h) The observed signals are the exact size and shape normally present in the circuit.

(i) You can vary the signal amplitude and force a

large signal through a partially defective circuit.

(j) When a circuit is known to be operating properly, that circuit has been eliminated as a possible cause of the defect.

(k) Early, since these are primarily isolation techniques.

(l) Tuner, video i-f amplifier, agc circuits, and video detector.

(m) Just following the horizontal sync pulse. This is sometimes called the back porch of the horizontal sync pulse.

(n) Sharp spikes obscuring the video.

(o) Signal from a color bar generator. Because it produces known quality signals throughout the signal path of the receiver. Also most service literature includes waveforms produced by the bar pattern.

(p) 0 to 4.5 mc response is needed to see all the information in its respective amplitude. However, a scope with a lower response will produce usable information.

(q) About 43 mc. Modulating the 43 mc signal with a 400-cycle signal will produce horizontal bars on the screen.

(r) Local oscillator stage. The rf signal from the signal generator performs the same function as the signal normally produced by the local oscillator.

(s) The circuit functions. While other information about the circuit is useful, you must at least know what functions the circuit normally performs.

(t) Generates a signal, amplifies a signal, or modifies a signal that passes through the circuit.

(u) Signal tracing.

(v) Voltage and resistance readings.

(w) Operate the set with high or low line voltage. Use heat on components that show defects only at high temperatures.

(x) Voltage and resistance readings.

(y) Short circuit in the power supply; probably in the power transformer.

(z) Lowest reading on the ohmmeter. The point in the circuit with the lowest reading is closest to the short circuit defect.

(aa) Loose laminations in the core.

(ab) A burned resistor that was overloaded by the shorted tube.

(ac) Oscillations.

(ad) Install replacement parts in the exact location as the old part to prevent upsetting alignment or causing oscillation.

(ae) Poor high frequency response which may be caused by excess shunt capacity or by defective peaking coils.

(af) A defect that causes a phase shift or poor low frequency response such as a defective coupling capacitor.

(ag) An open shunt resistor across a peaking coil.

(ah) Turn up the volume control, touch the slider of the volume control pot and listen for a loud hum.

(ai) Defective speaker, misaligned sound detector or sound i-f.

(aj) Because correct video input signals to the circuit are dependent upon a correct agc voltage. If the agc voltage is wrong, it is nearly impossible to evaluate the signals into the circuit.

(ak) Inject a 60-cycle signal, such as filament voltage, to the grid of the output tube. This will produce some vertical deflection if the output circuit is good.

(al) Misadjust vertical hold to move the sync pulse to the ramp portion of the waveform.

(am) Grid of the horizontal output stage.

(an) Yes, you should be able to adjust hold to get a picture that holds steady momentarily. This indicates that the oscillator is capable of running at the correct frequency.

(ao) The capacitors often have small temperature coefficient tolerances.

(ap) The circuit contains very high voltages.

(aq) The color killer circuit is the best bet when a receiver does not produce color under any conditions. Also the defect could be in the bandpass amplifier.

(ar) On many color receivers, the color killer keeps the bandpass amplifier cut off unless the 3.58-mc oscillator is synchronized with the incoming burst signal. Therefore color will not be displayed unless it is in sync.

(as) Rough handling that has caused physical damage to the control board, convergence yoke, or interconnecting wires.

(at) The defective tube can upset the dc voltages to the grid of one gun of the picture tube by a greater amount than the drive controls can offset.

(au) Vertical hold control.

(av) Low voltage power supply, vertical and horizontal sweep, and high voltage power supply.

(aw) Signal path sections of the receiver.

(ax) If the characteristic "hammer head" is visible the sync pulses are being processed through the video amplifier. Therefore, sync trouble must be confined to the sync circuits or the sweep circuits.

(ay) Sync clipper stage or video i-f amplifier. This indicates that video is getting into the sync signals. It may be caused by poor separation of the sync and video in the sync clipper or by compression of the sync signals in the video i-f circuits.

(az) Tuner. The snow is produced by high amplification of noise from the tuner stage.

(ba) Video amplifier and i-f.

(bb) Yes, because the video i-f amplifier runs wide open amplifying noise present in the tuner.

(bc) Improperly terminated delay line.

(bd) Low voltage power supply.

(be) Sweep-forming circuit at the grid of the horizontal output tube.

(bf) Vertical sync will usually be affected first.

(bg) It shows that the color circuits are capable of producing color but it tells nothing about the quality of the reproduced color.

(bh) Blue.

(bi) Color bar/dot/pattern generator.

(bj) Loss of color balance that cannot be corrected by adjustment.

(bk) Yes, the reproduced colors may be of the wrong hue but all colors can be produced and they can be fully saturated.

(bl) Loss of color sync.

(bm) When the color is very far out of sync, the rapid sequence of colors produces a white blur that appears as if no color is present.

(bn) Defective delay line, misaligned bandpass amplifier.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. What is the important advantage of using a scope to trace the signals through TV circuitry?

2. What is a convenient "first test point" for signal tracing with a scope in a receiver?

3. What percentage of the total amplitude of the detected video waveform should the sync pulses occupy?

4. What might you use an oscilloscope for when checking a low voltage power supply?

5. What are several things you should check before removing the shield of a tuner for troubleshooting?

6. What is a useful technique for troubleshooting the i-f section when signal tracing, voltage tests, and resistance tests produce inconclusive results?

7. What defect in the agc circuits can cause the picture to flicker as if responding to a received signal of widely varying strength?

8. Besides amplitude and shape, what other factor is important when evaluating the horizontal drive signal to the horizontal output stage?

9. What special care in soldering should be taken when making connections in the high voltage section of a receiver?

10. Can you be fairly certain that a color picture tube is good if it produces a satisfactory black-and-white picture?

B518
TV RECEIVER ALIGNMENT

●

STUDY SCHEDULE

> For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with a quick reading to fix the important facts firmly in your mind. Study each other step in this same way. Be sure to test yourself by answering the Self-Test Questions at the end of each major section. You'll find the answers at the end of the lesson.

☐ **1. Introduction. . . . . Pages 1-3**
  This is a general discussion of alignment and how to recognize the need for alignment.

☐ **2. Video I-F Alignment. . . . . Pages 4-12**
  In this section you study both peak and sweep alignment techniques. You learn how to set up your equipment for alignment and how to set the various traps in the i-f amplifier.

☐ **3. RF Alignment. . . . . Pages 13-16**
  You study alignment of both vhf and uhf tuners. You learn how to set up the local oscillator, check rf response and how to neutralize the rf amplifier.

☐ **4. Sound Section Alignment. . . . . Pages 17-20**
  You learn how to align the sound section of the receiver in the field, and also an alignment procedure to use in the shop.

☐ **5. Color Section Alignment. . . . . Pages 21-27**
  You learn how to align the color i-f stages and also the color oscillator and oscillator control stages.

☐ **6. Alignment As a Servicing Tool. . . . . Pages 28-32**
  In this section you learn that alignment can be a useful tool in locating defective stages.

☐ **7. Answer the Lesson Questions.**

☐ **8. Submit Your Final Exam for Grading.**

TV RECEIVER ALIGNMENT
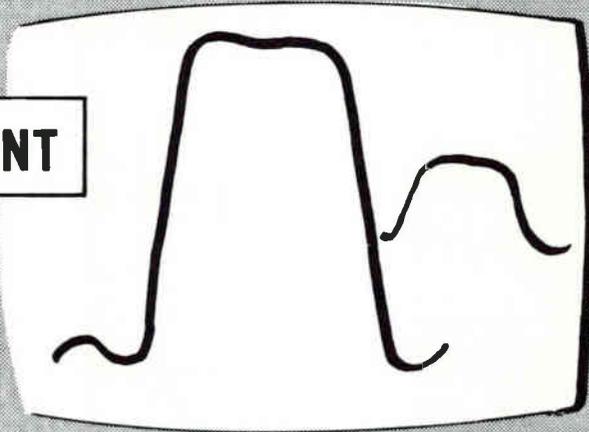
The process of adjusting the frequency response of various tuned circuits in a TV receiver is known as alignment. Ordinarily when we speak of receiver alignment, we refer only to those circuits in the signal path of the receiver. Adjusting the frequency of the sweep oscillators is basically an alignment process, but in a TV receiver it is handled as a setup adjustment. Some other alignment procedures are often handled as setup adjustments. These include adjusting the local oscillator in the tuner; adjusting the sound detector; and adjusting the afpc circuit in the color section of a color receiver. Two different procedures will often be provided for this type of alignment. A "field adjustment procedure" enables the technician to align the circuit in the home using a minimum of test equipment. Then a "shop alignment procedure" is provided. This procedure requires a full compliment of test equipment and produces more accurate results.

Alignment of the signal path circuits of a TV receiver must be performed with suitable test equipment. Thus, there is no "field adjustment procedure" for touching up the video i-f alignment. It is impractical to judge the correct setting of an i-f transformer slug by observing the picture. You must be careful not to touch these adjustments unless you are set up to perform the circuit alignment.

This lesson covers the shop alignment procedures for aligning a TV receiver. The lesson is divided into sections corresponding to the signal handling circuits of the receiver. One section covers alignment of the rf section of the receiver. This of course is limited to the tuner where the circuits are aligned to accept the frequency of the transmitted TV signal. One section covers alignment of the video i-f circuits of the TV receiver. Another section covers the shop alignment procedure for the sound circuits of the receiver. One section is devoted to the alignment of the color signal handling circuits, in the chrominance section of the receiver. Finally, one section shows you how to use alignment procedures as a servicing tool for

locating defects in the circuitry.

Receiver alignment is often considered a difficult part of TV servicing. One reason for this is lack of experience. Receivers seldom need alignment so the average technician doesn't get much practice at it. Then when he needs to align a receiver, he doesn't know how to go about it.

Circuitry usually does not get out of alignment unless the adjustments have been moved. This can happen if you fail to identify an adjustment before you move it. Or, a customer or inexperienced technician will try to correct a defect by turning every adjustment he can find. In these cases, the only remedy is to go through a complete alignment procedure.

Knowing when to perform alignment on a receiver is very important. A defective receiver may appear to need alignment. However, after you locate and repair the defect, you will probably find that the picture is perfect and alignment is not necessary. On the other hand, you should not avoid alignment just because it is an unlikely cause of the trouble. Many circuit defects that cannot be located by usual procedures will become readily apparent when you attempt to align the circuit. Also, setting up and checking the circuit alignment gives you needed practice. The time is not wasted even if the circuit did not need alignment.

Successful alignment requires a thorough knowledge of receiver circuits, the signals you are working with, and your test equipment. The signals you work with are usually quite high frequencies so you must take special care with lead lengths and ground connections. You must know how the circuit should respond to the signals you apply to them. Likewise, you must be familiar with the operation and limitations of your test equipment. An inexperienced technician can easily spend an hour or so before he gets a response curve of any kind on the scope. Don't let this discourage you. For example, when you setup to align the i-f section of a receiver, you may have four or five pieces of equipment connected to the receiver.
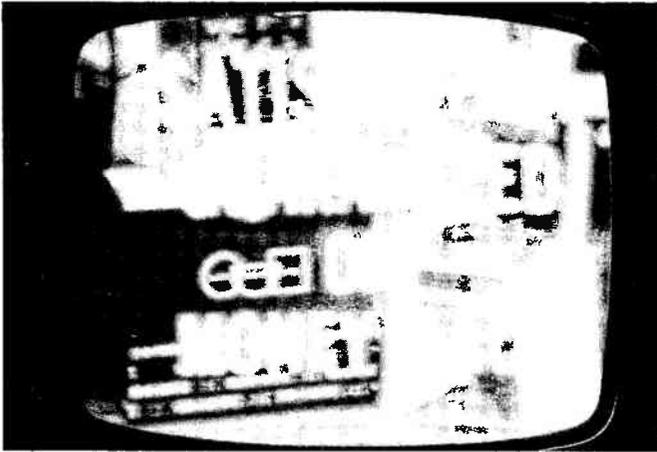
Fig. 1. A normal picture on a typical TV receiver.

Every item must be setup correctly before you get an indication. You may have to go over the setup several times before things are right. With experience you will be able to set it up in the 10 minutes required for the generator to warm up.

The alignment discussions in this lesson are designed to familiarize you with general alignment procedures and alignment problems. When you align a particular receiver, always consult the service literature on that receiver. It will specify the alignment conditions and response curves. Also, it will usually have drawings or photographs to help you locate the adjustment points. For example, it would be meaningless to attempt to align an i-f amplifier with zero agc bias if the response curves are shown for alignment with -3 volts bias.

Specialized test equipment is needed for aligning TV receivers. In addition to the ordinary shop equipment, such as a vtvm, a bias supply, test leads, and oscilloscope, you need a sweep generator and a marker generator. These two items are necessary to accurately evaluate the response of the wide bandpass amplifiers in the TV receiver. To see the relative response of the circuits to the different frequencies within the band of frequencies amplified, you observe a response curve. The response curve is produced by sweeping the circuit with a varying frequency and observing the detected output. The sweep generator must become capable of sweeping a band of frequencies broader than the passband of the circuit.

The marker generator is required to accurately identify various points on the response curve. For accuracy, the marker generator should be crystal calibrated. In addition to the sweep and marker generators you often need special coupling devices and alignment tools. You can make the couplers and other alignment aids. These will speed and simplify your alignment work.

Need For Alignment.

It is difficult to look at the received picture on a TV receiver and tell for sure whether or not it needs alignment. There are many defects that can cause exactly the same effect in the picture as improper alignment. In an area close to the station where the TV signal is strong, weak reception seldom indicates

improper alignment. A TV receiver normally has a wide bandwidth and one or more of the tuned circuits would have to drift considerably before you would have weak reception. However, in a fringe area, where each circuit must be operating at its peak efficiency in order to give satisfactory results, a small amount of drifting in one or two circuits may be sufficient to cause weak reception.

It is more common to find that the first indication of a need for alignment is poor low or poor high frequency response. However, both of these defects may also be due to a defect in the video amplifier; therefore, before starting to align the receiver, you should first determine definitely that the set needs alignment.

The effect of poor low or high frequency response can best be seen by observing a test pattern. Unfortunately TV stations seldom transmit test patterns except during the middle of the night when they may be adjusting the transmitter. Therefore you will have to evaluate the performance of the receiver on a program transmission. Poor high frequency response is indicated by a lack of detail in the picture. By carefully examining the picture to determine whether or not the fine detail is present, you can learn a great deal about the high frequency response of the receiver. When performing this type of test, check the picture on another receiver to be sure that the quality of the program is good. Perform the test on a live program originated by your local station rather than a network program. Sometimes network programs are lacking in fine detail because the bandwidth of the cable used to transmit the program may be restricted. Avoid using programs on which old motion pictures are being shown when you are evaluating the high frequency response of the receiver. Often a lack of background detail in a program transmission of this type is due to the poor quality of the film.

In a color receiver, misalignment that causes loss of high frequency response can also produce a weak color signal. If the response curve falls off in the area occupied by the color subcarrier signal, the color signal receives insufficient amplification. However, before deciding that a weak color signal is due to misalignment be sure there are no defects in the color
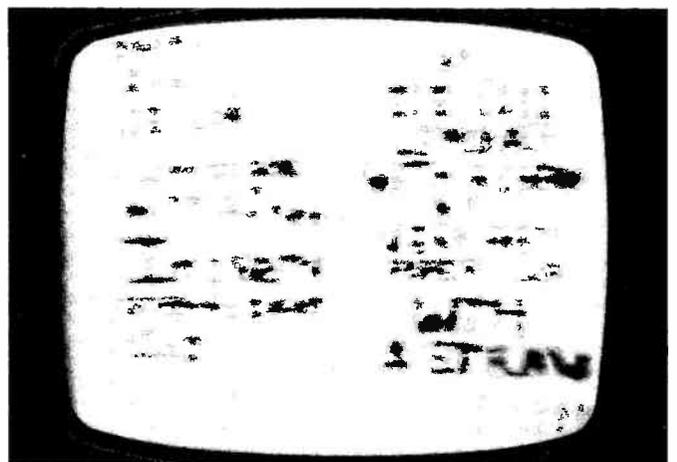
Fig. 2. The fine picture detail is missing due to poor high-frequency response.
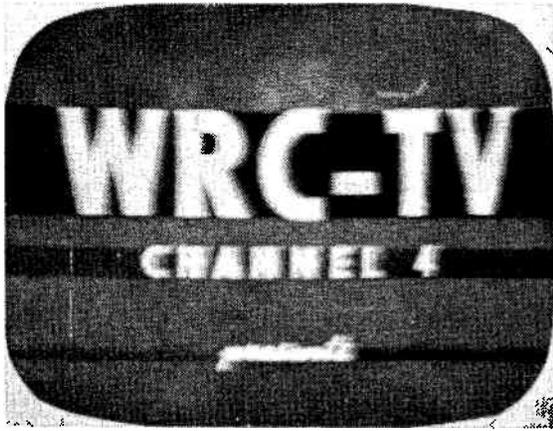
Courtesy RCA

Fig. 3. Poor low-frequency response.

signal circuits of the receiver. Defects in these circuits cause weak color far more often than misalignment.

Before attempting to evaluate the response of the receiver, make sure that the focus is adjusted for maximum sharpness and the contrast and brightness controls are set for the best possible picture.

Fig. 1 is a normal picture on a typical TV receiver. Fig. 2 illustrates poor high frequency response. Notice the detail is lacking in the picture. The fine picture detail is carried in the higher modulating frequencies and if these frequencies are lost, the picture will lack detail.

Fig. 3 illustrates poor low-frequency response. Study the picture carefully. Notice that the picture is smeared. The dark background runs into the left side of the large white letters. Also the right sides of the letters smear into the background. Because of the loss of detail that occurs in the printing process, the smearing is not as apparent in Fig. 3 as it may be when this defect occurs and is actually observed.

Another common indication of misalignment is the appearance of sound bars across the picture as shown in Fig. 4. Frequently this can be corrected simply by adjusting the fine tuning. However, if adjusting the fine tuning does not eliminate the sound bars, it may indicate that the sound traps are not properly aligned, that they are aligned to the wrong frequencies, or that the oscillator needs alignment.

All these defects can be caused by defects other than misalignment. Poor low frequency response or poor high frequency response may indicate a defect in the video amplifier. Sound bars in the picture might indicate coupling between the audio and video circuits

due to a power supply defect. Therefore you should not attempt to align a TV receiver to eliminate one of these defects until you have checked the other possible causes of trouble. After you have decided that alignment is necessary, it is worth while to look at the receiver response curve with a sweep signal generator and an oscilloscope before starting alignment. This will serve as an additional check so you can find out definitely whether or not the receiver needs alignment and also get a rough idea of how badly out of alignment the receiver may be.

Need for alignment of a color receiver is indicated by distorted color or by poor color definition. When the receiver displays color only in large areas, the passband of the color i-f amplifier may be too narrow so the fine detail color information is lost. The amount of fine color detail in a color telecast varies widely with program material. Evaluate several programs, live if possible, before deciding if the poor fine detail is due to misalignment.

Any alignment condition that results in unequal amplification of the color subcarrier sideband can cause distorted color. An example is mistuning the fine tuner. This produces the wrong colors along the edges of the bars in a color bar pattern. Misalignment of the color i-f can produce the same condition. The sidebands of the color subcarrier do not receive equal amplification. Also, the condition can shift the phase of some of the color signals and thereby change their hue. Special alignment techniques are used to evaluate the overall response of the i-f and color circuitry to the color signals. Again, this misaligned condition seldom develops in a receiver.

Fig. 4. Sound bars.

Video I-F Alignment

The video i-f amplifier in a TV receiver provides most of the selectivity and gain for the TV signal. The passband of the video amplifier is designed to give the desired relative amplification to the various signals within the band of frequencies occupied by the TV signal. At the same time, the selective nature of the amplifier discriminates against those signals that are not within the desired passband. Thus, signals lower in frequency than the 41.25-mc sound carrier and signals higher in frequency than 47.25 mc receive little or no amplification. The 6-mc band of frequencies between these extremes is selectively amplified. That is, some frequencies of the band of frequencies receive more amplification than others. The required relative amplification for different parts of the TV signal is due in part to the manner in which the sound and picture information are applied to the transmitted signal. Also, selective amplification in the i-f will vary from one receiver to another. The way the video i-f amplifier responds to the band of i-f frequencies contained in the TV signal is known as the i-f response of the receiver. This response is shown by a curve in which signal gain is plotted against frequency. The process of adjusting the tuned circuits in the amplifier to obtain the desired response is known as i-f alignment.

The response of the video i-f amplifier combines with the response of the tuner to produce the overall receiver response to the received TV signal. Therefore the i-f amplifier response will be different for different receivers. You must always refer to the servicing literature for a particular receiver before aligning that receiver.

Fig. 5 shows an idealized response curve for the frequencies passed by the video i-f amplifier. A few frequency points are identified on the curve. The i-f sound carrier frequency, 41.25 mc, is placed in a dip on the curve indicating that it gets very little amplification. As you know, the 41.25-mc sound carrier beats with the picture carrier (45.75 mc) in the picture detector (separate sound detector in color receivers) to produce the 4.5-mc sound i-f frequency. The 41.25-mc sound i-f carrier is kept at a low amplitude so that it will not produce interference in the picture.

The curve shows the i-f color subcarrier frequency of 42.17 mc at the 50% point on the curve. The sidebands of this frequency carry the color information. At this position on the curve, the upper and lower sidebands of 42.17 mc will not receive equal amplification. Therefore, if this is an i-f response for a color receiver, the passband of the color i-f amplifier will have to be shaped to compensate for the unequal sideband amplification. The top of the curve flattens off at the frequencies around 44 mc. The i-f picture carrier, 45.75 mc is located at the 50% point on the curve. This position is selected to compensate for the vestigial sideband transmission used in TV. As you recall, the lower sidebands of the picture car-

rier is attenuated to keep the transmission within the 6-mc band of frequencies allotted to a TV channel. Some of the lower frequencies close to the picture carrier are transmitted by both upper and lower sidebands. High video frequencies are transmitted by single sideband transmission only. If all these frequencies receive equal amplification at the receiver, the detected low frequency signals (double sideband transmission) would produce much greater amplitude signals than the single sideband high frequency signals. By placing the picture carrier at the 50% point on the curve, the recovered video signals are reproduced with their correct relative amplitudes.

The dip in the curve at 47.25 mc is designed to attenuate the sound carrier from an adjacent TV channel. For example, the local oscillator of the TV receiver operates at 107 mc when receiving channel 3. The front end is broad enough to accept some of the rf signal from a channel 2 transmission. When the 107-mc frequency heterodynes with the 59.75-mc rf sound carrier of channel 2, the mixer produces a 47.25 mc intermediate frequency. The trap at 47.25 mc in the i-f amplifier prevents the channel 2 sound carrier from interferring with the reception of channel 3.

The response curve in Fig. 5 illustrates one possible i-f response curve. The response curves for particular receivers usually have six or more frequency points identified on the curve. The position of the identified frequencies are considered critical by the designer of that set. Again, this is another reason for using the service literature for the particular receiver you are aligning.
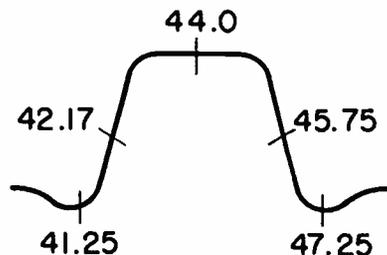
Fig. 5. Idealized response curve of an i-f amplifier.

The response curve in an i-f amplifier is produced by the combined effect of the tuned circuits in the amplifier. Certain coils are adjustable so the response can be changed. This is necessary to compensate for circuit variations that occur from set to set of the same type. The circuit variations are caused by normal parts tolerances and by variation in distributed capacitance caused by positioning of parts. After the set is manufactured and aligned, there is very little reason for the circuit response to change. Such factors as aging of parts and lowered gain of some stages will affect the response curve only slightly. Even replacing a tube in the i-f strip usually has very little affect on

the quality of the reproduced picture. However, you may see some change in the response curve.

Fig. 6 shows how the response of several tuned circuits combine to produce the overall flat topped response curve. Each response curve is identified by a line through the peak of that curve and the letter LA, LB, LC, LD, or LE. The amplification represented by each curve adds to that of the other curves at various frequencies to produce the dotted overall response curve. Also points on the dotted curve identifies the effects of three traps. To get the overall response curve, it should only be necessary to tune each circuit to the indicated frequency. For example, the circuit producing curve LA should be peaked at that point.
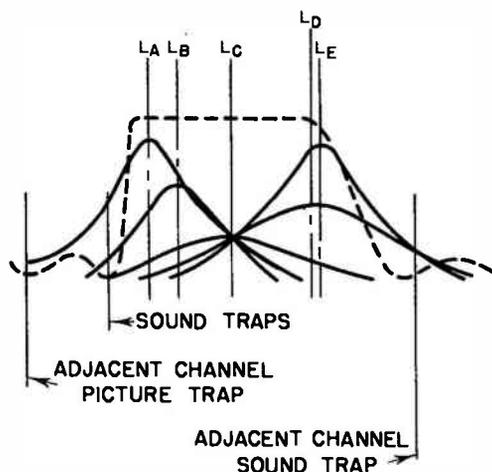
Fig. 6. Individual and overall response of a stagger-tuned i-f section.

Peak Alignment.

One method of aligning the i-f amplifier is to peak each of the tuned circuits to a specified frequency. An rf signal at the specified frequency is applied to the input of the amplifier. A dc voltmeter is connected to the video detector. The coil is adjusted to produce maximum voltmeter indication. Each tuned circuit is adjusted in this manner. When the traps are adjusted, the coil is adjusted for minimum reading on the voltmeter. In this way, each circuit is adjusted to its correct frequency. In theory, this procedure should produce the correct overall response curve. In practice, it will not. Normal parts tolerances and other circuit variations produce individual curves with various amplitudes. For example, in Fig. 6, if the circuit producing curve LA has a higher than normal Q, the curve will have a higher than normal amplitude. This would cause the dotted resultant curve to be tilted up on the left side. This distortion would not be indicated using the peak alignment method.

Peak alignment is an accepted procedure for setting traps and for preliminary adjustments. Traps can be accurately set using peak alignment methods because they are correctly set when they are peaked (tuned to produce maximum attenuation) at a specified frequency. When a receiver is badly misaligned, peak alignment is a convenient method of bringing the set

into approximate alignment. Then, the response curve is viewed on an oscilloscope using sweep alignment techniques and the coils are readjusted for best possible alignment.

Sweep Alignment.

This is an alignment technique that enables you to see the response of an amplifier to the band of frequencies that it is designed to amplify. The signal fed into the amplifier is "swept" across the i-f band of frequencies. That is, the input signal is varied in frequency over the entire band of frequencies that the amplifier is designed to pass. An oscilloscope is connected to the output of the video detector. The horizontal sweep rate of the oscilloscope is synchronized with the sweep rate of the signal generator that is feeding the signal to the amplifier. The vertical deflection of the oscilloscope beam corresponds to the amplification experienced by the signals fed to the amplifier.

Fig. 7 shows a block diagram illustrating the principle of sweep alignment. The sweep generator generates an rf signal that varies at a 60-cycle rate between 38 and 48 mc. This signal is fed into the input circuit of the video i-f amplifier. The vertical deflection plates of the oscilloscope are connected to the output of the video detector. Therefore, the oscilloscope beam will be deflected vertically by the detected signal. The horizontal plates of the oscilloscope are connected to the sweep rate signal, usually 60 cps at the sweep generator. This sweep rate signal is the same signal that varies the output frequency of the sweep generator. In this way the scope trace is synchronized with the sweep generator.

In operation, the scope trace moves from the low frequency (38 mc) at the left of the trace to the highest frequency (48 mc) at the right of the trace. The frequency response of the amplifier changes for different frequencies within the band. Thus, where the generator is putting out a 41.25-mc signal, the traps in the circuit attenuate this frequency and the video detector produces a low output. The scope trace shows the 41.25 mc response as a pronounced dip in the trace. As the frequency increases toward 44 mc, the circuits in the amplifier respond by producing maximum amplification. The amplified 44-mc signal is rectified by the video detector producing maximum output that is indicated by the high flat portion of the oscilloscope trace. In this way the scope trace plots the response
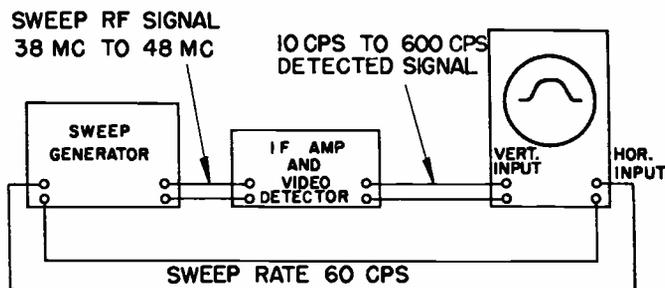
Fig. 7. The oscilloscope displays the amplifier response curve when a Sweep Generator signal is applied to the amplifier.

of the amplifier to all the frequencies within the swept band frequencies. Some scopes display the response curve with a high frequency on the left and a low frequency on the right. Also the response curves in the service literature may be drawn either way. This causes no difficulty because you will be using markers on the display to identify the various frequency points.

A marker generator is used to identify the frequency at various points on the response curve. Accurate known-frequency signals can be used to place marker pips on the response curve. The marker generator may be combined with the sweep generator or it may be a separate instrument. For accuracy, its output frequency should be crystal calibrated. The marker signals can be injected into the signal with the sweep rf signal or at a later point in the signal path. The marker signal produces a "pip" or marker by a heterodyning process. When the sweep generator signal approaches the frequency of the marker generator, the difference signal becomes a very low frequency signal. At the zero beat frequency, the scope displays a pronounced dip at the exact frequency of the marker generator on the scope trace.

The frequency response of the vertical amplifier is kept low to produce a smooth noise-free trace. The displayed scope trace represents frequencies from about 10 cycles to about 600 cycles so you do not need a scope with a broad frequency response. To lower the response, a .001 to .01-mfd capacitor is often placed across the vertical input terminals of the scope. This added capacitance attenuates any high frequency signal and noise that may be present. It removes the fuzzy wiggles near the marker pips so that the marker position is more clearly defined.

EQUIPMENT SETUP

A large part of any alignment job consists of getting your equipment properly set up and adjusted. This includes both the physical arrangement of the test equipment and its electrical operation. Fig. 8 shows a photo of a TV chassis set up for i-f alignment. As you can see, numerous cables and test leads are used to interconnect the equipment. You should plan your
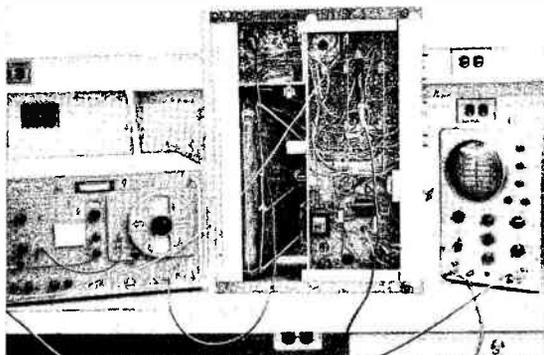
Fig. 8. TV receiver set up for i-f alignment.

setup so interconnecting leads will be out of your way. Position the chassis so that you can reach all the adjustment points when you perform the alignment. Also the signal generator and the oscilloscope must be located where you can conveniently operate the controls.

Fig. 9 shows the electrical connections for a typical i-f alignment setup. The exact electrical connections depend on the alignment equipment that you are using. Notice for example that marker generator output is applied directly to the vertical terminals of the oscilloscope. This arrangement is known as a "post injection" marker technique. The sweep generator signal is heterodyned with the marker frequency in the marker generator producing the marker "pip" that marks a particular frequency on the scope trace. The advantage of this technique is that the marker frequency is not passed through the tuned circuits of the amplifier being aligned. A large amplitude marker signal can easily overload a circuit in the amplifier and distort the shape of the response curve. With "post injection", this will not occur.
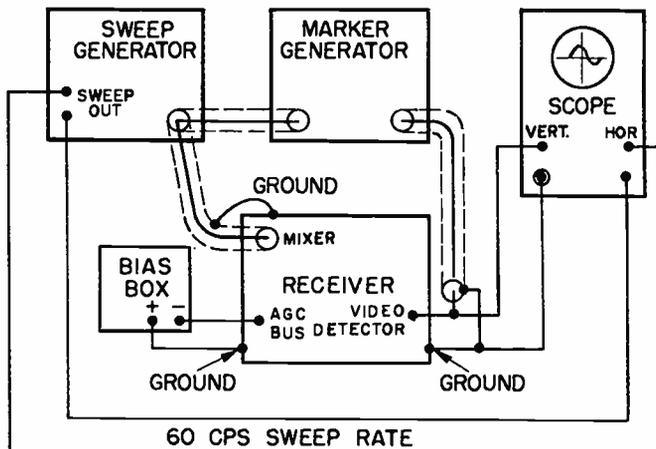
Fig. 9. Electrical interconnections for a typical alignment set-up.

When the marker signal is injected with the sweep signal, the marker input must be loosely coupled to the circuit. A suitable method is to position the "hot" lead of the marker generator near the output lead of the sweep generator. For example, you can clip the "hot" lead of the marker generator to the insulated wire near the clip on the output lead of the sweep generator. Enough rf energy from the marker generator will be radiated into the circuit to produce usable marker pips. Then adjust the size of the marker pips by varying the attenuator on the marker generator.

The rf output from the sweep generator is shown connected to the mixer in Fig. 9. The signal may be injected to the control grid of the tuner mixer stage or radiated into the tube. The i-f alignment instructions usually specify one of the above injection points. A test point on the tuner is often provided for connecting the generator output into the mixer grid. A small value capacitor should be used to isolate the generator lead from the test point because the circuit

may have B+ voltage on it.

A device for radiating the generated signal into the mixer stage is shown in Fig. 10. A snug fitting tube shield is "floated" over the mixer tube. A small value capacitor soldered to the shield couples the rf signal onto the shield. Enough capacity exists between the plate of the tube and the shield to couple the signal into the plate circuit. The shield must be held up on the tube so that the shield does not short to the chassis. Instead of a tube shield, you can form a band of shim brass that will just fit over the top of the tube. This is convenient when the mixer tube has a fixed shield that retracts only part way down on the tube.
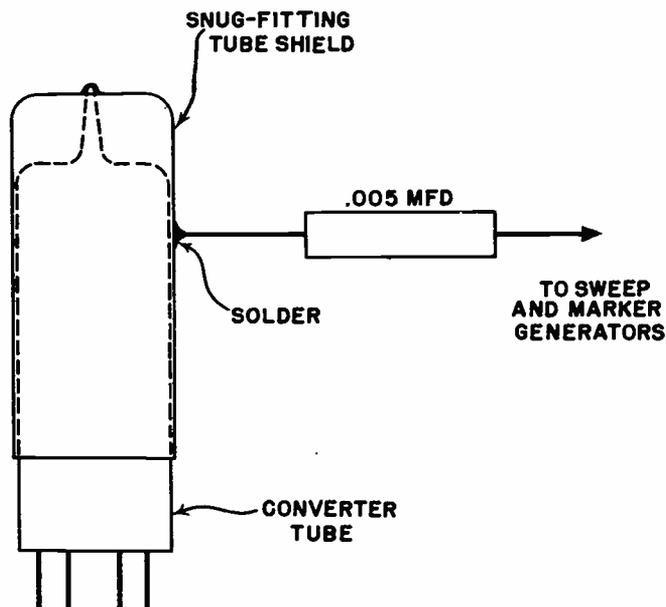
Fig. 10. Simple method of coupling a signal generator to a set.

These methods of injecting a signal into the mixer stage will not work in a transistorized tuner. In tuners using transistors there is a test point provided that will permit injection of the signal into the mixer input circuit.

A sweep output signal from the sweep generator is connected to the horizontal input terminals of the oscilloscope. This is usually a 60-cycle sine wave and it represents the waveform used to vary the frequency of the oscillator. Thus the waveform displayed on the scope is synchronized with the sweep generator output. Since the horizontal sweep is driven by a sine wave, it produces a trace sweeping right to left and left to right. Most sweep generators blank the rf output of the sweep generator on the return sweep so a response curve is produced with only one trace. The return trace then produces a straight line across the scope that can be used as a zero reference line for the displayed response curve.

Some sweep generators have a phase control that shifts the phase of the sweep signal. This enables you to center the response curve on the trace by varying the starting time of the sweep. With other sweep generating equipment, the sweep output is simply used to synchronize the horizontal sweep in the scope. The centering of the scope display is then accomplished by varying the sync control on the scope.

A bias box is shown connected to the agc line in Fig. 9. A variable bias supply enables you to clamp the agc line at the specified bias voltage. The positive lead from the bias box is connected to chassis ground while the negative lead is connected into the agc circuit. Select a point in the agc filter circuit that places a large resistor between the agc tube and applied bias voltage. This enables the bias box to overcome any agc voltage developed by the tube. It is a good practice to measure the bias at the grids of the i-f stages to make sure the applied bias voltage is actually getting to the grids.

The vertical input to the scope is connected to the output of the video detector in the receiver. A test point is often specified in the alignment instructions. The test point usually connects to a point in the detector filter circuit. It may connect to the control grid of the video amplifier. If the receiver uses capacitive coupling to the video amplifier, do not connect the scope to the output side of the coupling capacitor. It is possible for the capacitor to cause a phase shift that will distort the response curve. Since the detector circuit has low impedance, the scope connection usually does not affect the circuit. However, it is good practice to use an isolating resistor (about 47K-ohm) in the vertical input lead to the scope. Then connect a capacitor (.001 to .01 mfd) across the vertical terminals. This forms a low pass filter that gives a smooth trace free from noise.

Ground Connections.

Good ground connections between the receiver and the alignment equipment are a basic requirement for successful alignment. If you find that touching the chassis, the scope, or the signal generator or moving the interconnecting cables causes the waveshape on the oscilloscope to change shape, the ground connections are not good enough. Connecting additional ground leads between the equipment will usually overcome the difficulty. In severe cases use short heavy grounding wires to bond the chassis of the receiver and the test equipment together.

It is very dangerous to set up an ac-dc receiver for alignment without using an isolation transformer. You risk a severe shock hazard, you risk damaging the receiver or test equipment and it is difficult to secure adequate ground connections. A 1:1 isolation power transformer should be placed between the ac outlet and the receiver. Then you can interconnect your receiver and test equipment without danger.

Disabling Horizontal Sweep.

Many technicians prefer to perform alignment with the horizontal sweep disabled. The horizontal and high voltage section of the receiver generates high amplitude pulses that tend to radiate a sizeable amount of rf energy. This rf energy is often picked up by the signal path and puts spikes on the displayed response curve. The spikes make it difficult to see the marker pips. Also on some chassis, it may be difficult to reach some adjustments without getting your hands near high voltage points.

The horizontal section can be disabled by removing the horizontal output tube on receivers with parallel heaters. Or, the cathode circuit of the horizontal output stage can be opened. Another method is to apply a very high negative bias to the control grid of the output tube.

If you disable the horizontal section, you must take steps to keep B+ at its normal value. B+ may increase 50 volts or more on some receivers when the power drain for the horizontal section is removed. This large a change in B+ will affect the response curves. Measure the value of B+ with the set operating normally. The measured B+ value may vary considerably from that listed on the service literature. This may be caused by high or low line voltage or by normal parts tolerances. Since this is the B+ value that the set will operate with, B+ should be maintained close to that value during alignment.

B+ can be brought back to its normal value by using a resistive load to replace the drain of the horizontal section. The resistor should be connected between B+ and B- (usually the chassis). Receivers often have two B+ values such as +265 and +150. The horizontal section is supplied from the high B+ voltage so the

dummy load resistor is placed across it. The resistor must pass about the same current as the horizontal section. This may be as much as 200 ma so the resistor must have high wattage. A 2000-ohm, 100-watt resistor usually will provide enough load to reduce B+ to near its normal value.

TYPICAL I-F ALIGNMENT

The alignment instructions in service literature are usually shown in an abbreviated chart or tabular form. It lists a step-by-step sequence for performing the alignment. Fig. 11 is the reproduction of a set of typical alignment instructions. Figs. 12 and 13 show the circuitry referred to in the chart. Most service literature will also have drawings or photos to help you locate the test and adjustment points. The chart takes up very little room in the service literature but it contains all the essential instructions. It does not specify particular alignment equipment, only frequencies and alignment conditions. For example, in the top block it specifies that you use an isolation transformer because this is a transformerless receiver. If your ac line voltage is appreciably off from 117

ALIGNMENT INSTRUCTIONS

Use an isolation transformer and maintain voltage at 117 volts. Allow a 20-minute warm-up period for the receiver and test equipment.
Suggested Alignment Tools: A1 thru A13 .... GENERAL CEMENT #8606, 8869, 9302 ... WALSCO #2511, 2543, 2588
Mixer Plate Coil ... GENERAL CEMENT #9296, 9300, 9302 ... WALSCO #2510, 2511, 2547

VIDEO IF ALIGNMENT

Connect the synchronized sweep voltage from the sweep generator to the horizontal input of the oscilloscope for horizontal deflection.
Use only enough generator output to provide a usable indication. Note: Response may vary slightly from those shown.
Connect a variable bias supply to the IF AGC line (point Ⓐ) and adjust to obtain a response curve which shows no indication of overload.
Disable Oscillator section of Mixer-Osc. Set the Channel Selector to any non-interfering channel.

	INDICATOR	GENERATOR COUPLING	SWEEP GENERATOR FREQUENCY	MARKER GENERATOR FREQUENCY	ADJUST	REMARKS
1.	Connect DC probe of a VTVM thru a 47K resistor to point Ⓑ. Common to ground.	Connect high side to ungrounded tube shield over Mixer-Osc. Low side to ground.		39.75MC 41.25MC 47.25MC	A1 A2 A3	Adjust for MINIMUM.
2.	Connect DC probe of a VTVM thru a 47K resistor to point Ⓑ. Common to ground.	Connect high side to ungrounded tube shield over Mixer-Osc. Low side to ground.		45.3MC 42.7MC	A6 A7	Adjust for maximum.
3.	Connect vertical input of a scope to point Ⓑ. Low side to ground.	Connect high side to pin 1 (grid) of V3. Low side to ground.	44MC (10MC Sweep)		A4, A5	Adjust for maximum amplitude and MINIMUM tilt with markers as shown in Figure 1.
4.	Connect vertical input of a scope to point Ⓑ. Low side to ground.	Connect high side to ungrounded tube shield over Mixer-Osc. Low side to ground.	44MC (10MC Sweep)	39.75MC 41.25MC 42.6MC 44.25MC 45.75MC 47.25MC	A6, A7, A8, Mixer Plate Coil	Adjust for maximum gain and symmetry of response with markers as shown in Figure 2. In order to obtain a proper response, it may be necessary to slightly retouch A4 and A5.

4.5 MC TRAP ALIGNMENT

Tune in a strong TV signal and set the Contrast at maximum. Adjust the Fine Tuning until a beat pattern is visible on the screen.
Adjust A13 for MINIMUM beat interference.

SOUND IF ALIGNMENT

Tune in a station and adjust A9 for maximum sound. Reduce signal strength at the antenna terminals until distortion appears.
Continue to reduce signal while aligning for undistorted output by adjusting A10, A11, and A12.
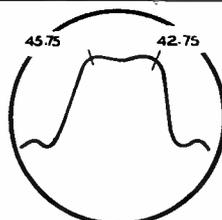
FIG. 1
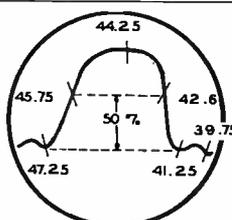
FIG. 2

Courtesy Howard W. Sams, Inc.

Fig. 11. Sample of the i-f alignment instructions from typical service literature.
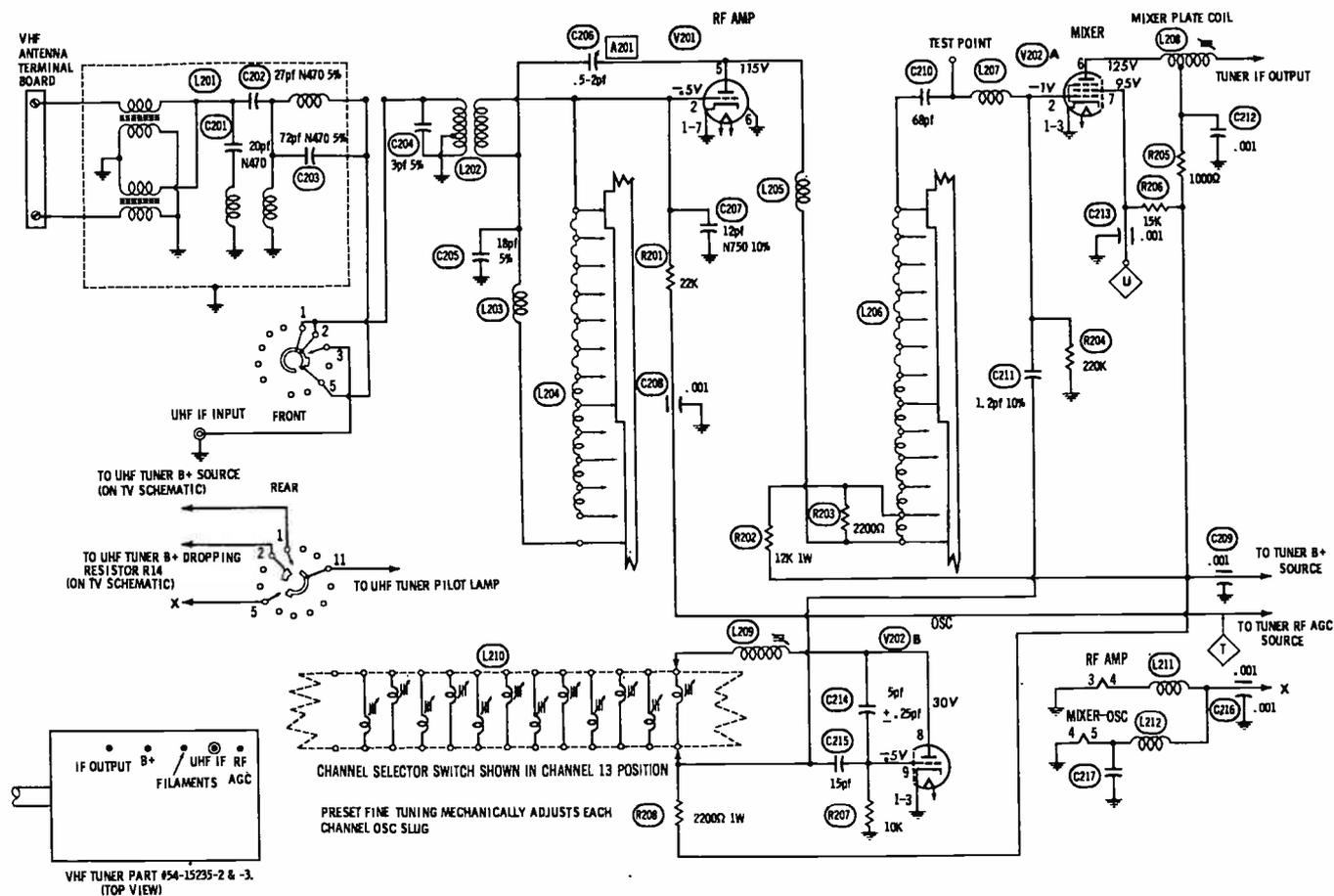
Fig. 12. Schematic diagram of the vhf tuner circuit.

VAC, you would need an adjustable transformer such as a Variac, to maintain the supply voltage at 117 volts during alignment. Also, it cautions you to let the receiver and the test equipment warm up for 20 minutes so they stabilize at their normal operating temperatures. Most technicians will not wait for the warm-up period. They turn on the equipment and go ahead with the setups and adjustments. By the time they are ready to make a final evaluation of the response curves, the warm-up period has elapsed. If any adjustments have drifted slightly during warm-up, they will correct them at this time.

The chart lists suggested alignment tools that will fit the various adjustments on this receiver. It lists tools made by two manufacturers and each size is listed in several lengths. The slugs in coils are made with hexagonal openings in only two or three standard sizes for most TV receivers. When you first start aligning receivers, buy only one tool of each size needed for the set you align. As you gain experience you will probably find you prefer alignment tools of a certain length or those with or without handles. By buying only what you need as you go along, you accumulate a set of alignment tools that meet your preference.

The alignment instructions in Fig. 11 do not specify the exact agc bias voltage that you should apply to the agc line. Instead, you are instructed to adjust the bias until the response shows no indication of overload. Also, you are cautioned to use only enough generator signal to produce a usable response indication. These instructions leave it up to the judgement of the technician to determine signal strength and agc bias. If the receiver is badly misaligned, you need some approximate values to start with. For example, a 2-volt peak-to-peak response signal is a reasonable value at the output of the video detector, so work toward getting approximately 2-volts response. An agc bias of -2 to -4 volts is a reasonable value, so set the adjustable bias at -3 volts. This value could vary widely depending upon receiver circuitry. Next adjust the signal generator attenuators until the indicated response reads about 2 volts. Increase and decrease the agc bias as you observe the response curve. The shape of the curve should not change over a range of several volts of agc bias. Likewise, the shape should not change as you decrease the strength of the generator signal. In both cases the amplitude of the waveform will, of course, change.

The instructions call for disabling the oscillator section of the mixer-oscillator stage in the tuner. Also, the instructions call for setting the channel selector to any noninterferring channel. Disabling the oscillator prevents the local oscillator frequency signal from interferring with the alignment generator signal. However, the instructions do not tell you how
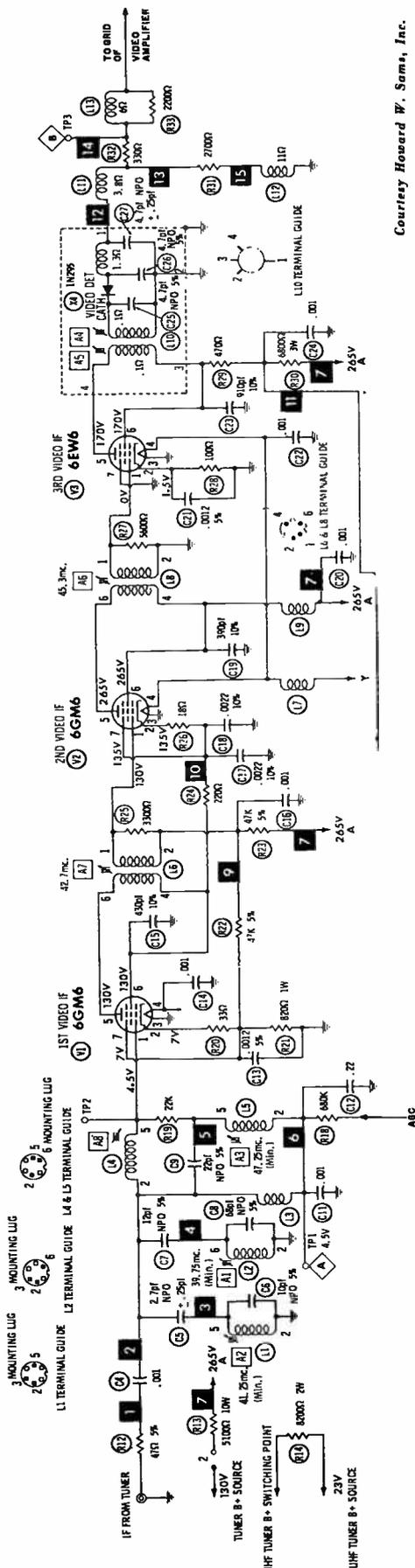
Fig. 13. Schematic diagram of the i-f circuitry with alignment frequencies identified.

to disable the oscillator. One way is to set the channel selector to position 1 which is the uhf position. This removes the plate voltage from the oscillator section of the mixer-oscillator stage and effectively kills the oscillator. Unplug the cable from the uhf tuner to eliminate noise from the uhf tuner. Or use a separate bias applied to the tuner agc line. A negative 8 volts or so will bias off the rf amplifier in the vhf tuner and reject any noise or signals from the uhf tuner.

The alignment procedure in Fig. 11 specifies peak alignment and sweep alignment steps. In Step 1 you use a single frequency marker generator and a vtvm indicator to set the three sound traps by peak alignment techniques. In Step 2 you peak two i-f transformer adjustments using a single frequency signal and a vtvm indicator. This step brings the first two i-f transformers into approximate alignment and is useful if the set is badly misaligned. Step 3 uses sweep alignment to adjust only the third i-f transformer. Step 4 uses sweep alignment to evaluate the overall response curve and to adjust the remaining coils.

The intermediate frequencies in the receiver originate in the mixer stage of the tuner and are present to the video detector. Thus i-f alignment covers the above circuitry in a receiver. Fig. 12 shows a schematic of the tuner referred to in Fig. 11. Likewise Fig. 13 shows a schematic of the i-f circuitry referred to in Fig. 11. Notice that the letter B in a diamond shaped enclosure identifies the point on the schematic for connecting the response indicator. This point is also labeled TP_3 in Fig. 13. The adjustments A_1 through A_8, referred to in the alignment instructions are identified on the schematic.

Before you start an alignment procedure read the instructions carefully. Relate the instructions to the schematic diagram and to the components in the receiver. Identifying the various coils, transformers, and adjustments before you start alignment will help to prevent mistakes. Now that we have discussed the alignment procedures shown in Fig. 11, let's go through the alignment steps.

Peak Alignment.

The first step in Fig. 11 calls for adjusting A_1, A_2, and A_3 using single frequencies from the marker generator. In Fig. 13, we find A_1 is the slug adjustment for coil L_2, an input circuit trap tuned to 39.75 mc. This trap is tuned to the picture carrier of an adjacent channel above the received channel. The adjustment A_2 is the slug adjustment for coil L_1 which is tuned to 41.25 mc and is designed to trap the i-f sound carrier of the received channel. Adjustment A_3 is the slug adjustment for coil L_5 which is tuned to 47.25 mc and traps the i-f sound carrier of an adjacent channel station operating below the received channel.

The response indicator in Step 2 is a vtvm connected to TP_3 which is the output of the video detector. A 47K-ohm isolation resistor is connected between TP_3 and the dc probe of the vtvm. The common, or ground lead, of the meter is connected to chassis ground of this receiver. Since the detector rectifies the i-f signal, the voltage developed at TP_3 will be dc. The video detector diode is in the circuit with

the cathode of the diode toward the coil (source) so the rectified voltage will have a negative polarity. Therefore we set the vtvm to read -dc volts on the 3-volt range.

The output of the marker generator is radiated into the mixer-oscillator tube of the tuner. Since coupling into the circuit is poor, it requires a larger output from the generator than if the generator were connected into the circuit. Adjust the generator frequency to produce exactly 39.75 mc. Do not use a generator of doubtful accuracy. Check the calibration of the generator before you use it. Increase the output of the generator until the vtvm reads about 2 volts. Adjust A_1 for a minimum reading of the vtvm. Insert the end of the alignment tool in the hexagonal opening in the slug. Rotate the slug while observing the vtvm. The meter should show a pronounced "dip" at the correct adjustment point. Increase the generator output so you have some meter indication in the dip.

Change the generator frequency to 41.25 mc and adjust A_2. Again, adjust the slug for a minimum reading on the vtvm. In the same manner, adjust A_3 for minimum using a generator frequency of 47.25 mc. The traps are now properly set.

Step 2 in Fig. 11 calls for adjusting A_6 and A_7 using single frequencies from the marker generator. A_6 is the adjustment slug in the second video i-f transformer. A_7 is the adjustment slug in the first i-f transformer. The vtvm remains connected to TP3 and is used as the response indicator. Set the generator frequency to exactly 45.3 mc and adjust its output for a usable indication on the vtvm. Adjust A_6 for maximum readings on the meter. Attenuate the output from the generator to keep the meter reading on scale. A coil (or transformer) usually peaks at two positions of the slug as the slug is screwed from the top to the bottom of the coil form. The alignment instructions sometime specify which peak to tune to. If it does not, peak the slug in the position where the slug is closest to the circuit board. Where two slugs are located in the same coil form, position them for maximum separation between the slugs. That is, one slug toward the top of the coil form and the other slug toward the bottom of the coil form. This minimizes interaction between the circuits.

Change the generator frequency to exactly 42.7 mc and adjust A_7 for maximum reading on the vtvm. Attenuate the generator output to keep the meter reading at about 2 volts. This completes the peak alignment using a single frequency generator and the vtvm as a response indicator. Disconnect the vtvm from TP3. Remove the marker generator from the floating shield on the mixer tube. The first and second i-f transformers are now approximately aligned.

Sweep Alignment.

Step 3 in Fig. 11 gives a sweep alignment procedure for adjusting the third i-f transformer. This transformer contains two adjustment slugs labeled A_4 and A_5. The bottom slug, A_4, is associated with the secondary circuit while the top slug, A_5, is associated with the primary circuit.

The rf output of the sweep generator is connected to the control grid (grid 1) of the third i-f stage. No-

tice in the diagram that this grid is at zero potential so no special coupling device is needed. The tube isolates the generator from the tuned circuits that you are adjusting so the connections do not load the tuned circuits. The generator signal is amplified by the third i-f amplifier so the output of the generator must be greatly attenuated.

The vertical input of the scope is connected to TP3 in Fig. 13. This point develops the output of the video detector so the scope will display the response curve. The horizontal input to the scope is connected to the sweep output of the sweep generator to synchronize the response curve with the generator output. The sweep generator frequency is centered at 44 mc and is set to produce a sweep 10 mc wide. This means that the rf output will vary between 39 mc and 49 mc at the sweep rate of 60 cps.

The instructions in Step 3 of Fig. 11 do not specify any marker generator frequency. Instead the instructions refer you to the response waveform that shows markers at 45.75 mc and 42.75 mc. Therefore you must connect a marker generator into the circuit, preferably at the vertical input terminals of the scope. Notice that the response curve shows the high frequency toward the left end of the curve. You can move a marker along the response to determine if your scope presents the waveform left to right or right to left.

To reach adjustment, A_4, you must use an alignment tool that will pass through the A_5 slug and engage the hexagonal opening in the A_4 slug. Alternately adjust A_4 and A_5 to duplicate the response curve shown. Reduce the generator output as necessary to prevent overloading that will distort the response curve. The instructions call for maximum amplitude and minimum tilt with the two markers in the positions shown in the figure. Greater amplitude of the response curve improves the receiver sensitivity. You must compromise the amplitude to get the necessary bandwidth.

To make the adjustment, observe the response curve as you move an adjustment. Locate the hump on the curve that moves when you move that adjustment. Place that hump on the 42.75-mc marker. Then go to the other adjustment, place its hump on the 45.75-mc marker. Now readjust both A_4 and A_5 to duplicate as nearly as possible the exact response curve shown.

Step 4 in Fig. 11 gives a sweep alignment procedure for checking the overall i-f frequency response of the receiver. The sweep generator signal is again a 10-mc sweep centered at 44 mc. The sweep generator signal is radiated into the plate circuit of the tuner mixer-oscillator stage using a floating tube shield. This loose coupling into the circuit does not load the tuned plate circuit of the mixer stage. Therefore you can adjust the mixer plate coil, L208 in Fig. 12. This step also calls for adjusting A_8 which is the input grid coil, L4, of the first video amplifier. The first and second i-f transformers, A_7 and A_6, are readjusted in this step. You recall that they were set to a specific frequency by peak alignment in Step 2. In Step 4 they are readjusted for proper overall response of the curve. Also in Step 4 it is permissible to retouch ad-

justments A4 and A5 slightly to obtain the correct response curve.

Six marker frequencies are specified in Step 4. These frequencies mark the important points on the desired response curve shown in the figure. 39.75 mc, 41.25 mc, and 47.25 mc marks the positions of the trap settings. Turn up the gain on the scope so you can clearly determine if the markers are centered in the "dip". The 42.6-mc marker and the 45.75-mc marker are positioned at the 50% points on the curve, meaning that they are half way between the base line and the top of the response curve. The 44.25-mc marker marks the center of the flat top of the curve.

The sequence of adjustments in Step 4 is important. If the receiver is badly out of alignment, A_8 and the mixer plate coil L208 should be adjusted first. All other adjustments have been set to approximately their correct frequency. Adjustments A_6, A_7, A_4 and A_5 should not be touched until A_8 and the mixer plate coil have been adjusted to approximate the response curve shown in the figure. Then touch up A_6, A_7, A_4 and A_5 to improve the response curve. Work toward getting maximum amplitude while maintaining the indicated bandwidth. Be sure to attenuate the sweep signals so the signal does not overload any circuit in the amplifier. Keep the output waveform down to less than 2 volts. Vary the agc bias over a small range (from -2 to -4 volts for example) to see if the response curve changes shape. Its amplitude should change smoothly with changes in agc bias but the shape should remain unaffected.

This completes the alignment procedure for the i-f section of this receiver. Alignment procedures for most receivers will be similar to that given in Fig. 11. Some service literature gives two separate i-f alignment procedures. One procedure will be for peak alignment and the other for sweep alignment. The peak alignment can be used if you do not have sweep alignment equipment. Sweep alignment will always give the best results.

Experienced technicians would skip the first three steps in Fig. 11 and simply set up for the overall response curve in Step 4. Then, if they could not bring the set into alignment, they would go back to the previous steps and align individual sections of the circuit. Unless the receiver was far out of alignment to start with, Step 4 would enable them to touch up the alignment quickly and accurately.

SELF-TEST QUESTIONS

(a) How wide is the passband of the video i-f amplifier in a TV receiver?

(b) Why is the sound carrier in the video i-f attenuated by traps?

(c) Why is a trap placed at 47.25 mc in the i-f circuits?

(d) What provisions are made in the i-f amplifier circuits for adjusting the response of the amplifier?

(e) What kind of alignment technique is most suitable (accurate) for setting the traps of an i-f amplifier?

(f) What alignment technique must be used to see a response curve of an i-f amplifier?

(g) What is used for a response indicator when performing peak alignment?

(h) What does a response curve show?

(i) What is the technique called when the markers are made up separately and applied to the vertical input of the scope?

(j) Why is loose coupling desirable when coupling a marker generator signal into a circuit?

(k) What control is provided on some sweep generators for centering the response curve on the scope trace?

(l) What is one advantage of radiating the i-f sweep signal into the mixer stage of the tuner when performing i-f alignment?

(m) Why is a resistor sometimes placed in series with the vertical scope probe when viewing the response curve at the output of the video detector?

(n) Describe the test used to determine if the interconnecting ground connections are adequate between the set and test equipment.

(o) What is the advantage of disabling the horizontal sweep during alignment?

(p) Why should you use an isolation power transformer when aligning a transformerless receiver?

(q) Why is a warm-up period desirable for the receiver and generator before performing alignment?

(r) Describe two ways to check for signal overload when performing i-f alignment.

(s) Why is it desirable to keep the amplitude of markers small during alignment?

(t) What kind of alignment technique should be used on a receiver that is badly out of alignment?

(u) When adjusting a trap using a vtvm for a response indicator, do you tune for a maximum or a minimum reading?

RF Alignment

Modern TV receivers contain two tuners one for vhf and the other for uhf. Both tuners are considered part of the rf section of the receiver. However, you will remember from an earlier lesson that when the receiver is tuned to a uhf station that the rf stage and mixer stage in the vhf tuner actually operate as i-f stages and the oscillator stage is made inoperative.

The rf section of a TV receiver is broadly tuned and seldom needs alignment. The receiver selectivity does not depend on the tuned rf circuits. The i-f section of the receiver provides most of the selectivity. Therefore, the rf circuits are broadly tuned to accept more than the full band of frequencies from the selected TV channel. The job of the rf circuits is to deliver an amplified, noise-free, rf signal to the mixer stage. Tuners are made from high quality parts and are compactly built so the alignment does not tend to change.

Except for the local oscillator adjustments and the mixer plate coil (i-f) you will seldom have to perform any alignment adjustments on a tuner. You may want to look at the rf response curve to see if it is correct, but you must be very sure of the need for alignment before you perform it. The high frequencies present in tuners are difficult to work with. Small variations in equipment setup can greatly influence the response curve. If you get a response curve that approximates the response curve given in the service literature, the alignment is probably correct and any adjustment you might make would not improve the receiver operation. Of course if the adjustments have been moved or if you have performed repairs in the tuner circuitry, alignment may be necessary.

VHF TUNER

In the section on i-f alignment, the plate circuit of the mixer stage in the tuner was tuned to the intermediate frequency. The other circuits in the vhf tuner are tuned to either the incoming rf signal frequency or to the local oscillator frequency. Alignment of the local oscillator is usually considered a setup or secondary control adjustment. Electrically, it is an important part of the TV alignment.

Local Oscillator Adjustments.

The local oscillator must be operated at an exact frequency so that when the local oscillator frequency is mixed with the incoming rf signal, the difference frequency will be the receiver intermediate frequency. No test equipment is needed to adjust the frequency of the local oscillator. It is simply adjusted for best picture and sound on each of the active channels. As you know, a customer operated fine tuning control is provided to accurately adjust the local oscillator frequency for best picture and sound. Most tuners have oscillator adjustments in addition to the fine tuning adjustment.

Fig. 12 illustrates one type of local oscillator adjustment arrangement. The channel selector switch inserts a different coil, L210, into the oscillator cir-cuit for 12 of the 13 positions. Position 1, which is the uhf position, has no coil so this position removes plate voltage from the oscillator tube and disables the local oscillator. In each of the 12 vhf positions, a fine tuning control adjusts the inductance of L210 for that channel to accurately set the local oscillator frequency. Inductance L209 is in the oscillator plate circuit at all times. If the fine tuning cannot produce the correct oscillator frequency, L209 must be adjusted. This affects the setting of fine tuning for all 12 channels. This overall oscillator adjustment will seldom have to be made. In this tuner it is reached by removing the tuner cover.

In other tuners, the fine tuning control is an adjustable coil or capacitor that affects the local oscillator frequency for all of the channels. In turret-type tuners, a slug is provided in each vhf channel position. The fine tuner is centered, then the slug is adjusted for best picture and sound. The fine tuner can then change the local oscillator frequency a small amount each side of the preset value. In some switch type tuners only two or three adjustment points are provided in addition to the fine tuning control. For example, one adjustment will be for the high channels, one for the middle channels, one for the low channels. Making these adjustments is usually referred to as "oscillator tracking" adjustments in the service literature. In tuners of this type, you always adjust first at the high channels and work toward the low channels. If an overall oscillator frequency adjustment is provided, it will be identified in the alignment instructions for that receiver.

Some alignment instructions call for a preliminary setting of the local oscillator using a signal generator. A sample of the local oscillator signal is mixed with a signal from a signal generator that is set to produce the correct oscillator frequency. The local oscillator is then adjusted until the two signals "zero beat" indicating that they are the same frequency. This procedure sets the local oscillator frequency close to its correct value. The adjustment is then refined by adjusting it for best picture and sound while receiving a TV receiver station on that channel.

RF Sweep Setup.

Sweep alignment is ordinarily used to align the rf circuits in the vhf tuner. The sweep generator must be capable of producing the frequencies of the vhf channels -- 54 mc through 216 mc. Fig. 14 shows a block diagram of a typical alignment setup. The sweep generator signal is coupled through a matching pad to the antenna terminals of the tuner. The matching pad is necessary to match the output impedance of the signal generator, usually 50 or 72 ohms, to the balanced 300 ohm impedance of the antenna input circuit. Fig. 15 shows two resistive pads that you can make. The output impedance of your generator determines which pad you should use.

The marker generator signal must be loosely coupled into the signal path. Loose coupling prevents up-
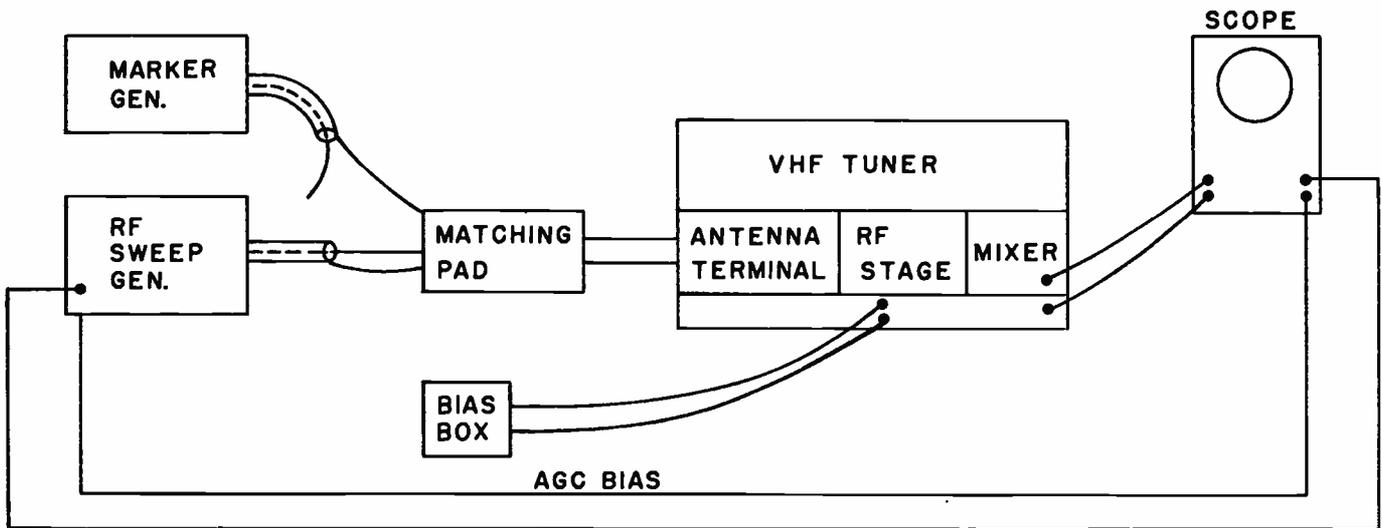
Fig. 14. Setup for aligning the rf section of a vhf tuner.

setting the impedance match which can cause response curve distortions. Clip the hot lead of the marker generator to the outside insulation of the sweep generator lead. Or simply lay the marker generator lead near the matching pad. Enough rf energy will be radiated into the circuit to produce markers. If your marker generator is equipped to produce the markers internally, use the post injection technique. In this case your marker signals are applied directly to the vertical input terminals of the scope.

As shown in Fig. 14, an adjustable bias box is used to put a negative bias on the tuner agc line. This negative bias sets the operating point of the rf amplifier. The service literature will specify the correct bias, usually -1 to -3 volts, to be used during alignment.

The vertical terminals of the scope are connected to the tuner mixer circuit. The mixer stage demodulates the rf sweep signal by grid-leak detection. The response curve is developed in the mixer plate circuit. The scope can be connected into the plate circuit or to a test point provided on the tuner. For example,

in the tuner in Fig. 12 test point U connects to the screen grid of the mixer stage. The response curve is developed on the screen grid. Therefore test point U provides a suitable point to connect the vertical terminals of the scope. In either case, the mixer stage provides isolation between the scope connection and the tuned rf circuitry that is being aligned.

Set the sweep generator frequency to the center of the channel to be aligned. Set the channel selector to the same channel. Use a sweep signal at least 10 mc wide. Turn up the vertical gain on the scope. Reduce the amplitude of the input signal to get a usable response curve on the scope. As with any sweep alignment technique make sure the circuits are not overloaded by too large an input signal. Adjust agc bias to the value specified. Vary it a small amount above and below the specified value to again check for overload. Next inject the marker at the picture frequency and the sound frequency for that channel.

RF Response Curve.

Fig. 16 shows a response curve specified for the rf circuits of a receiver. The service literature usually specifies the peak-to-peak amplitude of the response
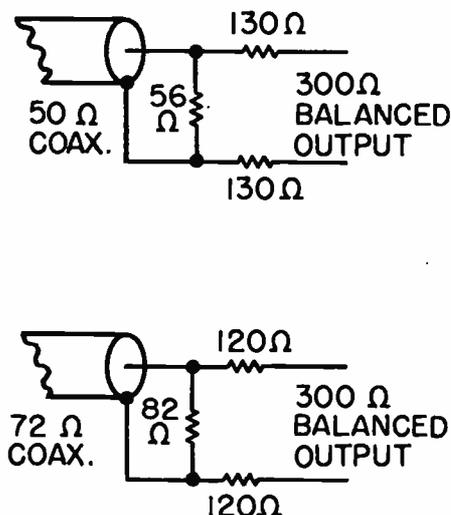
Fig. 15. Matching pads for terminating output cables.
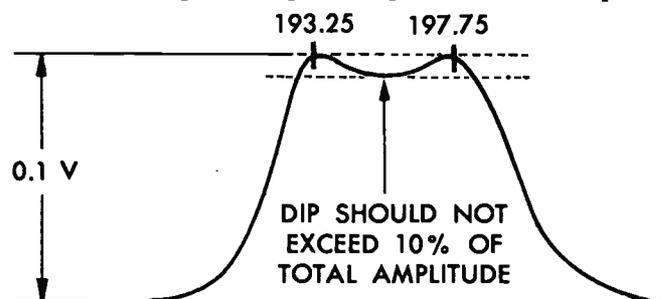
Fig. 16. RF response curve for channel 10 with sound carrier frequency and picture carrier frequency markers.

curve. You strive to duplicate the response curve as nearly as possible for each channel. For most tuners you will find sizable variations in the curve for vari-

ous channels. You can expect to have to increase the amplitude of the sweep signal at the higher channels. Often you have to compromise on the amount of waveform tilt as you adjust for the different channels. Only two markers are used to indicate the two peaks on the response curve.

Table 1 lists the center frequency for each of the 12 vhf channels. A column labeled "marker generator frequency" lists the sound carrier frequency and the picture carrier frequency for each channel. These two frequencies are used as markers to identify the sound and picture positions on the response curve for each channel.

Check the response curve for distortion caused by poor ground connections. Touching the tuner, sweep

CHANNEL & FREQUENCY CHART

SWEEP GENERATOR FREQUENCY	MARKER GENERATOR FREQUENCY	CHANNEL
57 MC	55.25 MC 59.75 MC	2
63 MC	61.25 MC 65.75 MC	3
69 MC	67.25 MC 71.75 MC	4
79 MC	77.25 MC 81.75 MC	5
85 MC	83.25 MC 87.75 MC	6
177 MC	175.25 MC 179.75 MC	7
183 MC	181.25 MC 185.75 MC	8
189 MC	187.25 MC 191.75 MC	9
195 MC	193.25 MC 197.75 MC	10
201 MC	199.25 MC 203.75 MC	11
207 MC	205.25 MC 209.75 MC	12
213 MC	211.25 MC 215.75 MC	13

TABLE I

generator, bias box or scope should not change the shape of the response curve. Use short lead lengths for connecting the generator cable to the matching pad and for connecting the matching pad to the antenna terminals. Remove the marker generator input connection while observing the response curve to see if the connection is loading the circuit and distorting the curve.

Neutralizing Adjustment.

The rf amplifier stage in a TV tuner usually must be "neutralized" because of the high frequency of operation. The grid-to-plate capacitance of the tube becomes an appreciable factor at TV station frequencies. If this grid-to-plate capacitance is not neutralized, the stage will tend to oscillate. The indication of oscillation is a sudden flattening of the response curve. The large oscillation signal overloads the circuits and the scope producing a meaningless scope trace.

Neutralization is usually accomplished by feeding a phase-shifted signal from the plate circuit back to the grid through an adjustable neutralizing capacitor. Capacitor C206 in Fig. 12 is the neutralizing capacitor for that tuner. The adjustment is labeled A201. The adjustment is performed by biasing off the rf stage and adjusting the neutralizing capacitor for minimum response at the output. A large sweep signal is applied to the antenna terminals. The grid-to-plate capacitance of the rf tube provides a feed-through path for the signal to the plate circuit. The neutralizing capacitor provides a feedback path from the plate to the grid. The neutralizing capacitor is adjusted to give a feedback signal that reduces the feed through the signal to a minimum. The alignment instruction usually specifies the particular channel to be used for making the adjustment.

The grid and plate circuits of the rf amplifier should be approximately aligned before the neutralizing adjustment is made. The alignment instructions call for adjusting the grid circuit and the plate circuit to produce a specified response curve. In the tuner in Fig. 12, the rf plate coil L205 and the grid coil L203 are adjusted for a desired response curve on channel 13. Next, the neutralizing adjustment is made with the channel selector on channel 10. Then the response curve is observed for channels 12 through 2 and compromise adjustments are made on individual channel coils of L206.

In tuners that use transistors you must also neutralize the rf stage. The procedure is essentially the same as that already outlined. You adjust the tuned circuits in the input and output of the rf stage first and then adjust the neutralizing adjustment.

Knifing Coils.

Since small values of inductance and capacitance form resonant circuits at the TV channel frequencies, the rf coils are often only a few turns of heavy wire wound on an insulated core. Or the coil may have an air core. Inductance of these coils is adjusted by squeezing together or spreading apart the turns. This procedure is known as "knifing" or "pruning" the coils. A plastic alignment tool is useful for moving the turns of the coil. Avoid using a metal screwdriver. It may damage insulation or short circuit the coil.

Also the presence of the metal near the coil will affect the inductance and make adjustment difficult.

Be certain that you have the correct coil before you make the adjustment. Spread or squeeze the coil only a slight amount as you observe the response curve. Adjust the coil for maximum amplitude of the response curve. At the same time you must maintain the correct shape of the curve. You usually have to settle for less than maximum amplitude in order to get the required bandwidth of the curve. In most cases you will be adjusting two or more coils that affect the curve. You can expect to have to go over the adjustments several times to get the best overall response curve.

UHF TUNERS

Some uhf tuners have no alignment provisions. The tuner is factory aligned and sealed with soldered shielding completely enclosing the tuner. Other uhf tuners have only two alignment points, a high frequency and a low frequency oscillator adjustment. Still other uhf tuners have an rf trimmer adjustment (capacitor). These adjustments are reached without removing the tuner shield.

Fig. 17 shows a diagram of a typical uhf tuner that operates from channel 14 through 85. A transistor oscillator injects a signal to the mixer diode where it combines with the incoming rf station frequency. The difference frequency is the receiver i-f frequency. A three-gang tuning capacitor tunes the rf, mixer, and oscillator sections of the tuner to select the desired uhf channel. Only the oscillator section is provided with adjustment points. Capacitor C304 is adjusted to bring the oscillator frequency to the correct value for receiving the low channels. Capacitor C303 is the oscillator adjustment for high frequency channels. Alignment instructions call for simply adjusting these two adjustments on the lowest and the highest channels available in your area. The low channel adjustment is made first. Then the high channel adjustment is made. Adjust for best picture and sound. The adjustments are repeated until no improvement is possible.

Except for the oscillator tracking adjustments, alignment is almost never performed on uhf tuners. The tuners are compactly constructed and the alignment does not tend to change.

The overall receiver response to uhf signals can be evaluated using sweep alignment techniques. The sweep generator must be capable of producing swept signals at the uhf station frequencies. The swept rf signal is applied to the uhf antenna terminals. The tuner is set to the desired channel and the sweep generator signal is centered in the passband of that channel. The response is usually viewed at the output of the vhf tuner. Or an overall response curve is obtained at the video detector. Since it is difficult to obtain accurate markers in the uhf band, markers are often injected at the i-f frequency. For example, a marker generator is set up to radiate into the mixer stage of the vhf tuner. The marker frequency then mixes with the i-f frequency producing markers in the i-f band. These markers identify frequency points on the response curve at the video detector. The response curve shows the overall response of the uhf tuner and the i-f circuitry in the receiver.
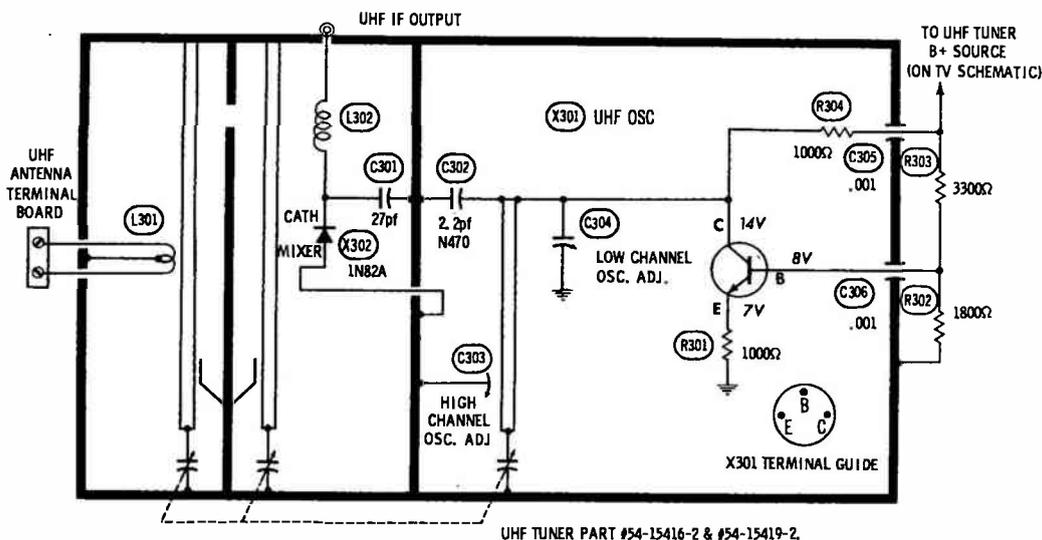
Courtesy Howard W. Sams, Inc.

Fig. 17. Typical uhf tuner showing oscillator tracking adjustments.

Sound Section Alignment

The tuned circuits in the sound section of a TV receiver are easy to align. The intercarrier sound system produces a readily available, accurate alignment signal from all TV broadcasts. The circuits to be aligned form a rather narrow passband so peak alignment produces good results. You need only align the circuits for maximum audio signal with minimum distortion. Therefore it is often practical to align the circuits using a TV program.

Circuits outside of the sound section of the receiver affect the sound signal. As you know, traps in the video i-f amplifier attenuate the video i-f sound carrier signal. In most receivers, the sound carrier is very small compared to the amplitude of the picture carrier at the video detector. This relationship is necessary so the 4.5-mc difference signal (difference between the sound carrier and picture carrier) will preserve the frequency modulation of the sound carrier which is the audio information. If the sound carrier is not properly trapped in the video i-f section, the 4.5-mc difference signal will carry along excessive video modulation (amplitude modulation) and result in excessive intercarrier buzz in the reproduced audio. Also improper video i-f alignment can excessively attenuate the sound carrier so that sound is not present, or has low volume, when the set is fine-tuned for the best picture.

FIELD ALIGNMENT OF SOUND

The service literature for most receivers gives a sound alignment procedure that can be performed in the home using a TV program. Experienced technicians regularly perform touch-up sound alignment on service calls without reference to alignment instructions. From the tube layout of the set, you can locate the tuned circuits of the sound system. Then you tune to a TV station and attenuate the signal until sound is barely audible with volume control turned up full. The tuned circuits in the sound system are then adjusted for maximum sound and minimum distortion. This procedure will usually produce satisfactory alignment.

Fig. 18 shows the sound circuits of a typical TV receiver. The sound takeoff transformer, L_{14}, in the plate circuit of the video amplifier performs two functions. It couples the 4.5-mc sound i-f signal to the sound i-f amplifier and it traps out the 4.5-mc signal from the video signal that is applied to the picture tube. The top slug in this transformer, labeled A_{13}, tunes the trap. It is aligned by tuning the receiver to a strong station. Misadjust fine tuning until the 4.5-mc grain is clearly visible in the picture. Adjust A_{13} for minimum grain in the picture. The bottom slug, A_{12}, is used to tune the secondary circuit to the sound i-f frequency.

Tune the receiver to a strong station and adjust the sound detector quadrature coil L_{19} (A_9) in Fig. 18, for maximum sound. If the receiver has a buzz control, set it at the minimum buzz position at this time. The quadrature coil slug will have two or more positions that produce sound. Peak the slug at the position
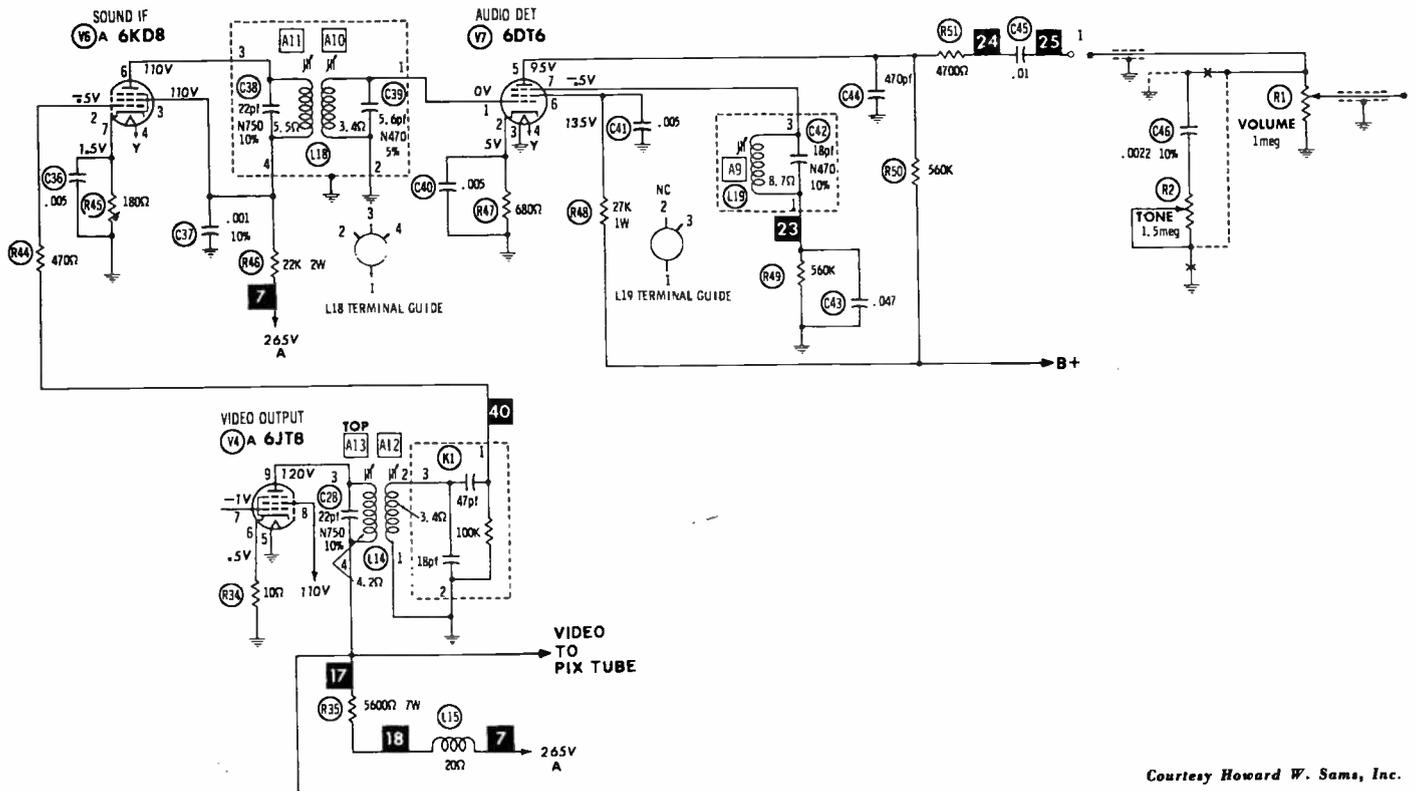
Courtesy Howard W. Sams, Inc.

Fig. 18. Sound circuits of a TV receiver.

that produces the loudest sound. Disregard distortion at this time.

The sound i-f circuits are aligned on a weak signal. Tune the receiver to a weak station and turn up the volume control. Listen for background noise indicating that the i-f signal to the sound detector is not being limited. As you recall in FM reception, the detector or stage ahead of the detector clips the i-f signal to make the circuit immune to amplitude modulation. This limiting action is necessary for noise-free audio. For accurate sound i-f alignment you must keep the signal below the limiting level so that you can hear the changes in signal amplitude produced by alignment adjustments. You will probably have to remove the antenna to reduce the signal to the desired level. Then it may be too weak. Attach a short length of wire to one antenna terminal. Depending on your signal area, a couple of feet of wire is adequate. Change its position or roll it up to vary the signal strength. Work with the smallest signal that you can hear. Disregard the picture.

Alternately adjust A_{10}, A_{11} and A_{12} for maximum sound with minimum distortion. As the adjustments are made and sound level comes up, attenuate the signal more so that you work with the smallest possible signal. When the coils are properly adjusted, you should be able to produce distortion by a very slight rotation of A_{10}, A_{11}, or A_{12} in either direction. If the circuits were far out of adjustment to start with, it may be desirable to readjust the quadrature coil on a strong signal before making the final adjustments to the tuned i-f coils.

SHOP ALIGNMENT PROCEDURES

The sound circuits of a TV receiver can be aligned using a signal generator and shop equipment. Two methods are in common use. One method uses an accurate 4.5-mc generator signal and a vtvm as a response indicator. The other method uses a sweep generator and an oscilloscope as a response indicator. Either method can be used to accurately align the circuits. These alignment techniques are particularly useful when troubleshooting a defective sound circuit. The use of a generator for the 4.5-mc signal enables you to apply a very large signal to the circuit. This enables you to drive the signal through a defective stage and helps you locate the defect. The sweep technique enables you to observe the operation of the sound detector and helps determine causes of distorted sound.

Fixed Frequency Generator.

When using a signal generator to supply the 4.5-mc alignment signal, the generator must produce an accurate frequency. The generator should have either a crystal oscillator or a crystal calibrated oscillator to produce the 4.5-mc signal. The accuracy of most marker generators is adequate. An unmodulated 4.5-mc signal is usually used. An amplitude modulated signal will produce an audible output from the sound circuit. The AM signal has enough frequency modulation on it to produce an output from the discriminator or ratio detector of the receiver. Some technicians prefer to use this audible signal as a response indicator. A vtvm indicating the response of the detector to an unmodulated signal gives a more accurate indication.

Follow a typical alignment procedure on the sound circuit in Fig. 19. Tune the receiver to any noninterfering, unused channel. If you want to get rid of noise from the front end, bias off the tuner and video i-f stages by applying a large negative bias to the agc line. Or unplug the i-f output from the tuner if a cable is used. Inject the 4.5-mc signal into the sound takeoff point in the video circuit. Use a .001-mfd isolating capacitor on the hot lead. The 4.5-mc signal is coupled through the 10-mmf capacitor to L_{27} in Fig. 19. Attach the dc probe of a vtvm to pin 7 of V12A. Set the vtvm to read negative dc volts on the 3 volt range. Adjust the signal generator output for a midscale reading on the vtvm. Adjust A_{12}, A_{13}, and A_{14} for maximum reading on the vtvm. Attenuate the output of the signal generator as necessary to keep the vtvm reading on scale. The sound i-f section is now properly aligned.

Ratio Detector Alignment.

Attach the dc probe of the vtvm to point G in Fig. 19. (Junction of R_{87} and C_{76}). Adjust A_{15} (top slug in the ratio detector transformer) for zero reading of the vtvm. On one side of the correct setting your vtvm will read positive. On the other side of the correct setting the vtvm will read negative. The sound circuits are now correctly aligned.

On some ratio detector circuits there is no place in the circuit to measure the dc voltage for aligning the ratio detector transformer. You can provide a measurement point by temporarily attaching two resistors across the ratio detector load resistors. Connect two 100K-ohm resistors in series. Connect one end of
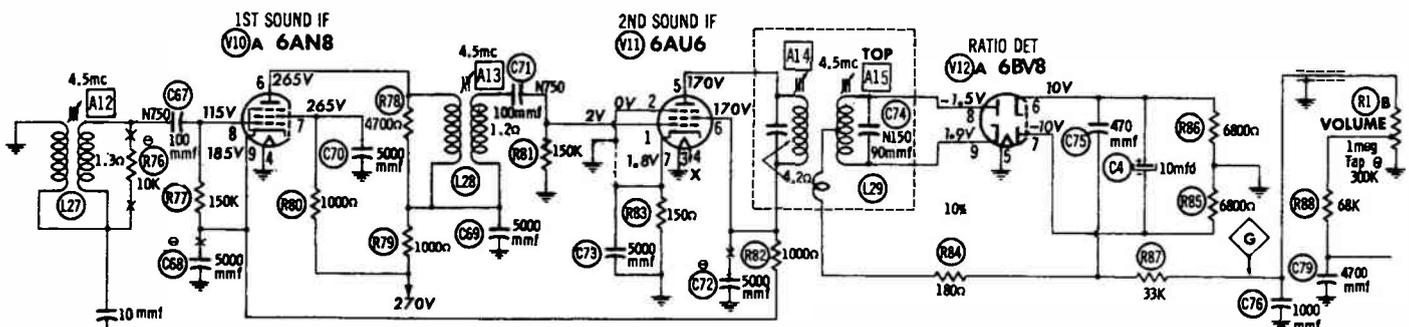
Fig. 19. TV receiver sound circuit using a ratio detector.

Courtesy Howard W. Sams, Inc.

this series combination to the ungrounded end of R_{86}. Connect the other end of the series combination to the ungrounded end of R_{85}. Connect the dc probe of the vtvm to the junction of 100K resistors. Adjust A_{15} for zero reading. Remove the 100K-ohm resistors.

Either of the above procedures balance the diode currents of the ratio detectors, and enables the detector to produce the maximum undistorted output. The service literature for some receivers may specify other points for connecting the vtvm for alignment. Use the connection points specified. They are either more accessible in the receiver or give a more accurate indication for that particular receiver circuitry.

The sound i-f circuitry in Fig. 18 can also be aligned using a fixed 4.5-mc generator signal and a vtvm. Most alignment instructions will call for final alignment of this type circuit on a TV program. Alignment on a generator signal is useful for troubleshooting a defective circuit or for initial alignment when the circuit is far out of alignment.

The detector circuit shown in Fig. 20 is used to detect the rf signal and to isolate the vtvm from the tuned circuit. Connect the diode to the grid pin 1 of V_7 in Fig. 18. Connect the dc probe of the vtvm to the junction of the two 470K-ohm resistors. Set the vtvm to read negative dc on the 3 volt range. Connect the output of the signal generator through an isolation capacitor to the control grid, pin 7 of V_4. Attenuate the generator signal to produce an on-scale reading on the vtvm. Adjust A_{10}, A_{11}, A_{12}, and A_{13} for maximum reading on the vtvm. Attenuate the generator as necessary to keep the vtvm reading on scale. The sound i-f circuits are now aligned. Disconnect the detector circuit and signal generator. Tune the receiver to a strong station and adjust A_9 for maximum sound output. The alignment of the sound i-f adjustments can be refined by attenuating the station signal and readjusting A_{10}, A_{11}, and A_{12} as outlined previously.
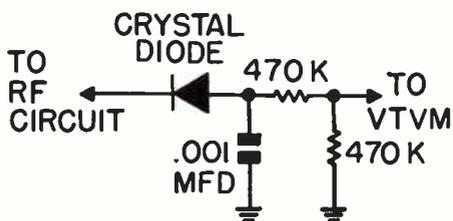
Fig. 20. Detector circuit used to align sound i-f.

Sweep Alignment.

The sound circuits of a TV receiver can be aligned using a sweep generator. The procedure is very similar to aligning the i-f and detector section of an FM radio receiver. The circuits are aligned in two steps. First, the sound i-f circuits are swept and adjusted for maximum response at the 4.5-mc sound i-f frequency. Then the sound detector is aligned for equal response above and below 4.5 mc.

Follow a typical alignment procedure by referring to Fig. 19. The sweep generator signal is coupled through the 10-mmf capacitor to transformer L_{27}. Set the

center sweep of the generator at 4.5 mc. Connect the diode of the detector circuit, shown in Fig. 20, to grid pin 1 of V_{11}. Connect the indicated ground of the detector circuit to chassis ground. Attach the vertical input of the scope to the junction of the 470K-ohm resistors. Attach the horizontal input of the scope to the sweep signal output of the sweep generator. Set the sweep width to about 1 mc. Tune the receiver to a noninterfering, unused channel. Inject a 4.5-mc marker with the sweep input or use post injection markers depending on your equipment. Attenuate the sweep signal to produce about 1-volt peak-to-peak waveform on the scope. Adjust A_{12} and A_{13} for maximum amplitude of the waveform centered at 4.5 mc. The response curve should be a smooth curve with a single hump peaked at 4.5 mc. Attenuate the input signal as necessary to preserve an undistorted curve. Most receivers have a sound i-f bandwidth of from 500 to 800 kc.

Remove the detector circuit from the grid of V_4 and move the scope to point G in Fig. 19. Adjust A_{14} and A_{15} to produce an undistorted "S" curve centered at 4.5 mc. A_{15} equalizes the parts of the curve above and below the 4.5-mc marker. Adjust A_{14} to produce a flat portion between the peaks above and below the 4.5-mc marker. Fig. 21 shows a typical "S" curve response with a 600 kc bandpass.
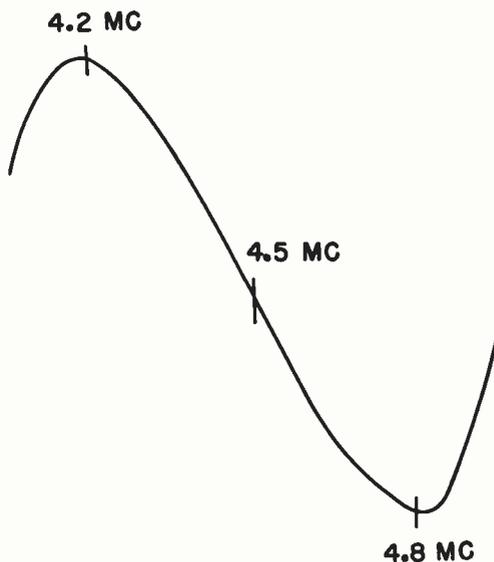
Fig. 21. A typical S-curve response for a TV sound detector.

SELF-TEST QUESTIONS

(v) Why is the equipment setup for rf alignment more critical than for i-f alignment?

(w) Which alignment adjustment on the tuner is often performed as a receiver setup adjustment?

(x) What is the most accurate and convenient signal source to use for making a local oscillator adjustment on a TV tuner?

(y) When aligning the rf section of a tuner, why do we view the response curve at the output of the mixer stage instead of using a demodulator

probe at some point in the rf circuits?

(z) Why are good grounds and short interconnecting leads more important in rf alignment than in i-f alignment?

(aa) What is meant by the term "knifing" coils?

(ab) Why are alignment adjustments seldom necessary on uhf tuners?

(ac) Where does the 4.5-mc sound i-f signal originate in a TV receiver?

(ad) What two circuits in the TV sound system require alignment?

(ae) The alignment of what circuits other than the sound i-f and sound detector can affect the sound signal?

(af) How do you adjust a sound trap that is designed to trap out the 4.5-mc signal from the video signal to the picture tube?

(ag) What received signal condition is necessary to accurately align the sound i-f while listening to the sound portion of a TV program?

(ah) Are the sound i-f circuits broad band or narrow band tuned circuits?

(ai) Which would produce the more accurate 4.5-mc signal source for sound alignment: an off-the-air TV program or a crystal calibrated marker generator?

(aj) What is the frequency of the sound i-f circuit in TV receivers?

(ak) What kind of modulation carries the audio signal on the sound carrier in a TV receiver?

Color Section Alignment

Two circuits in the color section of the receiver are subject to alignment. The circuits in the color signal path must be aligned to give equal amplitude to the upper and lower color sidebands that carry the color information. In most receivers this is the bandpass amplifier which is also called the color i-f amplifier. The other circuit that must be aligned is the automatic frequency and phase control circuit (afpc). This circuit includes the 3.58-mc oscillator and the control circuits that enable the oscillator to deliver a correctly phased 3.58-mc reinsertion signal to the color demodulators.

As you recall, the color signal is carried in the sidebands of the 3.58-mc color subcarrier. This signal appears at the video detector. The relative amplitude of the color sidebands depends on the shape of the response curve in the video i-f amplifier. In most color receivers, the upper and lower color sidebands do not get equal amplification in the video i-f amplifier. Therefore the response of the bandpass amplifier must be shaped to compensate for this unequal amplification. The aim is to get an overall flat response so the total amplification of the signal fed to the color demodulators will be the same for both the upper and lower sidebands. Thus when you perform alignment on just the bandpass amplifier the response curve will usually not be flat.

The fact that both the video i-f amplifier and the bandpass amplifier affect the color signals requires an accurate alignment of the circuits. You have already been alerted to the importance of careful alignment of the tuner and video i-f amplifier sections of color receivers. These circuits must be properly aligned before you attempt to align the color i-f amplifier. If you decide that a receiver needs color i-f alignment, it is worth your time to check the video i-f alignment first. Manufacturers alignment instructions vary for different color receivers. Follow them carefully for good results.

An unusual alignment technique called video sweep modulation (vsm) has been devised for checking the overall response of the circuits to the color signal. A swept color frequency signal (0 to 5 mc) is used to modulate the video i-f picture carrier frequency (45.75 mc). This produces a swept i-f signal that varies from about 40.75 mc to 45.75 mc. The swept i-f signal is injected into the video i-f amplifier. The video detector recovers the 0 to 5 mc signal. The video amplifier applies it to the bandpass amplifier. A scope connected to the demodulator displays the overall response of the circuits to the 0 to 5 mc signal. The color sidebands occupy a range of frequencies about 500 to 700 kc above and below 3.58 mc. Suitable markers on the 0 to 5 mc response curve enable you to evaluate the circuit response to the color signal frequencies. The vsm alignment technique is covered in this section.

You have already studied a field procedure for adjusting the color afpc circuits. You will normally use the field procedure when adjusting the receiver on service calls and on normally operating receivers in the shop. In this section of this lesson we give a shop procedure for color afpc alignment. This procedure requires the use of an oscilloscope and other shop test equipment. This shop procedure enables you to more accurately evaluate the operation of each part of the afpc circuit. It is particularly useful for troubleshooting marginal defects in the afpc circuit.

CHROMA BANDPASS AMPLIFIER

The bandpass amplifier is designed to pass a band of frequencies centered around the 3.58-mc subcarrier frequency. A sweep generator signal in the 2 to 5 mc range is suitable for producing a response to the frequencies handled by this circuit. Most bandpass amplifiers have a tunable input coil at the grid of the amplifier stage and a double tuned transformer in the plate circuit of the amplifier. These three tuned circuits are adjusted to produce the desired response.

Most alignment instructions specify the sweep alignment of the bandpass amplifier as a preliminary alignment step. Then the overall response of the video i-f amplifier and the bandpass amplifier is observed using video sweep modulation. During this step the bandpass amplifier adjustments are touched up to produce the desired overall response.

Fig. 22 shows a simplified schematic of a typical bandpass amplifier. The first step in alignment is to adjust the bandpass transformer, T_1. Connect the vertical input of an oscilloscope to point C, the top of the color control, in Fig. 22. Use a demodulator probe
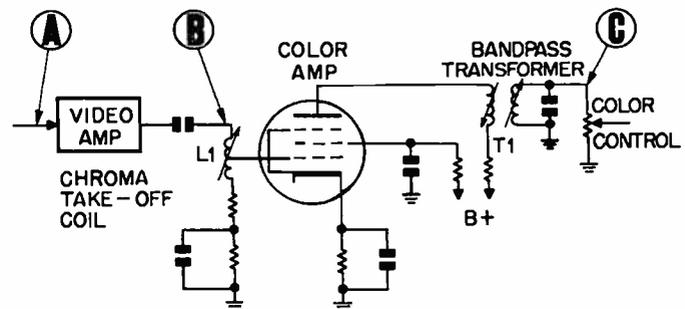
Fig. 22. Color i-f amplifier circuit.

or connect the detector network shown in Fig. 23A between point C and the vertical input to the scope. Connect a sweep generator to the chroma takeoff coil, L_1, in Fig. 22. This point is labeled B in Fig. 22. Connect the generator output through the matching pad shown in Fig. 23B. This pad matches the output impedance of the signal generator and loads the chroma takeoff coil. By loading the chroma takeoff coil, it will have no effect on the response curve displayed on the scope. The response curve will be due entirely to the primary and secondary circuits of the bandpass transformer T_1. Connect the sweep output of the sweep gen-
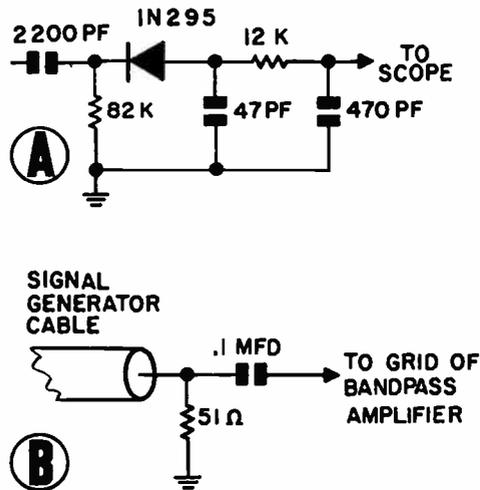
Fig. 23. Detector test circuit (A) and signal generator coupling circuit (B).

erator to the horizontal input of the oscilloscope. Loosely couple a marker generator signal into the circuit at point B or use built-in markers depending on your equipment.

Set the sweep generator to produce a swept output from 0 to 5 mc. If your generator does not go to zero, center the sweep output on 3.58 mc and adjust sweep width for a sweep output at least 1 mc either side of the center frequency. Adjust the generator output for a 1-volt peak-to-peak response curve on the scope. Adjust the top and bottom slugs in T_1 for the response curve shown in Fig. 24A. Adjust the slugs toward the ends of the coil. Notice that the response curve has two humps peaked at 3 mc and 4 mc.

Move the sweep generator input to the grid of the
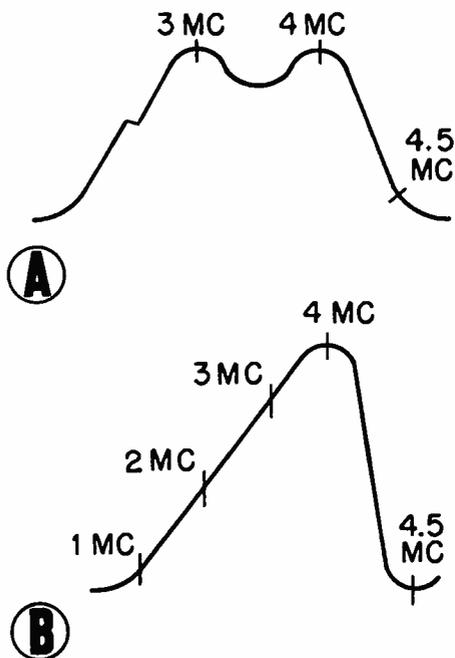
Fig. 24. Response curve for bandpass transformer (A) and overall response curve for color i-f amplifier (B).

video amplifier. The response curve will now display the effect of both the bandpass transformer, T_1, and the chroma takeoff coil, L_1. The video amplifier stage isolates the sweep generator from the chroma takeoff coil. Adjust the output of the sweep generator to maintain a 1-volt peak-to-peak waveform. Adjust L_1 to produce the waveform shown in Fig. 24B. If necessary retouch the adjustments in the bandpass transformer to duplicate the waveform. In this receiver, the rising slope of the color i-f amplifier response curve compliments the falling slope of the video i-f response curve. As a result the color signals above and below 3.58-mc receive equal amplification.

VIDEO SWEEP MODULATION

The video sweep modulation alignment technique was developed to evaluate the overall response of the video i-f, video detector, video amplifier, and color i-f circuits to the color signal frequency. In this system, the demodulated signals that produce the response curve pass through all of the above mentioned circuits. Therefore the response curve shows exactly how the circuits will respond to received color signals. Let's examine how the modulated signal is produced and how the receiver circuits handle the signal.

Fig. 25 shows a block diagram of how the vsm signal is produced and how it is used for alignment. A single frequency generator tuned to 45.75 mc supplies one signal to the rf modulator. A video sweep generator supplies a 0 to 5 mc swept signal to the modulator. (If your sweep generator cannot supply a 0 to 5 mc signal, set the center frequency to 3.58 mc and vary the signal 1 mc above and below this value.) These two frequencies heterodyne in the modulator producing sum and difference frequencies. The 40.75 mc to 45.75 mc difference frequency lies in the passband of the video i-f amplifier. Also, the original 45.75-mc signal is accepted by the video i-f amplifier. The sum frequencies lie above the passband of the amplifier while the original 0 to 5 mc signal is rejected because it falls far below the amplifier passband.

The video sweep modulation signal is applied to the video i-f amplifier of the color receiver. The video amplifier accepts and amplifies a band of frequencies including the 40.75 to 45.75 difference signal. The video detector (picture detector) detects the original 0 to 5 mc swept modulating signal and applies it to the video amplifier. Notice that the signal that is recovered at the video detector is a video signal varying in frequency from 0 to 5 mc. In the usual video alignment technique the signal recovered at the video detector is a dc voltage that varies in amplitude at a 60-cycle rate. In the vsm technique, the signal recovered at the video detector is the original 0 to 5 mc modulating signal.

The 0 to 5 mc swept signal output of the video amplifier is applied to the color i-f (bandpass) amplifier. The bandpass amplifier responds to a band of frequencies centered around 3.58-mc. The output of the bandpass amplifier is applied to a detector and the output of the detector is displayed on the scope. The
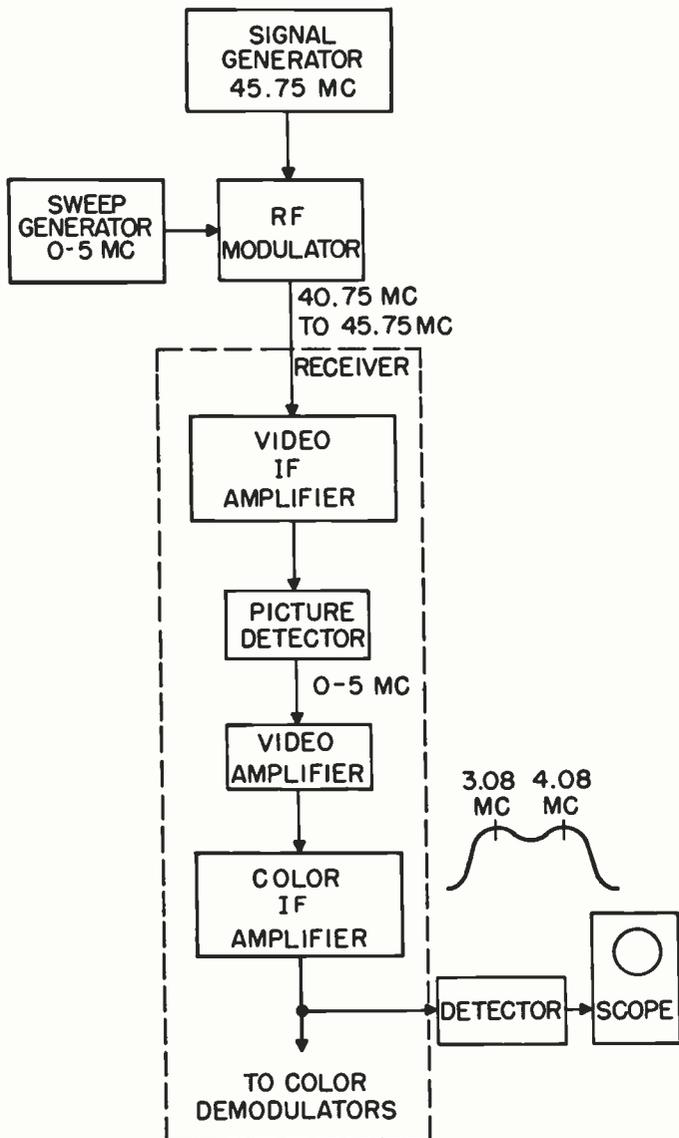
Fig. 25. Block diagram showing the scheme for generating and using the vsm alignment signal.

The 45.75-mc fixed frequency signal and the sweep generator signal are mixed in the diode of the modulator. The two original signals and the resultant sum and difference signals are coupled out through the 2200-pf capacitor. These signals are then applied to the grid of the mixer in the vhf tuner of the receiver being aligned. The rf stage of the tuner is disabled by applying a -15 volt bias in the tuner agc line. A -15 volt bias is also applied to the grid of the blanker tube. This prevents the blanker from disabling the bandpass amplifier during horizontal retrace and so gives a smooth curve on the scope.

As previously explained, the 45.75-mc signal and the swept difference signal passes through the i-f amplifier of the receiver. The video detector recovers the swept 0 to 5 mc modulating signal and applies it through the video amplifier to the bandpass amplifier. The bandpass amplifier amplifies this color frequency signal and applies it to the grids of the demodulator stages. The detector circuit shown in Fig. 26 is suitable for detecting the response curve of the signal. The detector rectifies the 0 to 5 mc signal and the scope displays a resultant response curve.

As we mentioned earlier, if your sweep generator cannot produce a 0 to 5 mc signal, set it at a center frequency of 3.58-mc and a sweep width of at least 1 mc each side of center frequency. The 3.58-mc signal will beat with the 45.75-mc signal and the difference signal will be 42.17 mc with sidebands 1 mc above and below this value. In the video detector in the receiver, the 42.17-mc signal will beat with the 45.75-mc signal

response curve varies in amplitude at a 60-cycle rate in accordance with the overall response of the circuits to the modulating signal.

Fig. 26 shows the rf modulator circuit for producing the vsm signal. The 45.75-mc fixed frequency signal is fed through the 27-ohm resistor and developed across the 75-ohm resistor. The sweep generator is set on the 0 to 5 mc range. The output of the sweep generator is fed through an absorption marker box. Absorption markers are more suitable for the video frequency range because they produce smaller markers than mixing frequencies at these low frequencies. An absorption marker is simply a high Q circuit tuned to a frequency within the video passband. The circuit absorbs or "sucks out" some energy at that frequency producing a marker. Markers are needed at 3.08 mc, 3.58 mc, and 4.08 mc. After passing through the absorption marker box, the sweep signal is applied through the 47-ohm resistor of the rf modulator circuit.

Fig. 26. RF Modulator and detector circuit used with vsm.

and produce a 3.58-mc signal with sidebands 1 mc above and below this value. Thus we will have a video signal varying in frequency from 2.58 mc to 4.58 mc. This signal when fed to the color i-f amplifier and viewed at the output of the color demodulator will produce the same type of response curve as shown in Fig. 27.

The generators require careful output adjustments to get a usable trace on the scope. Start with a sweep generator output at minimum. Measure i-f agc as you increase the output from the fixed frequency generator. Increase the output until i-f agc is normal for that receiver. Now turn up the output from the sweep generator and adjust for a 1-volt peak-to-peak waveform on the scope. Insert markers to be sure you are sweeping the correct video frequency range. Recheck i-f agc voltage. Decrease the fixed frequency generator signal if necessary. Check to make sure you are not overloading some of the circuits. Do this by raising and lowering the generator signals while observing the response curve. The amplitude of the response curve should change but the shape should not be affected.

Response Curve.

The circuits in the receiver should show an overall flat response to the swept signal from about 3.08 mc to 4.08 mc. As you recall, the color information is contained in sidebands above and below the 3.58-mc color subcarrier frequency. The passband of most color i-f amplifiers will extend only about 500 kc above and below 3.58 mc. Alignment instructions for the receiver you are aligning will show response curves. Fig. 27 shows a typical response curve. The top of the curve is not perfectly flat. The curve should be made as flat as possible consistent with the indicated bandpass of the curve. The chroma takeoff coil and the bandpass transformer are adjusted to produce the indicated response curve as nearly as possible.

3.08 MC   4.08 MC
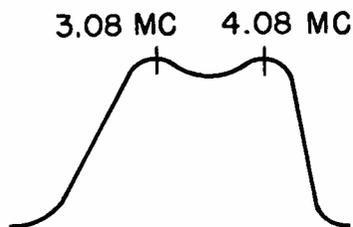
Fig. 27. Overall response curve of the i-f, video, and bandpass amplifiers produced by vsm alignment.

AFPC

In the shop alignment procedure for adjusting the automatic frequency and phase control (afpc) circuits of a color receiver, you use a color bar generator, an oscilloscope, and a vtvm. The main difference between this shop procedure and the field procedure is the use of the oscilloscope. By observing the color difference signals on the scope you can make a more accurate color phase adjustment. Also you are able to observe the relative amplitude of the color difference signals. The shop alignment procedure is rec-

ommended for troubleshooting in the afpc circuits and the demodulator circuits.

The afpc circuits are included in the typical color circuits shown in Fig. 28. The circuits we are concerned with are V703B, the 3.58-mc oscillator, V703A, the reactance control stage, and V705A, the phase detector circuit. The purpose of the alignment is to adjust the circuits so that a properly phased 3.58-mc reference signal, synchronized with the incoming burst signal, will be delivered to the color demodulator.

Connect the color bar generator to the antenna terminals. Adjust the receiver controls to produce a normal color picture on the bar pattern channel. Check for correct operation of the agc control. Adjust killer threshold control to disable the color killer stage (usually fully counterclockwise). This step is necessary in order to see the unsynchronized color bars on some receivers.

Oscillator Transformer Adjustment.

Connect the dc probe of a vtvm through a 470K-ohm resistor to pin 1 of V705A. Connect the vtvm common lead to chassis ground. Set the vtvm to read -dc volts on the 30-volt range. Connect a short jumper from grid pin 1 of V702 to ground. This shorts out the color burst signal and assures that the vtvm reading will be due entirely to the 3.58-mc oscillator signal. Adjust the core of the 3.58-mc oscillator transformer, T703, for maximum deflection on the vtvm. If the oscillator is not running, try a different setting of the reactance stage plate coil, L702, to start the oscillator and produce a vtvm reading. Readjust T703 for a maximum vtvm reading.

Phase Detector Transformer Peaking.

Remove the short from pin 1 of V702. This allows the burst signal to be developed in the burst transformer (plate circuit of the burst amplifier) and should cause the vtvm reading to increase. Adjust the slug in the burst transformer, T702, for maximum reading on the vtvm. This step tunes the burst transformer so maximum burst signal is coupled to the phase detector. Remove the vtvm from pin 1 of V705A.

Reactance Stage Plate Coil.

Ground the grid of the reactance stage. TP703 is provided on the chassis for grounding this circuit. The ground shorts out the correction voltage produced by the phase detector. Observe the picture tube. The color bars probably will be out of sync. If far out of sync the colors may be changing so rapidly that a white blur is produced and color will not be apparent. Adjust the reactance plate coil, L702, to produce solid colored color bars or until the colors drift very slowly. The 3.58-mc oscillator is now free-running at very nearly the correct frequency. The reference signal being furnished to the demodulators is of the correct frequency but its phase is not locked to the incoming burst signal. Therefore the color bars do not display the correct hues.

Remove the ground from TP703. The colors in the bars should lock solidly in response to the correction voltage from the phase detector. Check color sync as you reduce the color signal (color control). Or reduce the color signal at the color bar generator. The color should remain synced until the color almost completely
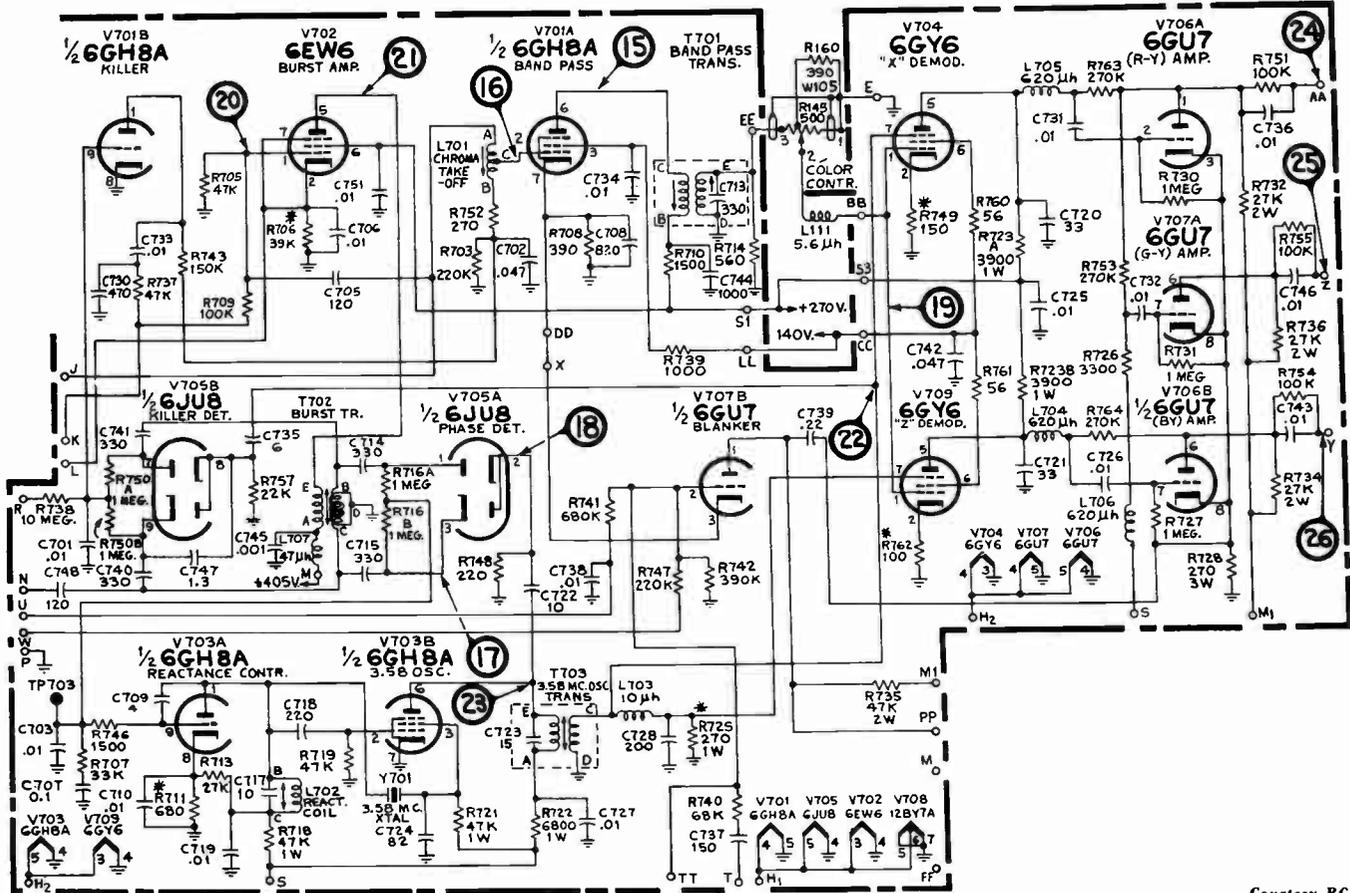
Fig. 28. Chroma circuitry of a color receiver.

fades out. If necessary readjust L703 for best color sync hold on a weak color signal.

Phase Adjustment.

Adjust the phase detector transformer, T702 (labeled burst transformer in Fig. 28), for correct colors in the bar pattern. Set the hue (tint) control at its midposition. Connect the vertical input of an oscilloscope to terminal AA in Fig. 28. This is the point that connects to the grid of the red gun of the picture tube. Adjust the scope horizontal frequency to display one horizontal line. (About 15750 cps.) The waveform shows the R - Y color difference signal. Adjust the burst transformer slug so the sixth bar is zero as shown in Fig. 29A. The bar pattern on the receiver should now appear with the correct hues in each bar.

Rotate the hue (tint) control to its extreme counterclockwise and extreme clockwise position. This should produce a total phase change of + and - 30° from the correct phase of the R - Y display on the scope. Fig. 29B shows the R - Y display with a -30° phase shift. Notice the fifth bar is nulled (zero) instead of the sixth bar. Fig. 29C shows the R - Y display with a +30° phase shift. Now the seventh bar is nulled. This is the normal range of the control provided by the hue (tint) control. The total phase shift produced by the control varies with different receivers. The important thing is to have the control centered in the adjustment range so the customer can change the picture hues about the same amount in either direction.

Readjust the killer threshold. Tune the receiver to an unused channel to obtain a snowy raster. Adjust the killer threshold adjustment to a point where color in the snow just disappears. Recheck the operation on a
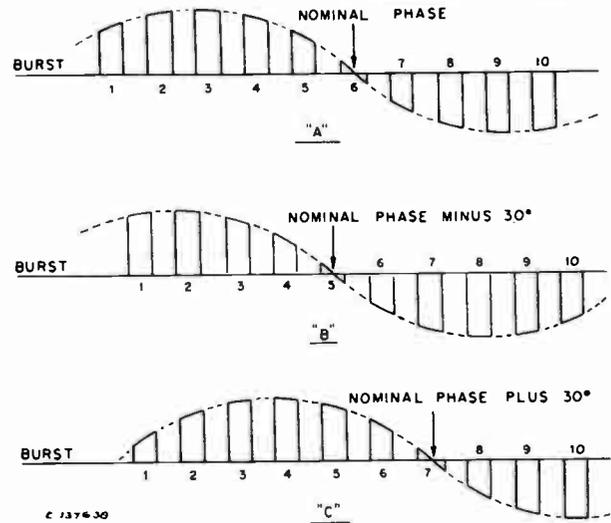
Fig. 29. R-Y waveform showing 6th bar nulled with hue (tint) control properly set (A), with hue control rotated for a minus 30 phase shift (5th bar nulled) (B), and with hue control rotated for a plus 30 phase shift (7th bar nulled) (C).

weak color bar signal, or color station. The killer circuit should not kill the color until the signal is too weak to give a usable picture.

Color Difference Signal Waveforms.

The above adjustments complete the shop alignment of the afpc circuits. At this point it is convenient to check the phase and amplitude of the other two color difference signals. This is an excellent check to assure yourself that the demodulators and color difference amplifiers are working correctly. The grids of the other two guns of the picture tube are easily identified. In most receivers the grid leads from the picture tube socket are colored to correspond to the colors produced by that gun. Therefore you can simply trace the red, green, and blue leads from the picture tube socket to the color board to locate suitable places to attach the scope probe.

Fig. 30 shows the phase and relative amplitude of the three color difference signals for one particular color receiver. The service literature for most receivers will give similar waveforms. The phase of each of the three color difference signals should be the same for every receiver when the difference signals are produced by a keyed rainbow pattern generator. However, the amplitude of each color difference waveform can vary for different receivers. The amplitude variations have to do with the efficiency of the color phosphors used in the picture tube and with the picture tube circuitry.
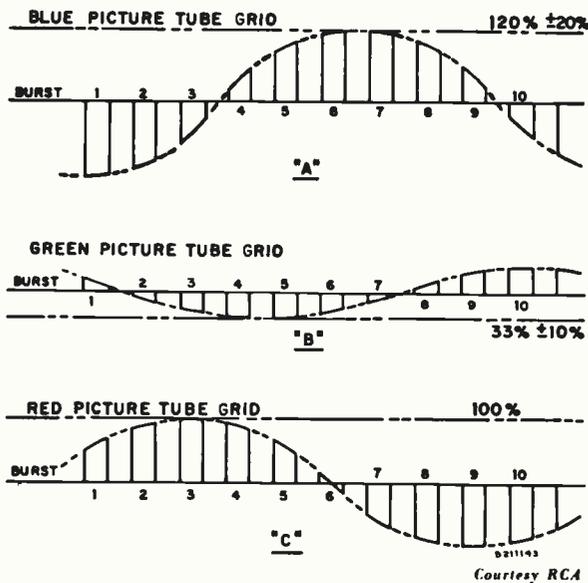
Fig. 30. Relative amplitude and phase of colors difference signals at the grids of the picture tube, blue gun grid (A), green gun grid (B), and red gun grid (C).

Set up your scope while viewing the R – Y color difference signal. Adjust the scope horizontal frequency to view one complete waveform. Identify the horizontal blanking pulses in the ten bars in the pattern. Note that the sixth bar is nulled. If necessary touch the hue (tint) control to exactly null the sixth bar. Adjust the vertical gain to produce a peak-to-peak waveform of some convenient measured height – for example,

one inch. This represents 100% amplitude as shown in Fig. 30C. Move the scope probe to the green picture tube grid. Do not touch the scope gain. The G – Y waveform should be about one-third the height (33%) of the R – Y waveform. Notice that it is permissible for the amplitude to vary 10% above or below the amplitude shown. The phase of the waveform should correspond very closely to that shown in Fig. 30B.

Next move the scope probe to the blue gun grid and observe the B – Y waveform. This waveform should be 20% higher than the R – Y waveform as shown in Fig. 29A. It has a tolerance of ± 20%. Again the phase of the waveform should be correct.

If the three waveforms are correct within the specified limits indicated, you can feel sure that the demodulators and the color difference amplifiers are working correctly. If the waveforms are not correct you should then signal trace in the circuits to isolate the fault. It might be well to mention that the quality of your scope is unimportant when comparing the three color difference signals. Deficiencies in the scope may affect the shape and amplitude of the signal but it will affect all three waveforms the same. Since you are comparing the three waveforms produced by your scope, the scope deficiencies will not affect the validity of your check. This is quite different from taking circuit waveforms where you are trying to reproduce the waveforms shown in the service literature. Here deficiencies of your scope may prevent you from getting the correct waveform even if the circuit is perfect.

SELF-TEST QUESTIONS

(al) Why is the response curve of the color i-f amplifier usually not flat?

(am) Can misalignment of the video i-f amplifier affect the hue of the displayed colors?

(an) What adjustment to the afpc circuit needs to be made if the hue (tint) control cannot be rotated far enough to produce good flesh tones?

(ao) In the vsm alignment technique, what is the signal recovered by the video detector?

(ap) What is the approximate center frequency of the band of frequencies amplified by the color i-f amplifier?

(aq) Why is the blanker stage disabled during color i-f alignment?

(ar) In the vsm technique, how does the swept video signal (0 to 5 mc) appear in the video i-f circuits?

(as) What kind of markers are most suitable for marking frequency points on a video response curve?

(at) Why is a coupling capacitor usually used at the end of a generator cable when coupling a signal into receiver circuitry?

(au) What position should the hue (tint) control be set at while making the phase adjustment?

(av) Why is it necessary to disable the color killer stage on some receivers in order to see an unsynchronized color bar pattern?

(aw) What adjustment needs to be made when the colors in the bar pattern are stationary but the

bars display the wrong hues?

(ax) When viewing the R - Y signal on a scope, which bar should be nulled (zero) when the hue control is properly set?

(ay) What is the normal range of a hue (tint) control on most receivers?

(az) Where is a convenient place to view the color difference signals on most color receivers?

Alignment as a Servicing Tool

Earlier in this lesson we pointed out that circuits seldom get out of alignment so the need for alignment seldom arises. As a result many technicians either never learn alignment techniques well or they let their skill become rusty from lack of practice. You can develop your alignment skill into a powerful servicing tool. The only requirement is that you practice alignment procedures regularly. If you will take the time to become very familiar with your alignment equipment, the actual procedures do not take long to perform.

Alignment is a servicing tool that is useful for particular kinds of trouble. The broad band, high frequency circuits in a television receiver cannot be adequately evaluated by any method other than alignment. Voltage and resistance readings will uncover simple defects in these circuits but many circuit defects will not change these readings. A defect that causes loss of signal gain at only some frequencies is an example. The low amplitude signals in the early stages of a TV receiver makes signal tracing difficult particularly if the circuit is defective. The use of alignment equipment enables you to adjust the size of the signal and make it large enough to drive through a partially defective stage.

Alignment can be used as a step in isolating a defect. When a circuit can be properly aligned, it is eliminated as a possible defective circuit. Checking the alignment, whether or not any adjustments are made, gives a definite indication whether or not the circuit is performing properly.

Performing alignment procedures increases your understanding of circuit operation. When you set up for alignment on an unfamiliar circuit you are forced to examine circuit details. Your attention is directed to the operating frequency, bias voltages, and circuit input and output impedances. After you have aligned a circuit you have a better grasp of how the circuit performs its intended job.

Get your initial alignment experience on receivers that are operating correctly. The technician who has had very little alignment experience can get it quickly by setting up for alignment on repaired sets. Make it a practice to check the alignment on every unfamiliar set that crosses your bench. At first you may have to spend an hour or so with each set. New problems will come up with each job. Each time you perform the setup, the job will go faster and easier. You will develop complete understanding of the capabilities and limitations of your alignment equipment. You will build and save test couplers, attenuator pads, and detector networks that will be useful on later alignment jobs.

At first you may want to only set up the equipment and get the correct waveforms on the scope. As time permits, identify the adjustment points. Move an adjustment only a small amount and observe the results. Then return the adjustment to its initial setting. The response curve will almost never be perfect when you check the alignment on a receiver that is operating correctly. Try to improve the shape of the response curve by touching up the adjustments. Be sure you do not make a radical change in the setting of an adjustment. If it appears that an adjustment requires several turns to affect an improvement in the waveshape, check to be sure you are on the correct adjustment. Remember that the set was producing a good picture before you started checking. It is unlikely that any adjustment is very far out. Recheck the setup, especially bias voltages. Check the signal amplitude to be sure you are not overloading the circuit or the scope.

Practicing the above suggested procedure will give you a feel for the way a receiver responds to adjustment. Note the settings on your alignment equipment when you get the equipment set up properly. For example, where is the sweep generator attenuator set when you get the correct response curve on a three stage video i-f receiver using an ungrounded shield to radiate the signal into the tuner mixer tube? Is it different on a two stage video i-f? Where should it be set when aligning a three stage transistor i-f amplifier? Knowing the normal equipment settings is of tremendous value when you set up to align a defective receiver. You are then able to judge if the set is showing average or low gain.

The experience you get practicing the alignment setup on working receivers will help you with both troubleshooting and alignment. When you get a receiver that needs alignment you will be able to confidently tackle the job and complete it quickly. When you use alignment procedures to help track down a marginal circuit defect you will know the circuits better and will be able to judge normal and abnormal circuit operation.

CARE OF ALIGNMENT EQUIPMENT

The signal generator, marker generators, and sweep generators are specialized pieces of equipment that find little use other than for alignment. Other devices used in alignment such as an oscilloscope, bias box, and test leads are regularly used in other shop service work. Every piece of equipment used in alignment work should be in perfect condition. Frayed connections on clip leads, poor ground connections on coaxial cables and poorly calibrated or unstable generators can turn a routine alignment job into a nightmare. Poorly maintained test equipment will not only waste time on the alignment job, but will also produce inferior results.

Provide a separate storage place for your alignment equipment in your shop. In a small shop, one end of a bench shelf can be adequate. In a large shop you may want to equip a mobile cart with all necessary alignment equipment. The cart can then be moved to a bench position where a set needs alignment. In any case keep specialized alignment equipment separate where it will not be used or damaged in other service work.

Make up separate test leads, grounding straps, attenuator pads, and test couplers. Keep these items with your alignment equipment and use them only for alignment. The limited use they get in alignment work will insure that they will remain in good repair. By always using the same test leads, couplers, detectors, etc., your alignment results will be more uniform and it will be easier to spot errors in your setup. Of course it is not practical to have a scope, vtvm, and bias suppliers that are used only for alignment but many small items can be made up at reasonable cost.

The calibration of alignment equipment should be handled as a routine check. A signal generator that is improperly calibrated is probably worse than one that is not working at all. If you rely on the settings of a generator that is not calibrated, you may end up with a receiver that is farther out of alignment than when you started.

The operation manuals that are supplied with test equipment almost always have a calibration and maintenance section. Spend a little time studying the circuitry. Run through the calibration procedure. Most test instruments are not nearly as complicated as a TV receiver. If the performance of a generator shows signs of deteriorating, troubleshoot the instrument. You will probably find the trouble to be simply a weak tube or an electrolytic capacitor with a reduced capacitance. Check the terminal posts to be sure they are tight. On some instruments they become loosened by repeated connecting and disconnecting test leads. This in turn can cause intermittent or reduced output signals. Any time spent in maintaining your alignment equipment will be more than repaid in quicker and more accurate alignment jobs.

SIGNAL INJECTION

Alignment procedures can be effectively used as a signal injection method of troubleshooting in the signal path sections of a TV receiver. This includes the tuner, video i-f, sound i-f, video amplifier, and color i-f sections of a receiver. You simply use the alignment equipment to provide the correct frequency signal handled by that section of the receiver and you use the scope or vtvm as a response indicator. When you make the alignment setup in accordance with service literature for that set, you can thoroughly check the operation of that section of the receiver. Let's examine some troubleshooting examples using alignment procedures.

Video I-F.

You have a receiver that produces almost no picture. Sound is fair. Raster is normal. Tube substitution does not improve operation. On the strongest channel you can see a faint picture without any snow. With the set on the bench you check agc voltage with your vtvm, and the input to the video amplifier with your oscilloscope. AGC is normal, that is, a slight negative voltage due to a very small detected video signal. The scope shows a very small video signal at the grid of the video amplifier when tuned to the strongest station. You put a demodulator probe on the scope

and view waveforms at the grid and plates of the video i-f amplifier stages. The signals are too small to identify. However, there appears to be an output from the tuner to the grid of the first i-f stage. You measure plate, screen, and grid voltages on the first i-f stage and find the voltages normal. Also you read normal B+ voltage to the tuner.

From the above tests you feel sure that the trouble is in either the tuner or the first i-f stage. You know that the mixer stage in the tuner is working because you get sound and a faint picture. Next, you disconnect the antenna and loop the lead-in around the mixer tube. This effectively bypasses the rf stage. You can no longer get the faint picture and now you have no sound. This is an indication that the trouble is not in the rf amplifier of the tuner. If the i-f section was working properly you would get a fair picture on a strong station when you coupled the antenna signal into the mixer stage.

This is a good type of trouble to use alignment troubleshooting. Other methods could of course be used. You are working in an area where the normal signal amplitudes are small and the circuits are tuned to specific frequencies. Your test probes can seriously affect the signal at these points. Even an isolation probe on the scope will have some effect. You set up the receiver for sweep i-f alignment in accordance with the service literature for that set. The scope is connected to the output of the video detector. You apply the specified bias to the agc line with a bias box. Inject the rf sweep (swept i-f frequency) output to a test point on the tuner that injects the signal to the grid of the mixer stage. You find that the attenuator on the generator must be set to minimum (maximum signal output) to get a useable response indication on the scope. With a demodulator probe you check the signal at the plates and grids of the video i-f stages. The signals are proportionately smaller as you work back toward the input. Since the signal is smaller than you would expect at the grid of the first i-f, you suspect the mixer stage in the tuner or the circuitry between the mixer stage and the first i-f.

Fig. 31 shows a partial schematic of the input circuit at the i-f amplifier. You move your scope demodulator probe to the point where the shielded cable
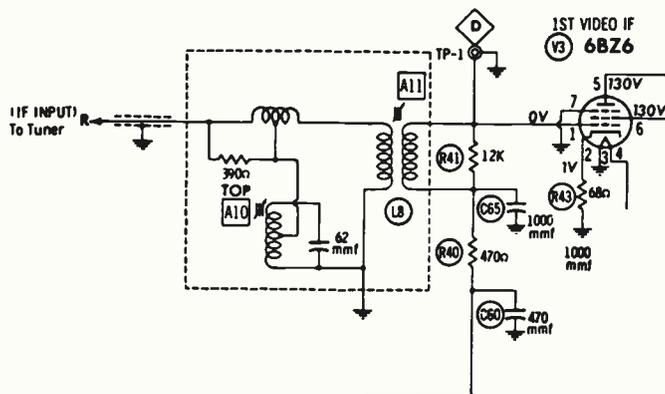
Courtesy Howard W. Sams, Inc.

Fig. 31. Input circuitry to the 1st video i-f amplifier of a TV receiver.

from the tuner connects into the i-f circuitry. The waveform here is larger than at the grid of V_3 but it is not as large as it should be. Next, you disconnect the tuner input from the circuit. The scope now shows a large signal from the tuner. This indicates that the defective circuitry is in the trap or the transformer, L_8. (In this case the primary of L_8 was shorted to ground). Since this circuitry is contained in a single shield can, you replace the entire unit. A very small sweep signal (almost maximum attenuation of the sweep generator) now produces a good response curve at the output of the video detector. You run through the i-f alignment procedure to improve the shape of the response curve and the job is completed.

Oscillations in the video i-f amplifiers is another defect that can be located by alignment techniques. The condition may range from momentary oscillations under certain signal conditions to continuous oscillation that completely blocks out the picture. If one or more i-f stages oscillate continuously, the high amplitude oscillations produce a large negative agc voltage that blocks the signal. The result will be a blank screen. Marginal oscillations produce picture defects similar to interference that breaks up the signal. The circuit may oscillate only on signal peaks. Or, weak signals that allow maximum gain of the stages may produce an oscillatory condition.

During alignment, these conditions can be simulated by reducing agc bias and by varying the signal strength. The response curve will flatten, peak, or saturate when the i-f oscillates. This may occur at only one point on the response curve, indicating that the circuit is oscillatory for that one frequency. Once you set up the conditions that produce the oscillations you can use standard troubleshooting techniques to locate the feedback path and eliminate the oscillations.

The Tuner.

Alignment can be used to verify whether or not a tuner is defective. When you apply a sweep signal to the antenna terminal and observe the response curve at the output of the tuner, you are testing all of the tuner circuitry. A defect in the tuner will either attenuate the strength of the signal or distort the shape of the response curve. If the alignment setup produces the correct response curve, you have eliminated the tuner as a source of trouble.

If the response curve from the tuner is not correct, you can try to realign it. Before you do, recheck your setup to be absolutely sure it is correct; that good grounds are used between the set and the test equipment; and that you are not overloading any circuit with too large a signal. As you make each alignment adjustment, you should be able to see a distinct change in the shape or amplitude of some part of the curve. If one adjustment produces little or no change, look for defects in that part of the circuitry.

Poor sensitivity is indicated when a larger than normal signal is required to produce a useable response curve. In these cases the shape of the curve may be approximately correct. Also, all alignment adjustments will probably produce the expected change in the curve. Poor sensitivity can be caused by plate or screen resistors that have changed value; defective

antenna matching transformer (balun); or defective coupling circuits between the tuner stages. This type of defect may not affect the tuned circuits and therefore will not be uncovered by alignment procedures.

Video Amplifier.

Alignment techniques can be used to locate trouble in the video amplifier section of a receiver. These circuits normally do not have tuned circuits or adjustment points. However, the circuit does have an overall response to the video frequency. This response can be evaluated by sweeping the circuit with a suitable signal.

To observe the video amplifier response, apply a 0 to 5 mc sweep signal to the grid of the video amplifier. Connect a diode detector circuit such as shown in Fig. 23A to the output of the video amplifier. This will usually be the point that connects to the picture tube. Connect the detected output to the vertical input of the scope. Adjust the amplitude of the signal to produce a useable response curve. Most video amplifiers will produce a fairly flat response out to about 3 mc above which it will fall off sharply. Some black-and-white receivers will have a sound takeoff transformer combined with a sound trap in the video circuit. The trap will produce a sharp dip in the response curve at 4.5 mc.

Two types of defects will show up when you sweep the video circuits. Poor low frequency response will cause the curve to fall off at a lower than normal frequency. Ringing will produce peaks in the response curve. By observing the response curve you can quickly judge the effect of any tests and repairs that you make to the circuit.

Color Circuits.

Troubleshooting in the color circuits is best accomplished with the signal from a color bar generator. You recall that the afpc circuits could be aligned with a signal from the bar generator and that these alignment steps are useful in troubleshooting that portion of the color circuits. Other tests were given following the afpc alignment for checking the operation of the demodulators by observing the recovered color difference signals.

The color bar generator signal is large enough to troubleshoot in the signal path of the color circuits. You can observe the color bursts and the color signal directly on your oscilloscope at the points in the burst amplifier and in the bandpass amplifier. Therefore, alignment techniques are not needed for signal tracing in these circuits. For most defects in the color signal path, the known quality color bar pattern signal will prove the easiest signal to work with.

Alignment techniques should be resorted to for troubleshooting only when you suspect misalignment in the color circuits. Use it to check the bandpass of the color i-f circuits. Use overall alignment (video sweep modulation) to check for the cause of color distortion.

Another color defect that can be located by alignment is the presence of excessive sound in the color signal. This usually shows up as an excessive 920-kc beat pattern that cannot be satisfactorily eliminated with fine tuning. The cause may be a misadjusted

sound trap. Use video i-f alignment to check the 41.25-mc sound traps in the video i-f circuits. Many color receivers have a 4.5-mc trap associated with the picture detector circuit. This trap is normally adjusted by viewing the screen. You simply tune far enough off channel to produce a visible 4.5-mc grain in the picture (preferably black-and-white programs). Then adjust the 4.5-mc trap for minimum grain.

SELF-TEST QUESTIONS

(ba) What must you do to make alignment procedures a useful servicing tool?

(bb) Alignment procedures are a useful troubleshooting procedure for what types of TV troubles?

(bc) How can you get experience so you know what alignment results to expect on a TV receiver?

(bd) What important maintenance step should be performed regularly on alignment generators?

(be) Why should specialized alignment equipment be separately stored in your shop?

(bf) Where can you find frequency calibration data for your alignment generators?

(bg) How can you use alignment procedures as a signal injection method of troubleshooting?

(bh) Is troubleshooting by alignment procedures limited to the signal path sections of a receiver?

(bi) What is the most reliable method of evaluating the operation of a broadband amplifier circuit?

(bj) What is indicated if a response curve shows a pronounced dip at one point on the curve?

(bk) During alignment, the scope trace suddenly moves off the screen and returns as a straight line instead of a response curve. What probably happened?

(bl) What kind of a signal is most useful for troubleshooting in the color circuits of a receiver?

(bm) How do you adjust the 4.5-mc trap in the video circuit of a receiver?

(bn) When sweeping the video amplifier of a receiver, what would cause a high peak on the curve at one point in the passband?

ANSWERS TO SELF-TEST QUESTIONS

(a) About 6 mc, 41.25 mc to 47.25 mc.

(b) To prevent interference in the picture caused by too large a sound signal.

(c) To trap out interference from the sound carrier of an adjacent (lower) channel.

(d) Adjustable coils.

(e) Peak alignment.

(f) Sweep alignment.

(g) VTVM.

(h) A plot of amplifier gain for the various frequencies in the passband. Vertical deflection shows relative gain while horizontal position represents particular frequencies.

(i) Post injection technique. This includes any marker system where the marker frequency is applied into the circuit at a point beyond the sweep signal injection point.

(j) To prevent the coupling from distorting the waveform by loading the circuit under test.

(k) Phase control.

(l) The loose coupling of the shield prevents loading the mixer plate circuit.

(m) To isolate the detector circuit from the capacitance of the scope probe.

(n) Touch the chassis and test instrument while observing the response curve to see if the curve changes shape.

(o) Prevents radiated sweep signals from putting spikes on the response curve.

(p) To protect yourself from electrical shock and to prevent damaging test equipment. Also it is difficult to get suitable ground connections without an isolation transformer.

(q) So the circuits will stabilize at their operating temperatures. Tuned circuits and oscillators change slightly from cold to normal operating temperatures.

(r) Vary the strength of the generator signal and vary agc bias. In both cases the amplitude of the response curve should change but the shape should not change.

(s) A large marker generator signal can overload the circuits under test. Large markers can distort the response curve or obscure the real shape of the curve.

(t) Peak alignment. This will bring the set into approximate alignment. Then sweep alignment can be used to improve the curve.

(u) Minimum. The trap is designed to provide attenuation of the frequency to which it is tuned. Therefore the vtvm reading will be minimum when the trap is correctly set.

(v) Because of the higher frequencies involved.

(w) Local oscillator adjustment. On some tuners the local oscillator tracking adjustment must be routinely made when replacing tuner tubes.

(x) A signal from the TV station for that channel. The oscillator is adjusted to produce best picture and sound.

(y) The mixer stage provides isolation. A demodulator probe would tend to detune the high frequency rf circuits.

(z) At the high frequencies used in rf alignment, small values of inductance and capacitance become significant. Good grounds and short connecting leads keep stray capacitance and ground loops to a minimum.

(aa) Adjusting the inductance of a coil by spreading or squeezing the turns of the coil.

(ab) UHF tuners are compactly constructed so the alignment does not tend to change.

(ac) Video detector in black-and-white receivers. In a separate sound detector in color receivers. The 4.5-mc sound i-f is the difference signal produced by beating the video i-f sound carrier (41.25 mc) against the video i-f picture carrier (45.75 mc).

(ad) Sound i-f and sound detector circuits.

(ae) TV signal path circuits through the tuner and video i-f amplifier, and especially the sound

carrier (41.25 mc) traps in the video i-f amplifier.

(af) Mistune the fine tuning so the 4.5-mc grain is clearly visible in the picture. Then tune the 4.5-mc trap for minimum grain in the picture.

(ag) The received signal must be weak enough so it does not produce limiting in the sound detector circuits.

(ah) Narrow band. The circuits produce a single peaked response, only a few hundred kilocycles wide.

(ai) The TV program, because the 4.5 mc difference between the sound and picture carrier is accurately maintained at the TV station.

(aj) 4.5 mc.

(ak) Frequency modulation.

(al) It is shaped to compensate for the unequal response experienced by the color signal in the video i-f amplifier.

(am) Yes. Color distortion can be caused by misalignment in either the color i-f or the video i-f circuits.

(an) Phase adjustment. The hue (tint) control is centered, then the phase of the reference signal is adjusted to produce the correct hues.

(ao) A signal that varies at the sweep rate between 0 and 5 mc.

(ap) 3.58 mc. The color i-f amplifier is designed to amplify the color signal that is carried in the sidebands of the 3.58-mc color subcarrier frequency.

(aq) The blanker stage normally blanks the bandpass amplifier at the horizontal rate, while the response curve is displayed at a 60-cycle rate. If the blanker was not disabled, the blanking pulses would appear on the response curve.

(ar) As amplitude modulation of the video i-f picture carrier (45.75 mc).

(as) Absorption type markers.

(at) To isolate the cable from any dc that may be present in the circuitry.

(au) Mid-position.

(av) The killer stage will bias off the bandpass amplifier if the 3.58-mc oscillator is not synced with the incoming color burst.

(aw) Phase Adjustment.

(ax) 6th bar.

(ay) 30° either side of the mid-position. That is, the control should shift the color one complete bar to the left and to the right of a bar.

(az) At the connections of the lead that go to the control grids of the color crt.

(ba) Practice alignment procedures regularly.

(bb) Defects in wideband signal circuit and circuitry where the normal signals are very small.

(bc) Set up for alignment of receivers that are operating correctly.

(bd) Check their frequency calibration.

(be) So it will not be used or damaged in regular shop work.

(bf) In the operation and maintenance manual furnished with the generator.

(bg) Set up for aligning the defective circuit. The alignment signal becomes the injected signal for troubleshooting.

(bh) In general, yes.

(bi) By viewing a response curve of the amplifier produced by sweep alignment techniques.

(bj) The frequency represented by the point of the dip is not being amplified by the circuit.

(bk) The circuit probably broke into oscillation and the large signal overloaded the scope.

(bl) Signal from a bar pattern generator.

(bm) Misadjust fine tuning so the 4.5-mc grain is clearly visible in the picture. Then adjust the 4.5-mc trap for minimum grain.

(bn) Excessive video peaking such as caused by an open damping resistor across a peaking coil.

LESSON QUESTIONS

Most students want to know their grades as soon as possible and mail their sets of answers immediately. Others, knowing they will finish the next lesson in a few days, send two sets at a time. Either way is acceptable, but don't hold answers too long; you may lose them. Don't wait to send in more than two sets at a time. You may run out of lessons before new ones arrive.

1. What alignment technique uses a single frequency signal to tune each tuned circuit to a specified frequency?

2. What signal is used to drive or synchronize the horizontal deflection of the oscilloscope in a sweep alignment setup?

3. What piece of test equipment is used to identify the frequency at various points on a response curve?

4. What can be done to get rid of noise on a response curve?

5. What must you do to the receiver B+ when you disable horizontal sweep during alignment?

6. When a coil form contains two adjustment slugs, what should be their relative position in the form?

7. As you try to adjust the rf circuits in a tuner, the circuit breaks into oscillation. What alignment adjustment needs to be made before you can properly tune the rf circuits?

8. What is the shape of the response curve produced by sweeping the sound detector?

9. What are two indications of misaligned color i-f circuits?

10. Which circuits of a TV receiver affect the response curve when video sweep modulation is used to align the color circuits of a receiver?

HE WON'T LET GO !

Off the coast of New England many years ago, a fishing boat was being tossed about in a rough sea. Suddenly a seaman noticed a young man clinging to the mast, lashed by the biting wind. In horror the seaman ran to the Captain and exclaimed. "Look, Captain, your son is up there in grave danger. If he lets go he'll be dashed to pieces!"

The Captain looked up calmly and replied, "He won't let go."

Here and there we find strong men who are masters of their own destinies. Whatever their futures shall be they know depends upon them and no one else. While others are willing to float with the tide, they swim upstream. They don't know defeat.

You've probably heard this philosophy before. But if only one man who reads this will do some soul-searching and say, "I won't let go," this page will be worthwhile. In time, this man will be a success. I hope it is you.

J. M. Smith

RADIO & TELEVISION DATA

for

RADIOTRICIANS* & TELETRICIANS*

(*Registered U. S. Patent Office)

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Especially for Members of the

NATIONAL RADIO INSTITUTE ALUMNI ASSOCIATION
Washington 9, D. C.

Compiled by John H. Battison,
Director of Education, National Radio Institute

The Inside Story About

Diagram labels:
ACCELERATING ANODES
DEFLECTION COILS
ION TRAP
FOCUS COIL
FLUORESCENT SCREEN
G₁
CATHODE
SPRING CONTACT TO DAG.
HEATER
INTERIOR DAG CONNECTED TO 2ND. ANODE IN GUN AND TO HIGH VOLTAGE CONNECTOR IN BULB.
EXTERIOR DAG, TOGETHER WITH GLASS DIELECTRIC AND INTERIOR DAG, MAKES HIGH VOLTAGE FILTER CONDENSER. EXTERIOR IS GROUNDED
HIGH VOLTAGE CONNECTOR
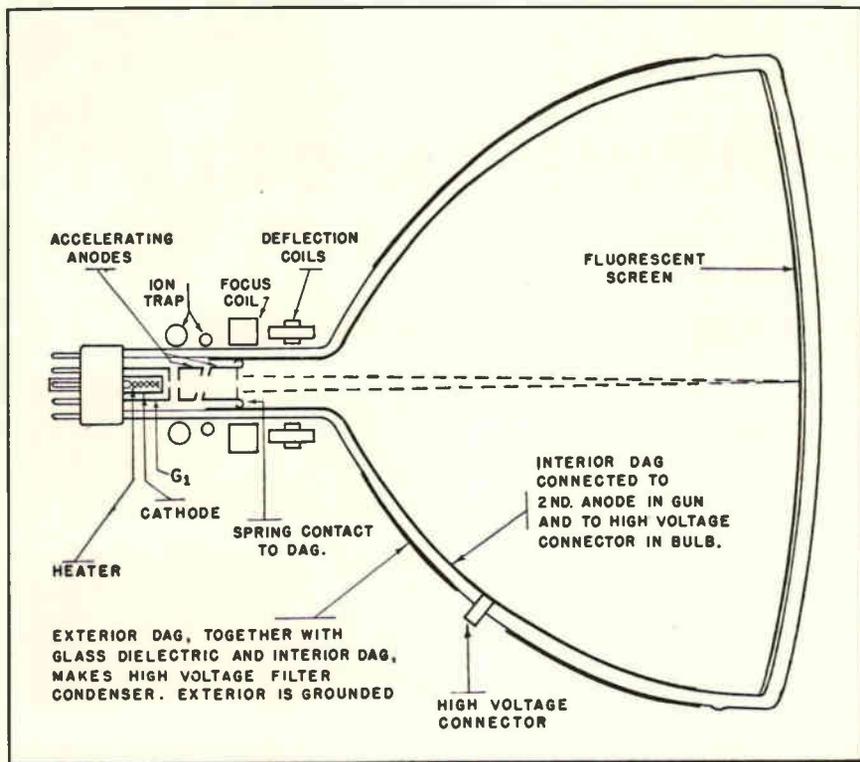
Answering the Serviceman's Questions Concerning CRT's. How They Are Made, Renecked, Reworked, Reactivated, etc. Facts to Consider in Buying and Selling Tubes for Replacement.

by Edward A. Campbell

● The business end of a TV set—and the largest and most expensive single component in it—is the picture tube. Dealers and set-owners alike have lavished a lot of concern on "the big tube," since its failure could mean a large outlay of money—to the dealer if the set were under contract, and to the set-owner if the receiver were out of warranty and not under contract. For the first two or three years of TV, these fears seemed somewhat groundless, for the failures were more or less infrequent. During the recent two or three years, however, more and more tubes are reaching old age, and the number of failures has greatly increased.

In order to combat the HCL with respect to picture tubes, there has been a flurry of activity in the fields of rebuilding, reactivating, brightening, etc.

While attempting to weigh the pros and cons of these various techniques, and to learn to interpret the condition of picture tubes as potential good or bad actors in the TV set, the retailer has been exposed to a welter of facts, half-truths, misconceptions, and in some cases, fictions.

The editors also hope to clear up some of the misconceptions, and to properly label opinions, theories and half-truths, to distinguish them from facts.

In order to properly cover the subject, we must first explain and define the processes which go into the making of the tubes.

In order to shorten this explanation, and at the same time show it in the clearest possible fashion, we have presented it in picture form on the next two pages. We have shown 20 stages in the making of high quality picture tubes, but actually there are many more steps—those shown are only among the most significant.

For instance, there are many steps to the making of the gun which we didn't have room to show: the manufacture of the individual elements, the coating of the cathode, test of the cathode's emissive qualities, assembly of the gun parts on glass bead or styrene supports, the sealing of the gun to the glass stem and the testing of the metal-to-glass seal, clearing the gun of impurities, etc.

You will notice in the picture story a lot of large and expensive machinery and many painstaking quality control tests and inspections. Picture tubes are large and heavy products (especially now that most production is devoted to 21's) and the mass production of uniform high quality tubes cannot be performed with a shoe-string operation.

Quality Controls Important

Tubes can be— and once were—made by hand. But mechanization under careful control insures that one tube will be just like the next one, and that pre-set standards of quality and long life will be met.

Each test and inspection is important, and many tubes are rejected because they do not come up to snuff. For instance, in the initial bulb inspection, there is a maximum permissible amount of bubbles and blisters in the faceplate —and the industry has established higher standards now than we had three years ago when tubes were smaller. Screen inspection is vital because a non-uniformity of coating thickness or of baking will produce bands or areas of lighter or darker color which will be very objectionable when in use. Air conditioning in the plant is important to keep impurities out of the bulb after it has been washed—and absolutely pure, distilled, de-ionized water is important in the washing for the same reason. Careful control of baking and cooling temperatures is necessary, not only to prevent bulbs from breaking in the oven, but also to prevent the development of stresses in the glass which would cause breakage during the exhaust process. Proper activation of the cathode and adequate aging are necessary in order to insure adequate emission and long life under actual use. There are some tubes which have been successfully reactivated which were successful because they weren't properly activated in the first place. Such tubes would go soft early in their lives.

But so much for the manufacturing processes—suffice it to say that there are no shortcuts to the making of good picture tubes.

Picture tube manufacture starts with the glass or glass-metal blank or bottle —and thereby hangs a tale. The contention of the rebuilders is that there is nothing old in a rebuilt except the bottle, and glass lasts a long time.

Television Picture Tubes

1 Picture tube manufacture starts with the empty bulb, envelope or "blank." Glass blanks are supplied to the tube maker by glass companies such as Corning and Kimble. First of many quality control tests and inspections is examination of the blank under a strong light for bubbles or other imperfections.—RCA

In another part of the plant, assembly of **2** the gun is performed—guns and bulbs will come together later in the process. Here complete guns (foreground) are being mounted on glass stems (to the right of the operator) containing leads for each tube element.—Haydu
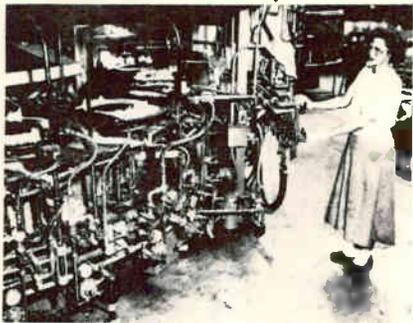
3 Metal cone tubes are usually assembled in the tube plant (as opposed to glass, which are received complete from the glass manufacturer). Here the glass faceplate is being fused onto the metal cone. The glass neck has been similarly fired onto the other end of the cone.—RCA

Close-ups of the gun after mounting on the **4** stem. The glass disc through which the leads go to the gun will later be sealed (by heat) into the neck of the tube. The tubulation at the left will then be used to exhaust the tube. This is an electrostatic focus "bent gun."—DuMont
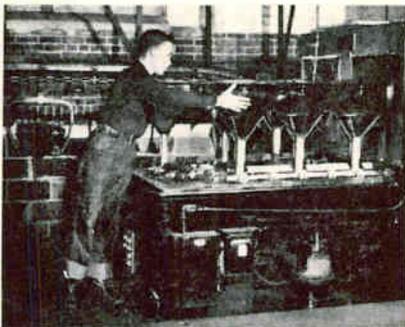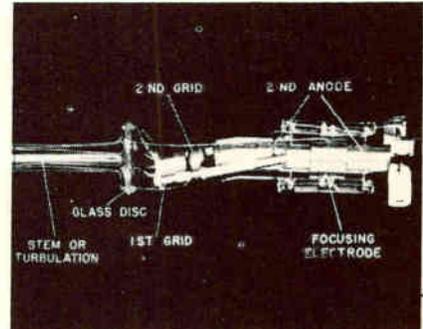
5 After inspection, bulbs are carefully washed with distilled, de-ionized water and strong chemical solutions. Here automatic conveyor takes bulbs into machine at right, where solutions will be sprayed up inside. After washing, the bulb is thoroughly dried.—National Union

Purity, uniformity and precise control are **6** important in the preparation of the phosphors which will make the screen inside the tube face. Here stainless steel vats and pipes with welded joints are used in an immaculate solution room. Small firms buy ready-mixed "slurry."—Sylvania

7 To make screen, phosphors are poured in bulb onto a "cushion" of pure water and allowed to settle. A binder in the solution makes it adhere. Bulbs are shown moving slowly along on huge settling conveyor in vibration-free, temperature and humidity controlled room.—RCA

At the end of the settling conveyor, bulbs **8** are very slowly decanted so as not to disturb screen which has been deposited. Cloudy water is washed out of neck, and then tube is dried with gentle warm air stream.—DuMont
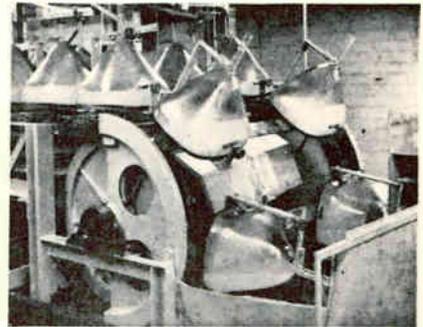
9 Next screens are inspected for uniform coating and for flaws under ultra-violet light which makes them fluoresce. Here screens are dried on way to inspector by a tube inside neck which blows warm air while bulbs move along an dollies.—Sylvania

Aluminized tubes require special handling. **10** After normal screen settling and drying, hot aluminum is evaporated onto back of screen and inside funnel while tube is evacuated. Bulb is then opened and goes through steps 14-18 (next page) like any other tube.—Rauland
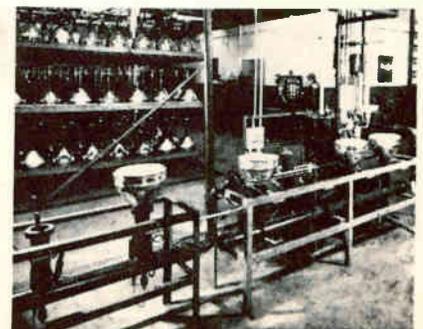
The Inside Story About
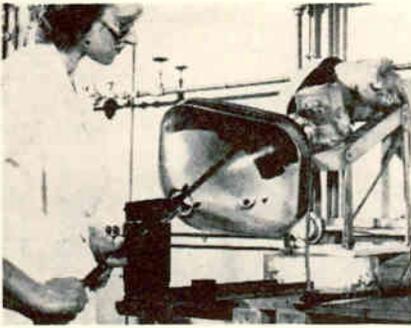
◄ **11** All metal and glass bulbs (except aluminized) are given an interior conductive coating of aquadag. Some firms float this graphite solution up into tube, most paint it by hand while tube is spinning, as in this photo. Dag contacts 2nd anode button.—General Electric

In this long, gas-fired oven, bulbs are **12** ➤ heated to bake the screen and aquadag and bake out impurities. In the long tunnel, bulbs are gradually brought up to a high temperature and then gradually cooled so they can be handled when they come out.—National Union
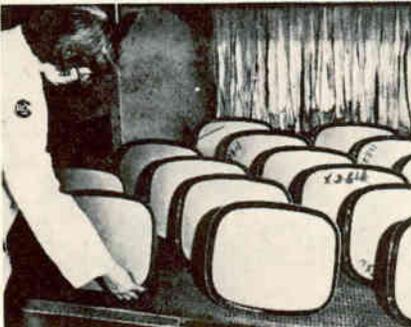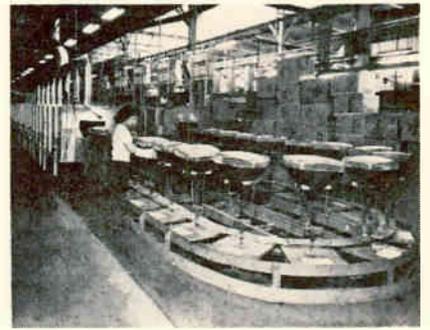
◄ **13** This is the entrance to a different type of oven (strips in background are to hold heat in). Process is the same as step 12, except that the oven is larger, allowing several tubes abreast to go in all at once.—RCA

Baked tubes are given another screen in- **14** ➤ spection and then go to the rotary machine in the background, where guns are sealed in. Gun is mounted on a jig, bulb neck is slipped over it, then gas jets seal the disc shown in step 4 to the neck of the bulb. Finished bulbs in foreground are ready for connection to the exhaust pump.—Thomas Electronics
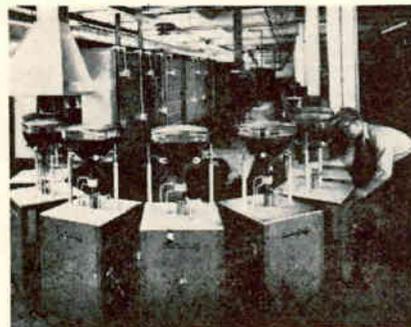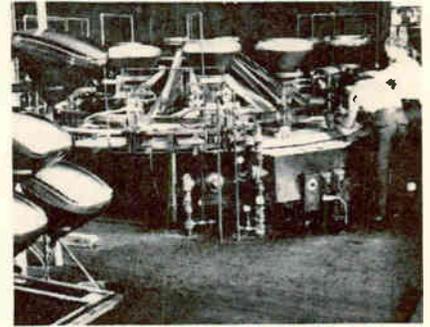
◄ **15** Individual exhaust dollies take bulbs into _nother oven where tubes are evacuated while heat drives gasses out of glass and gun. Filament voltage is applied to activate cathode, and RF heater (around neck) explodes a capsule of "getter" material which will further absorb gasses during life of tube.—Hytron

Coming out of exhaust oven, glass stem or **16** ➤ tubulation is simultaneously sealed up and snipped off, removing the tube from the exhaust pump. This is known as "tip off." Bulb is actually a vacuum tube now, complete except for base.—National Union
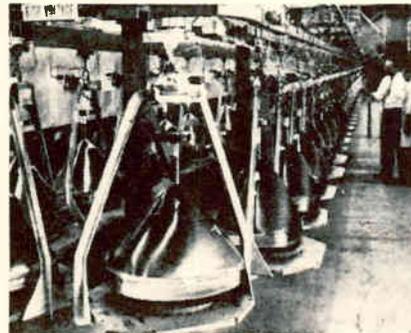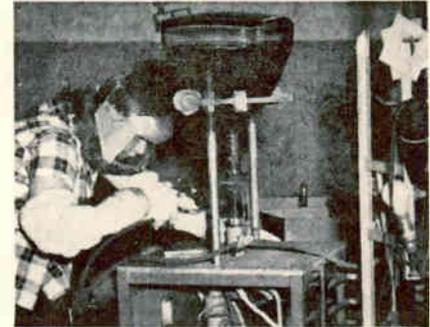
◄ **17** Next, tube base is soldered and cemented on, and then tube goes on these aging conveyors, where "accelerated" (higher than normal) voltages are applied to all elements to "set" cathode emission and age tube. A high voltage spark is applied to clear gun of impurities.—Sylvania

Tube is given an actual operating test, **18** ➤ covering spot focus and centering, brightness, color and operation with a real video signal. Shown here is the giant, metal-cone, 90-degree deflection 30-inch tube.—DuMont
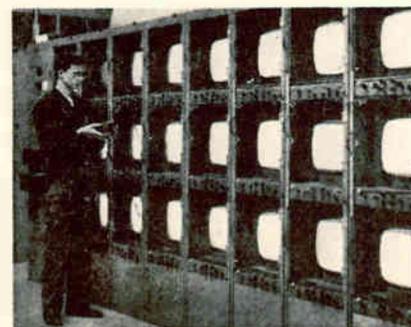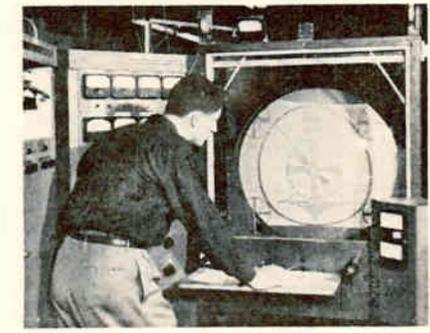
◄ **19** In most plants a certain percentage of tubes are withdrawn from production for various types of "life test." Some are on "accelerated" life (higher voltages), some are switched on and off periodically to simulate actual use, some have just a raster, some a pattern.—General Electric

After step 18, tubes in normal production **20** ➤ are put into storage for a while and then given another final test. The exteriors have been sprayed with dag, the type number stamped on, the faces polished, and then they are boxed. Here they are getting the final test before packaging.—General Electric
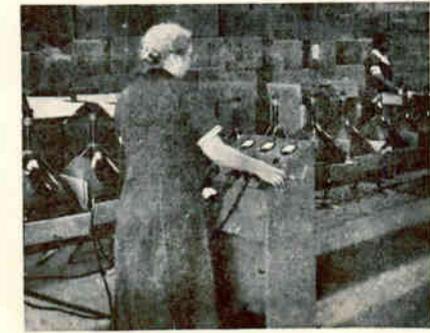
Television Picture Tubes

Before going into further details, we must define the term "rebuilt." We have investigated the field, and find (*not* to our surprise) that there is no hard and fast definition of that word.

We do find the word's meaning pretty well established by other uses, however. For instance, we have rebuilt vacuum cleaners, rebuilt typewriters, rebuilt carburetors and even rebuilt TV sets. But did you ever hear of a rebuilt bottle of "coke"? In other words, "rebuilt" usually conveys the idea of "reconditioned." If the contention we mentioned above were correct—namely, that there is nothing old in a "rebuilt" except the bottle—then the term "rebuilt" would obviously be a misnomer, just as it couldn't apply to "coke" in a re-used bottle. There are certain instances, however, where "rebuilt" could apply, as we will show later.

Here are some of the processes we have found in practice and how we would classify them: (1) In making glass blanks at the glass factory, some necks get broken, and the glass company puts new necks on before shipping the blanks to the tube maker. (2) In the making of tubes, some necks get broken, and new neck sections must be brazed on (at the tube factory); (3) In the making of tubes, some are rejected for one reason or other and are washed out and made over; (4) Some manufacturers of new tubes allow a trade-in allowance on "duds." The glass from the duds is re-used in the making of new tubes; (5) Some firms only make tubes from re-used bulbs, for the replacement market. These tubes are made the same way as are new ones, from the washed bottle onward, except that in some cases the firm does not have the full complement of equipment or trained personnel as do the larger tube makers. In a few cases, we have seen some tubes of this category sent out with the name of the original manufacturer still on them; (6) There are some firms who open the neck of a dud, repair the gun, and re-exhaust without washing and re-screening; (7) There are some firms who re-activate or spark bad tubes.

We would classify these types as follows: Types 1 & 2: re-necked; types 3, 4 and 5: re-worked tubes; type 6: rebuilt tubes, and type 7, reactivated.

Thus, we apply the term "rebuilt" only to tubes which have been re-conditioned, and not to tubes in which everything inside is new. As a matter of fact, many tube makers do not even go along with a word like "re-worked" (where everything inside is new) or any word with "re-" in it, since that implies that there is something inferior about the tube, when actually all their tubes must meet the same standards.

Why have we classified 3, 4 and 5 all the same way? Are they of equal merit? In some ways, yes, and in some
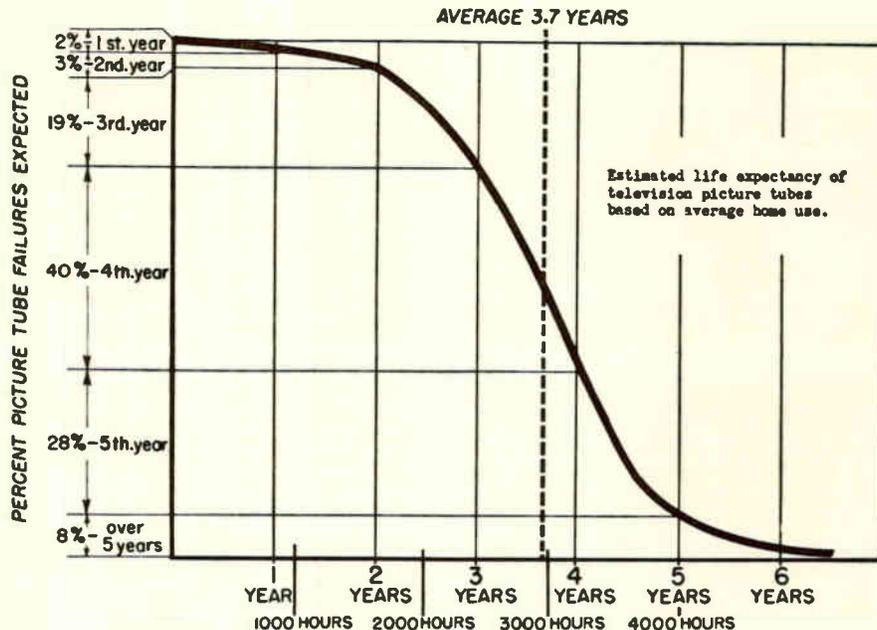
ways no. We find that most of the larger manufacturers, under certain conditions, do not distinguish between new and re-used glass. These conditions are that the re-used glass must have no deep scratches on the face, no scratches or bruises at all on the part of the funnel nearest the face, must conform to current industry specs on bubbles and blisters, must have no raster burns—must, in other words, be just as good as new glass.

Glass does not fatigue or weaken with age. It is, however, highly sensitive to scratches and bruises. The main trouble with a dud is that it is *liable* to have been mistreated, whereas a new tube is not. The only way you can be sure about the glass in the tube is to buy a brand which has a long reputation for quality, high standards and lots of know-how.

What about raster burns? Not all tubes get burns or discoloration on the face—but they can, especially if they have been in use a couple of years or more, and are 16-inch or larger tubes which operate at high 2nd anode voltages. A manufacturer with high standards would simply reject a bulb which had a raster burn.

How about a type 5 re-worked tube (from the firm which only makes replacement tubes with re-used blanks)? Does it have the same quality gun and screen as a good new tube? Was it as carefully screened, baked, sealed, exhausted, aged, tested? You'll have to depend on your knowledge of the manufacturer and his reputation in order to answer those questions. If you want to take a chance, it's your money. Or is it your customer's?

How can you tell whether a tube was re-worked without removing the name of the original manufacturer? Very

easily. If you only buy the original manufacturer's tubes from an authorized distributor of those tubes, you can be sure that he knows where he got them from.

Is it true that a re-worked tube has an *advantage* over a new one because the gasses normally given off in the life of the tube have been used up? No. Many gasses come from the gun, and a new gun would start the process all over again. In addition, old glass will start giving up gasses again if a tube is opened up and then re-evacuated.

Must a tube get a new screen once it's been opened? If the tube is opened suddenly, the inrush of air will blow the screen off, or at least parts of it. It is possible to control the inrush of air very carefully in order not to blow off the screen. But then you get dust, dirt and impurities in the bulb which cannot be washed out without washing off the screen. Most big manufacturers would consider this more trouble than its worth, even if there were no hazards.

Can tubes be reactivated? There are no statistics on this subject, but most authorities consulted seem to feel that at best this works in less than 1/3 of the cases, where the trouble is low emission. And even then, experience seems to show that the "success" is short-lived. If a tube's emission is so low that a satisfactory picture cannot be obtained, the tube is "over the hill," so to speak, and most expedients merely put off the inevitable. Naturally, expedients of this type wouldn't help if the filament were open (or any other element, for that matter) or if there were a dead short in the gun.

To sum up the case for and against rebuilt tubes, we believe that if we were

(Continued on following page)

AVERAGE 3.7 YEARS

PERCENT PICTURE TUBE FAILURES EXPECTED

- 2%—1 st. year
- 3%—2nd. year
- 19%—3rd. year
- 40%—4th. year
- 28%—5th. year
- 8%—over 5 years

Estimated life expectancy of television picture tubes based on average home use.

| 1 YEAR | 2 YEARS | 3 YEARS | 4 YEARS | 5 YEARS | 6 YEARS |

1000 HOURS 2000 HOURS 3000 HOURS 4000 HOURS

Improved Tri-Color TV Picture Tube

Chromatic Television Labs. has recently demonstrated an improved tri-color TV picture tube—the Chromatron—also known as the Lawrence tube. The tube's good resolution and excellent color fidelity proved to be comparable to, or better than, other types demonstrated to date. Unfortunately, facilities available for the demonstration limited the showing to standard color slides, which were made by Eastman Kodak for NTSC.

The single-gun, 22-in. tube, shown in Figs. 1 and 2, has a rectangular color face, 18.5 in. diagonally. Developmental work is also proceeding on a three-gun tube. In either case, dimensions, deflection components and deflection angle requirements of 70° to 90° are all similar to standard black-and-white tubes. Chromatic claims that the Chromatron utilizes 85% of the total electrons available, as compared to 14% possible with mask type units.

Cost for mass-produced tubes is expected to run about twice the amount for equivalent black-and-white types. On an individual sample basis, the metal-coned Chromatrons are presently being sold to laboratories for $500 each.

The recent demonstration of the single-gun tube employed the CBS color system, but it is not limited to any one system. It is possible to obtain very bright pictures with single-gun time-shared operation. Information received at press time indicates that further progress has been made in displaying NTSC signals on the single-gun tube using 3.6 mc switching and keying circuits for the color modulation. This advance is expected to be shown to the industry around the middle of Feb. 1953.

The tube of Fig. 1 contains 1000 vertical color phosphor strips with 500 grid wires. Still better performance should result from one developmental type which utilizes 1600 vertical strips, each 10 mils wide, and 20-mil wire spacing. One result of these narrow strips is a 300-line resolution.

Fig. 1: Front view shows 18.5-in. color face
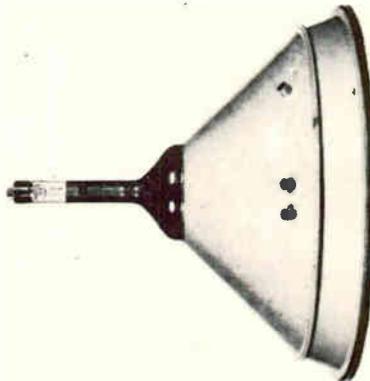
Fig. 2: Chromatron is built with metal cone

To review the operation of the Chromatron briefly, Fig. 3 shows how the electron beams in a three-gun tube pass through the color control grid and strike their respective red, green and blue phosphors. In the single-gun tube, Fig. 4, one electron beam passes through the double grid to strike the green phosphor strip. As the beam scans across one line, the potential on the grid wires is varied at proper time intervals in such a way that the electron beam is deflected slightly to impinge upon the red or blue strips, as desired.

It is of interest to note that the main horizontal deflection system (not shown) can cause the beam to scan
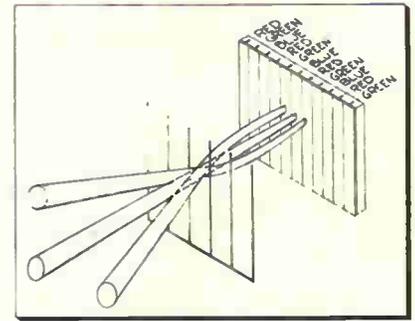
Fig. 3: Three-gun electron beams through grid

across the wires and phosphor strips at any angle to the wires, and still produce an excellent picture. The only thing that changes as the scan is changed from perpendicular through parallel to the wires, is that the basic picture element structure changes from line- to diamond- to checkerboard-shape. Since preferred element shape is in large measure a subjective reaction, more extensive personal reaction tests are planned.

Fig. 4: Grid structure for single-gun tube

TV Picture Tubes

(Continued from preceding page)

asked, "Which is better, a new or a rebuilt tube?" we would have to ask: What do you mean by "rebuilt"? Who made it? How did they do it? And so forth. Since in most cases the purchaser is unable to find answers for all these questions, he is faced with the alternatives of taking a chance on something he doesn't know, or sticking with something which has always been reliable.

We have dwelled at length in this article on the processes which go into tube manufacture and the necessity for them in order to get across the point that this is not something to "take a chance on." If a reliable tube manufacturer offers a tube with a weld mark on the neck, it is not a rebuilt, and not necessarily a re-worked tube. On the other hand, if such a manufacturer re-uses glass in making tubes, it is not incontrovertible evidence that all re-worked tubes are reliable. It is not even true that all tubes which are sold as rebuilt are actually re-worked from the bare glass up, as we pointed out above. From this point, the decision is up to the reader, but we believe that the answer should be fairly obvious.

SHOP HINT

Soldering Iron Stand

An extra soldering iron stand that takes up very little space can be made
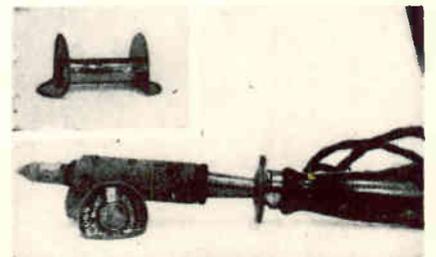
out of an empty solder spool by bending the ears flat, as shown. *Harvey Miller, Box 6, Danboro, Penna.*

Sound, No Raster

Fast Troubleshooting Procedure for Home Repair of Sets with Above Symptom

By Peter Orne

● This article is primarily concerned with the servicing of the television receiver in the customer's home when the symptom is *good sound, no raster*. In the preliminary check, all controls that the customer might have misadjusted should be turned through their range and effects noted. Special attention should be given to rarely-used switches that may accidentally have been turned. This applies particularly to the FM-TV switch on DuMont sets and the back panel phono-TV switch on many Philco and some RCA Victor models.

Care should be taken with the brightness and the drive controls if no raster is visible. These controls should be first turned through their entire range, then left in about the center of their range. In the case of the brightness control, mid-setting it is a precaution to prevent damage to the CRT if the ion magnet should be incorrectly positioned. It takes only a minute or so of operation with full brightness and incorrectly-set magnet to make the CRT gassy, or to burn a hole in the gun structure. In the case of the drive control, excessive drive may damage the horizontal output tube, the output transformer, or other components in this circuit.

It is important not to attempt readjustment of the ion magnet any sooner than is absolutely necessary. If the ion magnet has been reset and the trouble turns out to be elsewhere, the magnet may be out of position long enough to permit damage to the CRT before the serviceman remembers to readjust it.

Misadjusted Ion Magnet

Some symptoms definitely indicate a misadjusted ion magnet. In Rauland tubes, and in some rebuilt tubes, the aperture plate in the first anode is coated with a green phosphor to facilitate the ion magnet adjustment. If the phosphor glows when the brightness control is turned up, it indicates that the electron beam is hitting the first anode instead of passing through the aperture to the screen. In other CRT's the presence of

a bright bluish glow at one or two points on the neck of the tube indicates that the electron beam is hitting the neck, due to ion magnet misadjustment. In these two cases, immediate resetting of the ion magnet is indicated. In other cases, resetting should be deferred while likelier sources of trouble are checked.

The first logical test procedure is the inspection of the CRT filament. If the filament of the CRT is not lit, the trouble can only be a bad CRT or defective

Fig. 1 A) Straight gun. The axis of the gun is the same as that of the tube neck. B) Tilt gun. The gun's axis is tilted approximately 3 degrees from the axis of the CRT neck. C) Bent gun. The 1st anode (G₁) has a bend of app. 5°. Tubes employing tilted and bent guns use a single ion magnet; a double ion magnet is employed in CRT's with straight guns. (Courtesy, Capehart)

filament supply. The normal procedure with any bad tube would be to replace it, but since a good deal of mechanical labor is involved in the case of a CRT replacement, it is preferable to make certain first that the tube is really bad.

Measuring the CRT filament resistance (after removing the CRT socket) is the next logical step. If the filament resistance reads normal, the power supply becomes suspect. Note, however, that it is possible for the filament to read normal on the meter when cold and open-circuit when power is applied.

CRT replacement is therefore advisable if the supply voltages have been found normal. As far as the filament supply is concerned, the vast majority of sets use a filament winding on the power transformer. In most sets there is one filament winding for all the tubes except the rectifiers. If this winding is defective, the many unlit tube filaments present will point to the trouble. If the CRT is the only tube not lit, the trouble can lie in its socket or socket wiring.

CRT Unlit Due to Short

There are a number of sets where there is a separate winding for the CRT and damper tube, because their cathodes are at B+ potential and the cathode-to-filament potential must be kept low. In these sets, the filaments of the damper and CRT are returned to B+. A short in the damper circuit, or a shorted tube, may be responsible for the CRT not lighting. In some Emerson models the power amplifier is connected to the separate filament line referred to, since its cathode is at B+ potential in these sets. This special filament winding is apt to give trouble, since the transformer insulation may not be adequate. Incidentally, if such a separate winding is defective, it is generally more economical to install a small filament transformer than to replace the power transformer. The filament transformer should, if not internally well insulated, be mounted in such a way that it is insulated from chassis.

There are a number of sets with a transformerless power supply, in which the filaments are in series-parallel. Trouble in the filament circuit, such as bad ballast tubes or resistors, shorted filament bypass condensors, open filament chokes, tubes with open filaments or internal shorts, can cause the CRT to light dimly or not at all.

If the CRT filament lighting is normal, the next logical check is for high voltage at the CRT connector. The best way to make such a check is, of course, by using a high-voltage probe. The second best method lies in the use of a

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SHOP HINTS

Prolonging "Mike" Life

Moisture often gets inside crystal microphones (even though they are sealed against it) damaging the crystal element, with resultant loss of sensitivity and frequency response. When this happens, place the "mike" for twenty-four hours in a clean, dry airtight can containing one pound of fresh silica gel, and it will behave like new, with the beneficial effects lasting a long time. *Harry J. Miller, 607 Wynnewood Road, Phila. 31, Pa.*

Safety Trick

Whenever a hole is drilled in an appliance or its containing cabinet, the possibility is always present that the drill chuck may dent or otherwise mar the surface when the drill breaks through. To insure against this hazard, slide a rubber grommet over the bit and up to the chuck, to act as a buffer and cushion the blow. *Edward Mayover, 1501 N. 61st Street, Phila. 31, Pa.*

Preventing Capacitor Damage

Considerable damage to condensers may be caused by the heat of a soldering iron, especially where short leads are to be soldered. To reduce the amount of heat that reaches the condenser, grip the bare wire between it and the iron with a pair of pliers. This will divert most of the heat into the jaws of the pliers, but will not prevent or delay soldering, nor will the heat injure the condenser. *Harry J. Miller, 607 Wynnewood Road, Philadelphia 31, Pa.*

Trouble-Shooting Methods

CHECK CRT FILAMENT

- IF PURPLE GLOW IS SEEN IN LARGE PORTION OF NECK → **CRT IS GASSY; REPLACE**
- IF CRT FILAMENT IS PROPERLY LIT, BUT A GREEN OR BLUE GLOW IS SEEN IN NECK OF CRT → **RE-ADJUST ION MAGNET** → IF RASTER IS STILL ABSENT → **CHECK FOR SPARK AT CRT 2ND ANODE**
- IF CRT FILAMENT LIGHTING IS NORMAL → **CHECK FOR SPARK AT CRT 2ND ANODE**

- IF CRT FILAMENT IS UNLIT → **CHECK CRT FILAMENT RESISTANCE**
  - IF FILAMENT READS "OPEN" → **REPLACE CRT**
  - IF FILAMENT SHOWS CONTINUITY → **CHECK OTHER TUBE FILAMENTS**
- IF CRT FILAMENT SEEMS INSUFFICIENTLY LIT → **CHECK OTHER TUBE FILAMENTS**

- IF SOME TUBE FILAMENTS LIGHT WHILE OTHERS DON'T → **CHECK HEATER VOLTAGES ON THE UNLIT TUBES.**
  - IF FILAMENT CIRCUIT IS A SERIES ONE → **REPLACE THE BAD TUBE**
  - IF FILAMENT CIRCUIT IS A PARALLEL ONE → **TRANSFORMER IS PROBABLY DEFECTIVE**
- IF TUBE FILAMENTS ALL CHECK OKAY → **CHECK VOLTAGES ON CRT FILAMENTS**
  - IF FILAMENT VOLTAGE IS ABSENT → **TRANSFORMER IS PROBABLY DEFECTIVE**
  - IF FILAMENT VOLTAGE IS NORMAL → **TRY ANOTHER CRT, FILAMENT IS PROBABLY INTERMITTENT**

CHECK FOR SPARK AT CRT 2ND ANODE
- IF SPARK IS NORMAL → **RE-ADJUST ION MAGNET. IF THIS DOESN'T HELP TRY A NEW ION MAGNET** → IF THE RASTER REMAINS ABSENT → **CHECK VOLTAGES AT CRT SOCKET**
- IF SPARK IS ABSENT OR INSUFFICIENT → **CHECK FOR SPARK AT HV RECTIFIER PLATE**
  - IF SPARK IS ABSENT OR POOR → **REMOVE HV RECTIFIER PLATE CAP, AND CHECK SPARK AT CAP.**
- IF SPARK IS NOW OKAY → **TRY A NEW HV RECTIFIER TUBE**
  - IF SPARK AT HV RECTIFIER PLATE IS POOR → **CHECK FOR SPARK AT HV RECT PLATE WITH HV CONDENSER DISCONNECTED.**
    - IF SPARK REMAINS POOR → **SHOP REPAIR IS INDICATED**
    - IF SPARK IS NOW OKAY → **REPLACE HV CONDENSER**

CHECK VOLTAGES AT CRT SOCKET
- IF SPARK IS POOR OR ABSENT → **CHECK SPARK AT PLATE OF HOR. OUTPUT TUBE**
- IF GRID-CATHODE VOLTAGE IS INCORRECT → **REPLACE LAST VIDEO AMPLIFIER**
  - IF BIAS VOLTAGE REMAINS INCORRECT → **SHOP TROUBLE-SHOOTING OF BRIGHTNESS, FOCUS CIRCUITS INDICATED**
- IF VOLTAGES ARE OKAY → **REPLACE OR REPAIR CRT**
  - IF VOLTAGES ARE INCORRECT → **SHOP TROUBLE-SHOOTING OF BRIGHTNESS, FOCUS CIRCUITS INDICATED**

CHECK SPARK AT PLATE OF HOR. OUTPUT TUBE
- IF DC SPARK IS OBTAINED → **REPLACE IN TURN HOR. OSC., DISCHARGE AND OUTPUT TUBES**
  - IF TROUBLE IS NOT ELIMINATED → **SHOP REPAIR IS NEEDED**
- IF NO SPARK IS OBTAINED → **CHECK FUSE, REPLACE IF OPEN**
  - IF NEW FUSE BLOWS → **SHOP REPAIR IS NEEDED**
  - IF NO FUSE IS USED → **SHOP REPAIR IS NEEDED**
- IF WEAK AC SPARK IS PRESENT → **TRY NEW DAMPER TUBE**
  - IF THIS REPLACEMENT DOESN'T HELP → **HORIZONTAL OUTPUT TRANSFORMER IS PROBABLY DEFECTIVE**
- IF SPARK IS OKAY → **HORIZONTAL OUTPUT TRANSFORMER IS PROBABLY DEFECTIVE**

Chart of suggested troubleshooting procedures when symptom is good sound, no raster.

(Continued from preceding page)

calibrated spark-tester which is commercially available or can be constructed in the shop. Lacking either of these service instruments, a spark drawn between the high-voltage lead and the CRT connector can be judged for voltage by its length. With some practice this can be done with fair accuracy. *The high-voltage lead should never be sparked to chassis.* If the set contains a high-voltage circuit fuse, the latter will blow; in a set without a fuse, damage to the rectifier or transformer or other component in the high voltage circuit can result from such a practice.

It is important to remember that if the CRT is not drawing current for any reason, it will hold a charge, and no spark can be drawn to the high-voltage lead. The procedure in checking by the spark method is therefore as follows: With the set off, the high-voltage lead is disconnected from the CRT, the set turned on, and the lead brought near the CRT connector. If no spark or only a small one is obtained, the CRT is discharged to ground with a piece of wire.

The wire should be connected to ground first to prevent getting a shock. The high-voltage lead is then sparked to the CRT again. If a normal spark is now obtained, the trouble lies in either the ion magnet setting, the supply voltages at the CRT socket, or the cathode-ray tube itself. The ion magnet can now be readjusted, with the brightness control turned three-quarters up. If rotating and moving the ion magnet back and forth does not produce the raster, the adjustment can be tried rapidly with the brightness setting at maximum. If no raster is obtained even now, the brightness is turned down immediately, to the center position of the pot. The brightness must not be left fully up for more than one minute, without a raster.

If ion magnet readjustment doesn't help, a known good magnet should be substituted, especially on sets that are old and have lost their brightness gradually. The correct ion magnet for the tube can be determined by checking the shape of the CRT's electron gun (See fig. 1). A bent gun and an angled gun require a single ion magnet. Straight guns with the elements cut at an angle use double ion magnets. When the lat-

ter type unit is employed, the larger magnet is placed nearer to the CRT socket.

If adjustment or replacement of the ion magnet fails to fix the receiver, the voltages at the CRT socket should be checked. Since the base connections on magnetically-focused and deflected tubes are standard, it pays to memorize them (fig. 2). Electrostatic focus and self-focus tubes do not add too many complications; their base connections can be remembered readily too. Electrostatically-*deflected* tubes have high voltages at their sockets that cannot be measured with ordinary voltmeters. Since leaky condensers in the high voltage section are the most usual fault, and the sets are small and light, the best procedure is to take them to the shop for servicing.

In magnetically-deflected sets the CRT socket is removed and the voltages are checked with respect to cathode. The bias should vary with the setting of the brightness control, usually from −80V at cut-off to almost zero volts at full brightness. If little or no variation is found, the set usually needs major repair and should be taken to the shop. An exception to this statement is found

for Sound, No Raster

in the case of receivers using a direct-coupled video amplifier circuit. A bad video amplifier tube in such sets can cause incorrect bias voltage at the CRT. It is therefore a good idea to change the last video amplifier tube and check the voltages again, when the CRT bias is found to be wrong. If the first anode or electrostatic focus voltage is incorrect, the trouble is usually a shorted condenser or possibly a bad focus pot, and shop repair is indicated. If the CRT voltages are correct and vary normally, the CRT is defective (see fig. 3).

The reason that the CRT voltages are checked with the CRT disconnected is that an internally-shorted CRT will cause incorrect readings. The CRT may be checked for short or leakage in these cases with one of the new test-and-re-activation devices. On some of these, a high voltage is available for burning off the short, thus repairing the tube. (Such a procedure has its pros and cons . . . we do not necessarily endorse it. —Ed.) If no such instrument is available, CRT replacement becomes necessary.

Keep in mind that, with the tube disconnected, the voltages are measured when the CRT is not under normal load. The possibility that circuit trouble may be present even when CRT socket voltages read okay should not be overlooked. For example, the focus voltage may read normal yet there might be a resistor in the circuit which has increased in value, causing the voltage to go very low when the CRT is connected.

Going back—if the spark at the CRT is low or completely absent, remove the high-voltage cage and check the spark at the HV rectifier cap. This is an AC spark and can not be measured satisfactorily with a meter even when a high-voltage probe is available. Special

spark, once made, can be pulled out to more than twice its original length, unlike a DC spark which makes and breaks at about the same point.

The spark voltage can also be judged by drawing the arc to a screwdriver with an insulated handle. The same tool should always be used since the length of the spark varies radically with a change in the material of the handle. The spark should never be drawn to chassis for the reason mentioned previously (possibility of either burning out the fuse, or damaging tubes or components, mainly the horizontal output transformer).

If a normal spark can be obtained at the HV rectifier cap, but not at the CRT anode, the trouble is in the rectifier tube or circuit. The HV rectifier should be replaced first, which may repair the set. If it doesn't, the trouble may be a short or leakage in the HV filter condenser, an open or increase in value in the HV filter resistor, or a defective high-voltage lead.

It is a simple matter to check the high-voltage condenser (when one is present). If the set will operate with the condenser disconnected, the condenser should be replaced. (The condenser should not be left off permanently—the HV regulation will be impaired and the brightness decreased, if it is omitted). If there is no high voltage at the CRT with the condenser removed, shop repair is advisable, due to the difficulty of reaching the high-voltage rectifier socket.

If insufficient or no spark is obtained at the rectifier, the cap should be removed from the tube and the spark tried again to the lead. The reason for this is that a short in the cathode circuit of the rectifier may provide sufficient loading to prevent the normal spark at the
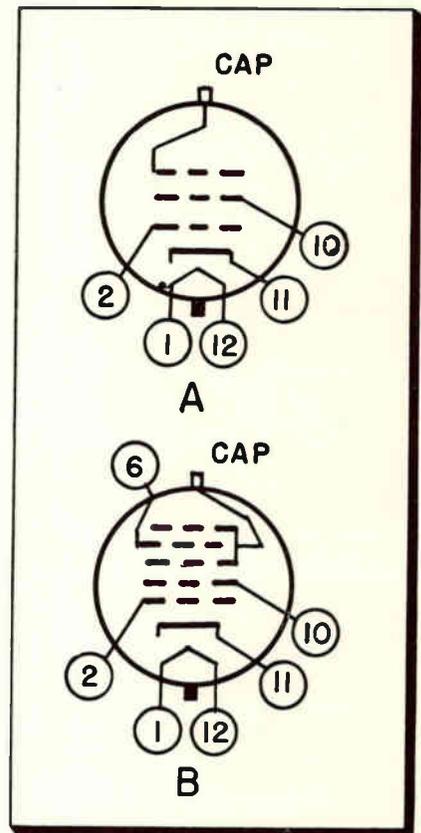
Fig. 2 A) Standard basing diagram for magnetically-deflected cathode-ray tubes that are magnetically-focused, self-focused or automatically-focused. B) Standard basing diagram for magnetically-deflected and electrostatically-focused cathode-ray tubes.

Element	Pin #	Voltage	Remarks
Filament	1, 12	6.3 A.C.	Filament current .6 Amp.
Cathode	11	0	CRT DC voltages are taken to cathode
Grid	2	0 to —80V	Full brightness to cut-off
1st Anode	10	300V	
Focus anode	6	—50 to 300	17H, L, R, TP4; 20HP4; 21FP4; 24BP4; 27AP4
Focus anode	6	3,000 to 4,000	14GP4; 17G, FP4; 20FP4; 20GP4
High voltage	cap	8,000 to 16,000	Varies with size, about 800V per inch
High voltage	cap	25000V	Projection tubes and 30 inch tube

Fig. 3—Chart listing normal voltages to be expected at CRT.

calibration for the meter would be required, since the voltage is in pulse, not sine-wave form, and the frequency is 15,750 cycles with high harmonic content beyond the range of most shop instruments.

A calibrated spark tester may be used for this HV test, with the voltage measured at the point at which the spark makes. This is important, since the

plate. If a spark of normal length is obtained at the lead, the trouble is in the rectifier cathode circuit.

In the case of voltage-doubler circuits, the most frequent component, next to tubes, that causes trouble is the resistor from the cathode of the first tube to the plate of the second. If this resistor is defective, the spark at the plate of the first tube may be normal when the sec-

ond tube's cap is removed. Half the normal voltage will then appear at the CRT connector. The defect is hard to find when the resistor reads normal on the ohm meter but breaks down under voltage. The unit is usually a carbon film resistor, two megohms with 10,000-volt breakdown rating. It can be replaced with the original part or with four 500,000 ohm resistors connected in series. The solder joints of the series resistors should be made round and smooth to prevent corona discharge.

In the vast majority of receivers the kickback power supply is used. In these sets, we must check the horizontal sweep section if no spark is obtained at the rectifier cap. The most popular output tubes, the 6BQ6, the 6BG6, and the 6CD6, have plate caps and the spark test can be used again. The spark should be about one third the length expected at the rectifier. If the output tube is a 6AU5 or 6BD5, the plate is at the socket and this test becomes inconvenient. The alternate procedure used then is to listen for the characteristic whistle of the horizontal sweep. It will be easier to hear this by listening for the change in pitch when the hori-

If You Overlook Likely Sources of Trouble When
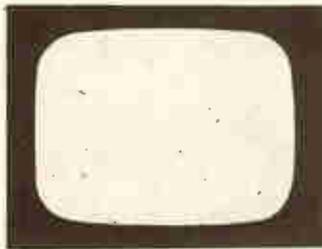
1—Normal raster
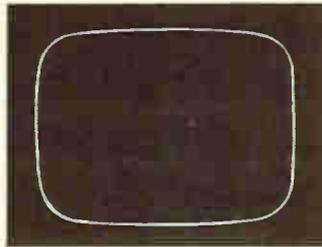
2—No raster, screen dark
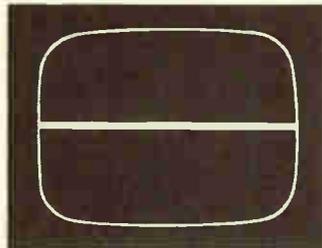
3—Vertical deflection absent
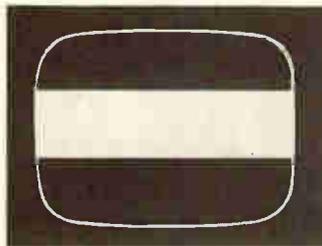
4—Insufficient raster height
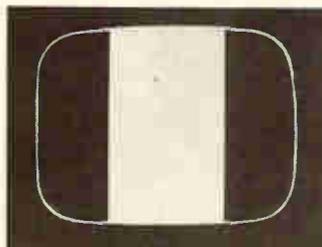
5—Insufficient raster width

GENERAL TROUBLE	PRIMARY SYMPTOM	ASSOCIATED SYMPTOMS	POSSIBLE CAUSES OF THE TROUBLE
DEAD SET	No Raster or Sound.	Tubes don't light.	Line Cord Plug doesn't make good contact in Outlet. Defective Outlet. Interlock Connector defect, or Contacts poor. Line Cord or Plug defective. Off-On Switch NG. Fuse in Low-Voltage Rect. Circuit open. Open Primary in Power or Isolation Transformer.
		Some Tubes light, others don't.	Open Tube Filament (in Sets with Series-Parallel Tube Filament Hook-ups). TV-FM-Phono Switch (in Combination Sets) in wrong setting, or defective.
		All Tubes Light.	Low-Voltage Rect. Tube Defective. Short or Open in "B" Line.
	No Raster, Sound Okay.	Unlit CRT →	Brightness Control Setting incorrect. Fuse in HV Section open. Ion Magnet improperly set or defective; wrong Ion Magnet. CRT 2nd Anode Lead defective, or making poor contact. CRT or CRT Filament Supply defective. CRT Socket defective, or making poor contact with CRT. Yoke Plug loose or disconnected. Bad contacts on TV-Phono Switch. Defect in HV Rect., Hor. Output, Damper, Discharge, Hor. Osc. Tube or Circuit. HV Transformer Section defective. Open Resistor in Filament Circuit of HV Rect. Leaky Coupling Condenser in Hor. Deflection Circuits. Hor. Output Transformer defective, or wrong type. Improper Voltages on CRT Elements (Excessive CRT Bias, etc.) Grounded Hor. Yoke Winding. Defective Sync Discriminator or Horizontal Osc. Control Tube or Circuit. Shorted or Leaky HV Filter Capacitor. Open HV Filter Resistor. Incorrect Drive Control Setting. CRT defective.
VERTICAL DEFLECTION ABSENT or INSUFFICIENT	Bright Hor. Line on Screen, No Raster.		Height Control Setting incorrect. Vertical Osc. Tube or Circuit defective. Vertical Output Tube or Circuit defective. Vertical Osc. Transformer open or shorted. Vertical Output Transformer open or shorted. Vertical Yoke Coils open or shorted. Defective Vertical Hold, Size or Linearity Control.
	Raster Collapses in Vertical Direction Intermittently.		Vertical Osc. or Amp. Tube defective (particularly 6BL7GT). Condenser across Secondary of Vert. Output Trans. shorts intermittently. Vertical Output Transformer defective. Poor connections at Terminals in Vert. Osc. and Amp. Circuits.
	Raster Height Insufficient.	Vertical Non-Linearity often Present.	Height Control Setting incorrect. Vertical Output Tube or Circuit defective. Vertical Osc. Tube or Circuit defective. Coupling Condenser between Vert. Osc. & Amp. leaky. Vertical Osc. Charge-Discharge Condenser leaky. Shorted Turns in Vert. Output Transformer Primary.
		Height Control has No Effect	Height Control defective.
HORIZONTAL DEFLECTION ABSENT or INSUFFICIENT	Bright Vert. Line on Screen.		Open in Horizontal Yoke or Yoke Circuit.
	Raster Width Insufficient.	Pix Size Reduced app. 1" on each side; brightness considerably below normal; Raster becomes larger when brightness setting is advanced.	Defective Horizontal Output Tube.
		Horizontal Non-Linearity may be present.	Horizontal Drive Adjustment incorrect. Width Adjustment incorrect. "B" Supply Voltage below normal. Horiz. Output Transformer defective. Horizontal Osc., Discharge, Damper, Hor. Amp. Tube or Circuit defective. Increase in Hor. Output Transformer Air-Gap due to insufficient tightening of the Screw Bolt between Outer Supporting Plates of this Transformer. Broken Slug inside Linearity Coil or Size Control Coil.
RASTER SIZE INCORRECT (HEIGHT AND WIDTH IMPROPER)	Raster Size Below Normal.	Focus may be improper. → Size reduced at least ½" on top, bottom and sides. Focus control provides optimum focus at extreme setting, or possibly doesn't go through proper focus at all.	AC Line Voltage too low. Height and Width Adjustments improper. "B" Voltage below normal CRT defective (presence of gas may decrease the tube's deflection sensitivity). Sweep Amplifier Tubes weak. Weak Low-Voltage Rectifier.
	Raster size excessive. Pix too large for mask.	Brightness below normal. → Raster increases in size, decreases in brightness, possibly defocuses, as brightness or contrast setting is advanced.	Height and width adjustments incorrect. High voltage below normal. Defective HV Rectifier Tube. HV Filter Resistor has increased in value.

6—Insufficient height and width

7—Vertical non-linearity at end of sweep

8—Vertical non-linearity at beginning of sweep
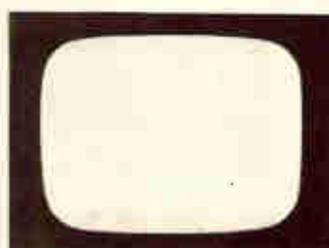
9—Horizontal non-linearity at end of sweep

Raster Defects

the Pressure is on, Keep This Chart Handy

GENERAL TROUBLE	PRIMARY SYMPTOM	ASSOCIATED SYMPTOMS	POSSIBLE CAUSES OF THE TROUBLE
RASTER ILLUMINATION IMPROPER	Brightness insufficient.	Insufficient width, poor Hor. Linearity. Raster size normal.	Horizontal Drive, Size or Linearity Control Setting improper. Horizontal Output Tube defective. Damper Tube defective.
		Pix size excessive. ➔	Increase in HV Filter Resistor. Open or Leaky HV Filter Capacitor. HV Rect. Tube or Circuit defective.
		Raster size below normal. ➔ Blue haze may be seen in CRT.	"B" Voltage below normal (due to weak rectifier tube or circuit trouble). CRT weak. CRT bias excessive; or other CRT element voltages are improper. Ion Magnet improperly positioned or defective.
	Brightness excessive.	Brightness control has no effect.	CRT defective. Trouble in CRT circuit (open in brightness control, if latter is in CRT grid circuit; shorted or leaky coupling condenser between video amp and CRT).
	1 or 2 thick black horizontal bars in Raster (Hum).	Hum may be present in sound; Raster's horizontal sides may be wavy.	Open or Partially-Open Condenser in "B" Supply. Cathode-Heater Leakage in Video Amp, Video Detector, CRT; or in Video IF, Front-End Tubes.
	Horizontal white bar at bottom of Raster.		Vertical Osc. or Output Tube defective. Low line voltage. Low "B" voltage (Rectifier Tube weak or defect in circuit). Shorted or leaky Cathode Bypass Condenser in Vertical Output Stage.
	Vertical white bar at left or right-hand edge of Raster		Horizontal Drive Setting incorrect. Horizontal Linearity Setting incorrect. Horizontal Output Tube or Circuit defective. Damper Tube or Circuit defective.
	Vertical white line near center of Raster.		Horizontal Drive Setting incorrect.
	Vertical lines at left-hand side of Raster.		Parasitic oscillation in Hor. Output or Damper Circuits, due to defect in tube. Open in Resistor or Condenser across one of the Hor. Yoke Windings. Units may have wrong value. Horizontal Drive Setting incorrect. Damper Tube or Circuit defective. Open "Boost" Capacitor in Damper Circuit.
	Vertical bars on right-hand side of Raster.		Horizontal Oscillator, Output or Damper Tube defective.
	Light and dark vertical bars in Raster.	Horizontal Linearity improper.	Damper or Horizontal Output Tube or Circuit defective. Horizontal Drive Setting improper.
RASTER FOCUS IMPERFECT	Proper focus cannot be obtained.	Focus control has no effect.	Open or Shorted Turns in Focus Coil. Component defect present that is causing current drain through Focus Pot to be excessive or insufficient. Short or open in Focus Pot. CRT gassy or otherwise defective. Defect in CRT Socket. Ion Magnet improperly set or defective. Focus Magnet not properly located or centered. Wrong or defective Focus Magnet present. HV improper. Magnetic Centering Device (on Electrostatically-Deflected Tubes) 180° out of position.
RASTER SHAPE INCORRECT	Raster's hor. sides are wavy with contrast setting low.		Cathode-Heater leakage in Sweep Amp. or Sync Tubes.
	Trapezoidal or Non-Symmetrical Raster.		Shorted Turns in Deflection Yoke. Short in Yoke Shunt Capacitor. Improper adjustment of Focus or Ion Magnet. Defective Focus Magnet.
	Shadowed or Rounded Corners on Raster.	Brightness normal. ➔ { Brightness insufficient. ➔	Deflection Yoke too far back on CRT neck. Centering Adjustment incorrect. Ion Magnet Setting improper. Ion Magnet Setting improper.
	Distorted Raster.		CRT too close to Speaker.
	"Xmas-tree" effect in Raster.		AFC Tube defective. AFC Adjustments improper.
RASTER NOT CENTERED			Deflection Yoke Setting incorrect. Centering Magnets improperly positioned. Defective CRT. Defective Ion Magnet.
RASTER LOOKS "ROUGH"			Parasitic Osc. in Horizontal Amp. due to defect in latter. Horizontal Amp. Plate Cap Connection poor.
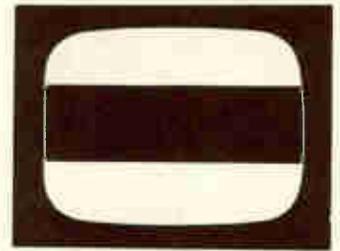
18—Non-uniform raster illumination due to hum
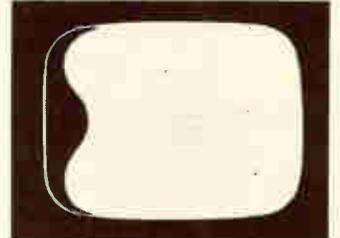
17—Wavy side in (decentered) raster due to hum
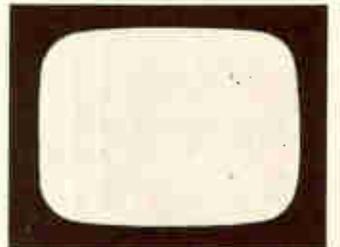
16—Vertical bars in raster
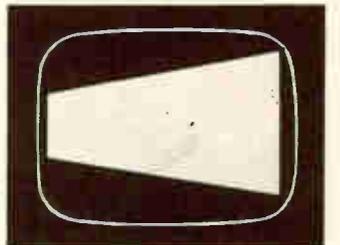
15—Trapezoidal raster caused by fault in vertical yoke circuit
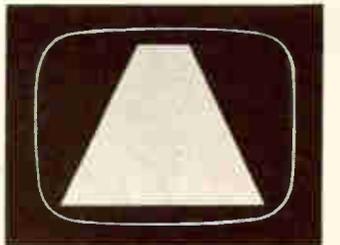
14—Trapezoidal raster due to fault horizontal yoke circuit
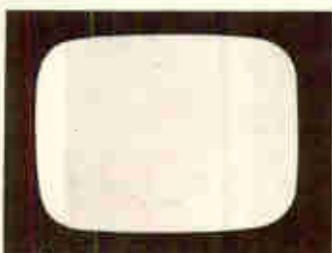
10—Horizontal non-linearity at beginning of sweep
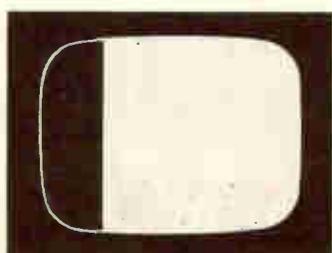
11—Raster decentered horizontally
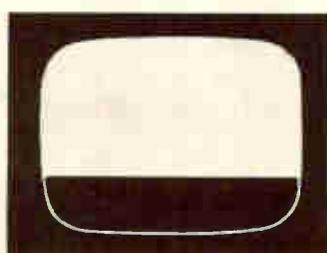
12—Raster decentered vertically
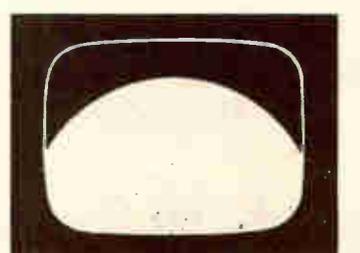
13—Shadowed corners in raster

11

Dynamic Cathode-Ray

Why a Simple Emission-Type of a CRT is Inadequate.

● Technicians not infrequently make incorrect diagnoses of the condition of a cathode-ray tube. Incorrect interpretation of the readings obtained with emission-type CRT checkers is often responsible. We can cite as an example the case where a CRT performs with no brilliance, due to a fault in the socket —say, an open cathode connection. The technician checks the operating voltages on the CRT and finds them normal. The picture tube itself is then checked. An emission reading of *low* is obtained. The technician concludes that the CRT is the source of the trouble, replaces it, then finds he is back where he started from.

In another instance, he may check a CRT that tests *good* on an emission
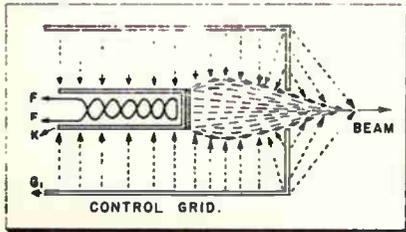
Fig. 1—CRT cathode-grid section (much enlarged).

check, but is actually *poor* in set operation.

What is obviously needed is a cathode-ray tube test under *dynamic*, or operating conditions. This article describes a way of making such a check.

Examine Fig. 1. This is the cathode-grid section of the CRT enlarged. Instead of the simple conception of a cathode releasing electrons through a grid peep-hole we find a complex network of electrostatic forces acting upon the electron beam. The geometry of the individual gun structure, the degree of evacuation of gas and the chemical composition of the gun elements affects the degree of control exercised by the grid on the electron beam.

Grid Control

The washed-out 'flat' picture associated with a faulty picture tube is less a problem of insufficient screen excitation than it is *faulty control* over the excitation available. Yet little attention is normally paid to the quality of grid control, the emphasis being placed on 'how much current.'

The quality of grid control is a difficult factor to determine over a wide range of operation. It is quite simple, however, to measure it at the point of greatest significance—at cut-off. Mathematically speaking, the degree of change

of light or grid-control at high brightness settings is slight. For example, a bias change of 15 to 20 V may be needed to effect a 2:1 change in brightness at a high brightness setting. At a lower brightness setting, however, a bias change of only 6 V may be needed to effect the same 2:1 variation in brightness. Just above cut-off, a 2:1 ratio in brightness can be accomplished with a variation of only ½ volt . . . control thus varying logarithmically as cut-off is approached. This is carried to the point of exact cut-off where a 2:1 ratio of brightness can be accomplished at a voltage increment hardly measureable on shop instruments.

This indicates that for analysis of maximum control action of the grid upon the electron beam we have but to measure the cut-off point of the picture tube under discussion.

Cut-off Voltage Measurement

This is quite practical in the field. Ambient light is removed by drawing the blinds, then the brightness control is rotated until screen brightness is extinguished. At this point measure the G_1 to K voltage and you have the *cut-off voltage*.

There is a definite relationship between cut-off and emission. Picture tubes having a low cut-off (i.e. . . . requiring a low negative voltage on the grid to extinguish the beam) will give

a *low* emission reading (in a CRT checker) even though the cathode is giving *normal emission* for that tube. Yet, such a "low emission" tube may operate perfectly in a TV set.

A second tube, having a *higher* cut-off will give a much higher emission reading, even though its performance may be no better than the low cut-off

tube with the low emission reading. The emission readings of tubes that provide the same brightness may thus be considerably different. The high cut-off tube might easily have a measured emission twice or three times that of the lower cut-off tube, and still perform no better than the latter.

Grading CRT's

By properly relating *cut-off* and *measured emission*, an exact qualitative figure of merit may be achieved to definitely grade any picture tube. For example, take a 10BP4 whose cut-off voltage is measured at 30 volts. If the cathode emission is measured at 0.1 ma. the tube is *poor*. If the emission is 0.2 ma. the tube is *fair*. If beam current goes to 0.3 ma. the tube is *good*. When the measured emission of such a tube is 0.4 ma. the tube is *very good*. If you can get 0.5 ma. (500 microamps) of beam current the tube may be properly classified as approaching *excellent*.

To make a CRT dynamic analysis, proceed as follows (a VTVM should be used for all voltage checks):

(1.) Measure (using the appropriate AC scale) the *filament* voltage of the operating picture tube. The nominal 6.3 volts may vary up to 10% under actual load. A variation of 20% or more is abnormal. Variation of 2 or more volts between load and no-load conditions of the picture tube filament indicates poor

Cut-off voltage	Emission in MILLIAMPERES									
	.100	.200	.300	.400	.600	.800	1.000	1.300	1.600	1.900
30v	POOR	FAIR	GOOD	VERY GOOD	EXCEL.	EXCEL.	EXCEL.	EXCEL.	EXCEL.	EXCEL.
40v	VERY POOR	POOR	FAIR	GOOD	VERY GOOD	EXCEL.	EXCEL.	EXCEL.	EXCEL.	EXCEL.
50v	VERY POOR	VERY POOR	POOR	FAIR	GOOD	VERY GOOD	EXCEL.	EXCEL.	EXCEL.	EXCEL.
60v	VERY POOR	VERY POOR	POOR	POOR	FAIR	GOOD	VERY GOOD	EXCEL.	EXCEL.	EXCEL.
70v	VERY POOR	VERY POOR	POOR	POOR	FAIR	GOOD	GOOD	VERY GOOD	EXCEL.	EXCEL.
80v	VERY POOR	VERY POOR	POOR	POOR	POOR	FAIR	GOOD	GOOD	VERY GOOD	EXCEL.

(COURTESY OF ELECTRONIC BEAM CORP)

Fig. 3—Table relating CRT cutoff voltage and emission.

regulation. This filament check is always indicated when the normal filament light cannot be readily seen in the picture tube neck.

(2.) Measure CRT emission as follows: (Make temporary hook-up as shown in fig. 2.) 1—Connect positive terminal of VTVM to CRT cathode. 2—Connect CRT cathode to CRT G_1. 3—

Tube Analysis

More Accurate Method of Locating Defective Picture Tubes.

Open G_1 circuit from CRT socket to set. Leave G_2 circuit alone. (It may be assumed that regular B+ is being applied to G_2 terminal.) 4—Lift off the anode lead from the CRT. Leave it hanging, where it cannot arc to chassis. 5—Open CRT cathode return to chassis. Connect the *chassis* side of the cathode lead to negative terminal of VTVM. 6—Hook up a 1,000 ohm resistor across VTVM terminals. 7—Turn the set on.
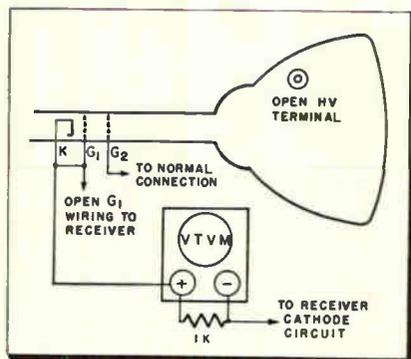
Fig. 2—Connections for CRT emission test.

Using the lowest DC voltage scale on the VTVM, read the voltage developed, but call it *milliamperes*. Thus, if the scale shows 0.76 volts, call it 0.76 mils (760 microamps). In this case, the tube would show 0.76 milliamperes of cathode emission under test.

Experimental CRT Checker

Considering this in further detail: By removing the anode lead, we've eliminated that element from the circuit. Tying the control grid to the cathode eliminates this grid's action—which leaves in the test circuit only the cathode and G_2.

The VTVM measures the voltage drop across the 1000 ohm resistor. By Ohm's Law, $E = IR$. When the resistor is 1000 ohms, the formula is $E = 1000 \times I$. Now, since I is in amperes, $1000 \times I =$ milliamperes. Therefore E (in volts) $= I$ (in MA). For every volt, then, there will be 1 MA flowing in the CRT circuit. Thus we get the true *current* reading with a *voltmeter*.

We now have an experimental CRT checker, with which we can measure picture tube emission between cathode and G_2. Of course that emission reading is meaningless unless we have standards to compare it with. The chart in fig. 3 provides such standards.

To make a dynamic check of a cathode-ray tube, its emission should first be determined, as described above. Its

cut-off bias should next be measured. To do so, proceed as follows:

With the picture tube operating normally, lower the blinds and turn off all room lights. Now, watching the raster (without signal) vary the brightness control until the screen goes completely dark. The control setting is now at cut-off. With the VTVM, measure the voltage between G_1 and cathode. Mark this down as *cut-off voltage.* It will, of course, be negative.

By inspecting the chart, it can now be readily determined in which category the tube falls. Let's consider some sample cases. Suppose a tube has an emission of .3 MA, and a cut-off voltage of —30. These two ratings intersect in a box labeled GOOD. If a tube with the same emission had a cut-off of —80 V, it would fall into the box labeled POOR.

G_1 Correlation Factor

If it is desired to avoid cutting into the circuits of the receiver to get the required readings, a simple inexpensive adaptor can be made up, much like the analyzer adaptors used in old-time radio testers, in using which a tube was removed from the set, the adaptor inserted in its place, and the tube plugged into the adaptor.

The need for making the measurements described, as well as adaptor rig-up, can be dispensed with by using one of the commercial CRT checkers available that is capable of making such a dynamic CRT analysis.

The table shown in fig. 3 was set up for tubes with a G_2 voltage of 300. If the G_2 voltage of the CRT under test is other than 300 V, the table in fig. 4 will have to be consulted. Find the G_2 voltage closest to the one actually present in the left-hand column of the table, and note the *Correction Factor K* inserted next to this voltage. *The cut-off voltage and emission current of the CRT under test should both be multiplied by the K value.* The table in fig. 3 is then used, as before, to evaluate the condition of the CRT.

Sample Analysis

Let's illustrate the procedure, assuming a tube with a G_2 voltage of 335 V. Inspecting Table B, we find that the listed G_2 voltage closest to 335 V is 325 V. The Correction Factor K for this voltage value is .95. Now, suppose that the measured CRT emission averages .4 MA, and the cut-off voltage is 60 V. Multiplying each of these two values by the .95 Correction Factor changes them to .38 MA and 57 V, respectively. Since .38 MA is much closer to .4 than it

is to .3, we start at the top of the .4 MA column (Table C) and move down vertically. 57 V falls between 50 and 60 V—the tube is therefore between *fair* and *poor,* and nearer to *poor* than to *fair.* If the final current value had been .35 MA, we would have determined the tube's "dynamic merit" at .3 MA, then found what it was at .4 MA. Its actual "dynamic merit" would have been about midway between the two.

(EDITOR'S NOTE: Several cathode-ray tube engineers have added some ifs, ands, and buts to the writer's basic thesis that "if two tubes have the same cathode emission, the one with the lower cut-off bias is the better tube."

The engineers say: "Of two picture tubes having the same emission, the

Table B CUT-OFF VOLTAGE Correction Factor K	
G_2 voltage	K
150	2.0
175	1.6
200	1.5
225	1.3
250	1.2
275	1.1
300	1.0
325	0.95
350	0.85
375	0.80
400	0.75
425	0.70
450	0.65

(COURTESY OF ELECTRONIC BEAM CORP.)

Fig. 4—Correcting for different G_2 voltages.

one with low cut-off bias has higher modulation sensitivity and is therefore better on weak signals, but is limited in light output capability; the one with the high cutoff bias requires more grid drive, but when adequate signal is available, greater light output will be obtained. Any appreciable drop in emission and consequent reduction in brightness will be more noticeable in a high cutoff tube than in a low cutoff tube.")

What to Expect in

Changes Ahead. 1N60 Video Detector, Direct-Coupled Video Amplifier, Intercarrier Sound, and Exceptionally Well-Designed AGC and Sync Circuits Will Probably Be Used in Sets Intended for UHF Reception.

With 2000 UHF stations possibly coming into operation in the not-so-distant future, the TV technician should acquaint himself with UHF-inspired changes in receiver design that are being made or contemplated.

The first basic question that might be considered is: what chief factors will affect the over-all design of sets intended to receive UHF signals?

It is known that the signal voltages at the receiver terminals will be lower than on VHF for similar transmitted powers and distances from the transmitter, yet the operating frequencies are such as to make good radio frequency amplifier design quite difficult. Measurements made from the Empire State Building on 910 mc in 1947; by G. H. Brown in Washington in 1948; and numerous field surveys of the Bridgeport Station show that for the same fringe area reception as on 60 mc, from 100 to 1,000 times the effective radiated power is required. Also, the noise factors of typical r-f amplifier circuits become worse as the operating frequency increases.

Hence, particular emphasis is immediately placed upon careful design of the input circuits of the receiver.

What, if any, demands will UHF make on other sections of the receiver? This question will be answered by discussing the overall design of a combined or composite U and V receiver.

Unchanged Functions

The standards approved for UHF transmission are the same as for VHF. Hence, there are many sections of a combination UHF and VHF television receiver whether for monochrome or color whose design will be unaffected by the new frequency allocations.

In Fig. 1, those sections which do not require change are shown in dotted outline. Because of the standardization with VHF above mentioned, the video detector, the video amplifier, horizontal AFC, deflection circuits, sound system and supply voltage sources need no basic changes. However, there may be advantages in using a germanium diode, such as the type 1N60, for the video detector. It may also be of interest to discuss the characteristics of direct-coupled video amplifiers and intercarrier sound operation.

High Forward Conductance

Video Detector: The germanium diode 1N60 is particularly suited to video detector application because of its high forward conductance, its low intrinsic capacitance and high back resistance (allowing good wideband operation).

Direct-Coupled Video Amplifier: Of all video amplifiers thus far used, that type which is direct-coupled to a negatively-polarized second detector can best provide reduction in the amplitude of incoming noise pulses, so that the synchronizing amplifier receives a smaller range of undesired voltages. Such direct-coupled video amplifiers provide a definite improvement in the contrast range of the reproduced picture. Also, the low video frequency response is excellent since there is no phase shift even at DC. It is to be noted that these characteristics of DC-coupled video amplifiers are independent of the use or non-use of AGC.

Intercarrier Sound: As has so often been mentioned before, the intercarrier sound system can give ease of tuning combined perhaps with less audio noise between channels. This is quite important on UHF where the great number of channels and the wide spaces between those which are active in a given location will make tuning difficult.

The block diagram indicates that the AGC, the synchronizing circuits, i-f amplifier and, of course, the tuner require modification or new design.

AGC: The AGC system should be the best possible since fading can be more severe on UHF than on our present television channels. For example, due to the sharper shadow regions—less diffusion of the wave front around obstacles—airplane flutter can produce larger ratios of signal strength change. Some keyed automatic gain control circuits may improve the stability of the background and brightness level for both rapid and

Fig. 1—Sections not requiring change in new UHF and VHF receivers are shown in dotted-lines.

slow variations of the signal amplitude.

Synchronizing Circuits: These should also be of the best possible design to reduce the effects of rapidly fluctuating signals and such interference as may occur due to cross-modulation. Cross-modulation may occur more readily at UHF due to the poorer discrimination against nearby channels by the limited number of tuned radio frequency circuits, and can produce additional synchronizing pulses with incorrect time delay.

The I-F Amplifier: The intermediate frequency is, in part, chosen for:

a. the best image rejection,
b. minimum power in the beat frequencies between harmonics of the i-f and the incoming signal,
c. minimum local oscillator radiation.

These three requirements call for a much higher frequency than has been

UHF-VHF Receiver Circuits

used in the past; yet the frequency has to be made as low as is feasible in order to provide:

  d. low noise factor,
  e. good gain for a given number of stages, and
  f. avoid regeneration on the low channels of the VHF band. That is, if the intermediate frequency approaches the region of 54 MC, it would be very difficult to avoid regeneration when tuned to channel 2.

It is to be noted, that going from an i-f frequency below channel 2 to one in the region of 120 MC degrades the noise factor of the i-f amplifier by at least 2 db. Also, an intermediate frequency higher than channel 2 can lead to difficulties in mixer and local oscillator design for the VHF portion of the combined V and U receiver. Hence, it seems that the choice of the i-f amplifier for complete U and V tuners should be in the frequency range as close to channel 2 as is consistent with reasonable freedom from regeneration.

The intermediate frequency proposed by the RTMA—41.25 for sound, 45.75 for the i-f picture carrier—is a reasonable choice. The frequency ranges chosen lie in a part of the spectrum where very few and only low-power radio transmitters operate (with the exception of some —we hope temporary—police transmitters). Other characteristics of the i-f amplifier will be discussed later.

UHF Tuning Section

Due to the large number of channels possible between 470 and 890 MC (70) as compared with the twelve of the present band, there are various schools of thought regarding the mechanical operation of the tuner.

It may be of interest to classify possible mechanical designs under three headings, shown in Table 1.

  a. Continuously tunable—examples of this are DuMont, RCA, and Mallory.
  b. Semi-Continuous—what may be called a "band-spread" type, in which a switch chooses various zones of the UHF band and a dial actually tunes in the channels in each zone.
  c. Selector Switching—where a choice of perhaps any six up to eleven UHF channels may be pre-set and then are tunable along with 7 or less VHF channels by the same selector switching as we have on the majority of VHF receivers.

Continuous tuning has many advocates since it is possible to choose any of the 70 possible channels between 470 and 890 MC, despite the fact that there are no locations planned where even 50% of these channels will be within a useful radius. (Example: the whole state of Pennsylvania with only 48 UHF proposed station allocations, whereas there are 70 channels to be tuned.) Con-

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TABLE I
UHF TUNER CLASSIFICATIONS

A—Continuous Tuning with Oscillator at Fundamental Frequency

B—Rotary Switch for Sectional L and C Change with "Band Spread" by Capacity Tuning.

C—Rotary Switch with VHF Oscillator and Crystal Harmonic Generator. Usually of Turret Type with Pre-Set Channels.

Methods of Tuning

1. Movable Core—Variable L and C
2. "Butterfly"—Cylinder or Ring
3. Sliding Contact

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tinuous tuning from 470 to 890 MC requires a precision mechanism and dial to enable sufficiently accurate tuning for best picture and sound. The most desirable system, perhaps, would provide selection by means of pre-set channel positions similar to the method used in the majority of present day VHF receivers. However, when the number of channels reaches 70, it is impractical to have this many fixed positions on one switch.

Plans are underway for tuners which may give 18 to 20 of mixed VHF and UHF channels chosen to suit the particular locality. This becomes entirely practical when the local oscillator operates in the VHF region and the UHF mixer operates with an equivalent local oscillator signal obtained from harmonics of the local oscillator. Surprisingly large harmonic powers are available from conventional VHF tube sources, e.g. one section of a 6J6 oscillator, by using a germanium or silicon diode as the harmonic generator. Of various types, the 1N34, 1N34A and 1N82 appear to be the most satisfactory, producing powers of 60 milliwatts at 500 MC and 30 milliwatts at 900 MC. This arrange-

Fig. 2—Two groupings that represent basic divisions of UHF tuners.

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ment, in combination with the new silicon diode, type 1N82 (used as a mixer), provides a very stable-frequency harmonic oscillator-mixer combination.

Tuner Electrical Design

It may be of interest to summarize the basic sections of UHF tuners by dividing them into two groups:

  a. The fundamental oscillator continuously tunable type,
  b. harmonic generation of the local oscillator frequencies, possibly together with selector switch tuning.

Fig. 2 shows the block diagram for these two basic groupings.

Both types require a high-pass filter between the antenna and the first UHF tuned circuit, to reduce interference from VHF, FM, short-wave and broadcast stations. Such a high-pass filter cuts off, or should cut off as sharply as possible below 450 MC. Next is the radio-frequency circuit, preferably double-tuned, so as to carefully match the antenna to the input impedance of the r-f amplifier tube or the mixer. Following this, there *should be* a radio-frequency amplifier tube with its output tuned circuit coupled to the mixer. Next, the mixer crystal with the output i-f circuit and the local oscillator with or without the harmonic generating crystal and tuned circuit. Both the r-f and mixer tuned circuits should provide as high a discrimination against nearby local television channels as possible in order to avoid cross-modulation. Then, the image selectivity will also be adequate.

A first stage of good quality radio frequency amplification is most desirable: (1) to reduce the local oscillator coupling to the antenna; (2) to improve as far as possible, the noise factor, thereby increasing the useful range of the transmitter; (3) provide increased image rejection and, also; (4) reduce cross-modulation at the mixer.

Suitable r-f amplifier tubes at acceptable prices are, however, not presently available.

I-F Amplifier; Antenna

If no r-f amplifier is to be included; and so far no commercial tuner covering the whole UHF range (470-890 MC) has an r-f stage—then it is particularly important to have a quiet first stage of intermediate frequency amplification. This stage should have the lowest possible noise factor to make full use of a silicon mixer, since the i-f voltage at the output of the mixer is lower than the r-f signal voltage applied to it.

The antenna is carefully matched to the transmission line to obtain the best overall noise factor. Any tube fluctuation noise transferred to the first tuned circuit together with thermal noise in this circuit is thus absorbed by the an-
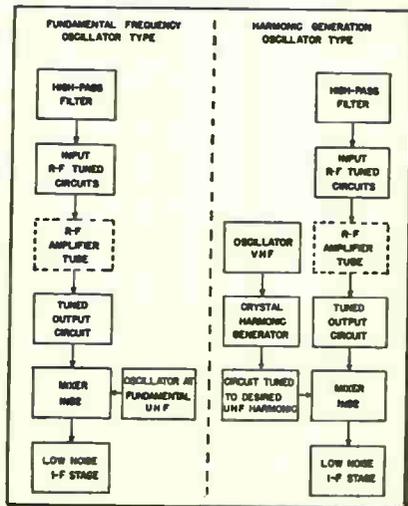
UHF Reception on VHF

Description and Analysis of Mallory Converter, Raytheon
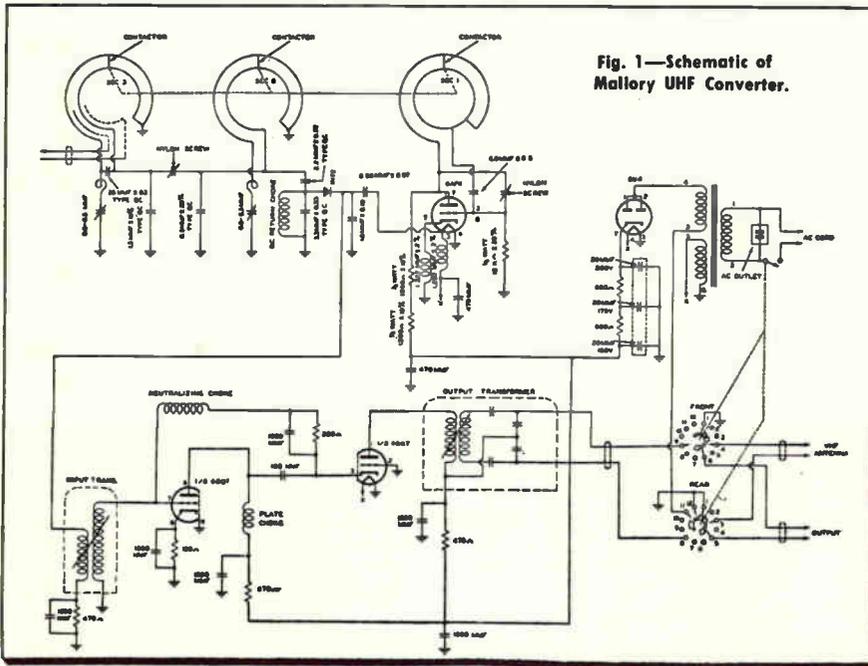
Fig. 1—Schematic of Mallory UHF Converter.

A representative converter circuit is shown in fig. 1. The first preselector circuit, redrawn into simpler form, is shown in fig. 2A. (The second preselector circuit is the input to the mixer.) The circuit may be redrawn once more, using symbols more familiar to the serviceman (fig. 2B). Note that this first tuned network is grounded at both ends —i.e., at G_2 and at G_1. This brings up the question, how can signals be developed across the two coils, if they are short-circuited?

The answer is, the short is effective only at relatively low frequencies, and is intended to eliminate or reduce low-frequency interference and oscillator radiation. For UHF signals, sufficient inductive reactance is present in the circuit, in spite of the grounds at both ends, to permit UHF voltages to be developed here.

Tuning is continuous, and is achieved in this, as well as in the mixer and oscillator circuits, by rotating the shorting bar back and forth, thus varying the amount of inductive reactance present in the circuit.

The inner concentric conductor is connected back onto itself, to avoid an undesired resonance, or suck-out, at approximately 780 MC (fig. 2C). The transmission line is capacitively-coupled to the preselector tuning inductor by the proper placement of two small arcs of silver ribbon on the *back* side of this inductor. The equivalent circuit present is shown in fig. 3.

The transmission line is applied to each inductor section through a capacitance labeled C_1. The two condensers labeled $2C_a$ represent the capacitances present between the conducting sections

Fig. 4—A) Schematic of Raytheon UHF Tuner. B) Pictorial sketch of Raytheon UHF Tuner. Note drive-gear meshing of VHF and UHF tuning units.
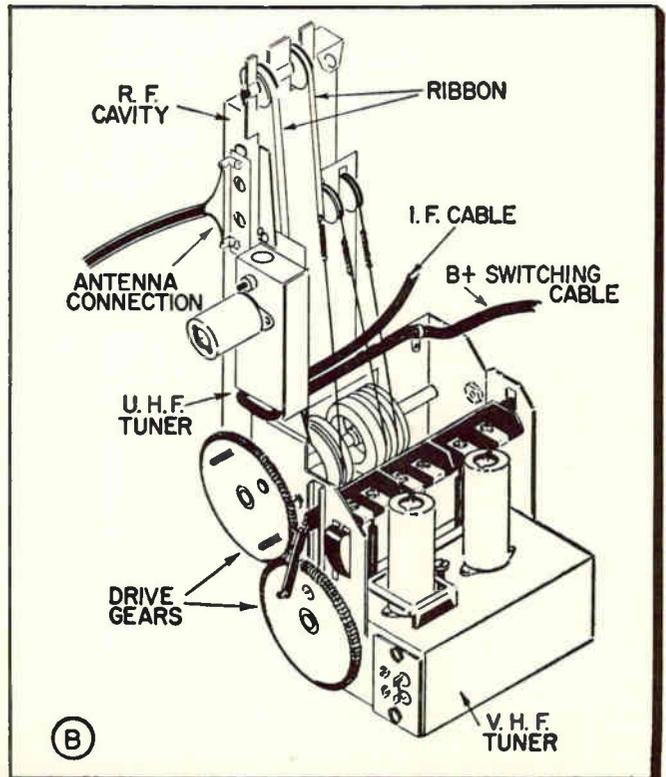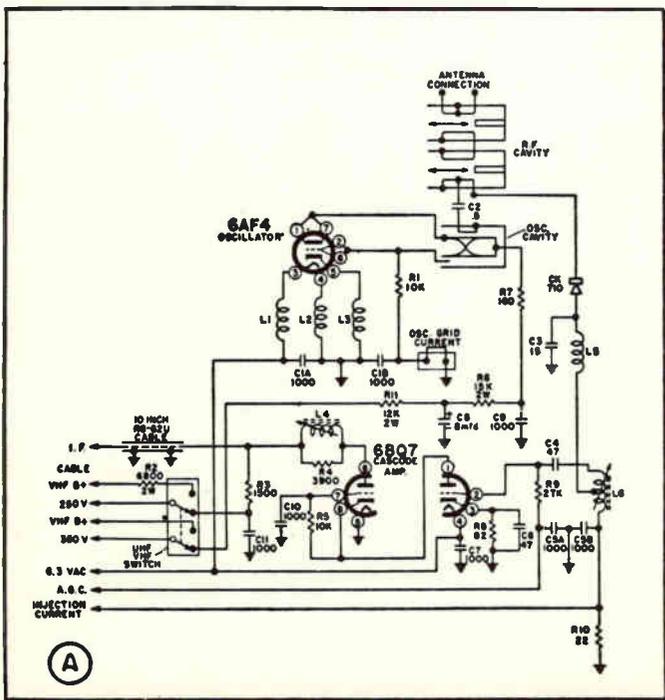
Television Receivers

Tuner and Stromberg-Carlson Television Converter
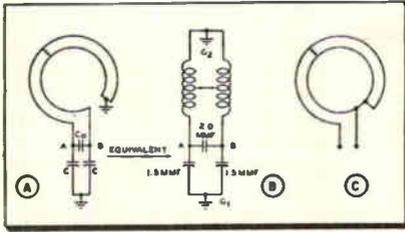
Fig. 2—A) First preselector circuit of schematic shown in fig 1. **B)** Circuit redrawn into more conventional form. **C)** Inner concentric conductor in oscillator circuit is connected back onto itself, to avoid undesired resonance effects at approximately 780 MC.

Fig. 3—Equivalent input circuit of Mallory UHF Converter. 300Ω line connects to antenna.

Neutralization is used, since triodes are inherently unstable when operated as amplifiers at high frequencies. Feedback from the output to the input of the first triode through a neutralizing choke opposes the in-phase or regenerative feedback that tends to occur between plate and grid in this tube. The grounded grid in the second triode provides a shielding effect that makes neutralization of this amplifier section unnecessary. Neutralization makes it possible to get more gain out of the IF amplifier, and thus improve the signal-noise ratio, without driving the amplifier into regeneration.

The bandpass of the IF circuit is approximately 12 MC at the half-power points on the response curve. The output transformer of the IF amplifier section feeds through the switch into the low-impedance antenna input circuit of the VHF receiver. An unusual amount of filtering and decoupling is employed, to keep RF voltages out of the power supply.

A UHF tuner schematic is shown in fig. 4A. The physical appearance of the tuner is indicated in fig. 4B. It is installed in the VHF receiver as follows:

A drive gear is mounted on the VHF tuner. The UHF tuner is then mounted over the VHF unit by means of four mounting screws. The IF and B+ switching cables are suitably connected under the chassis, a few wiring changes are made, and the UHF-VHF switch is installed at the rear of the cabinet.

The drive-gear meshing of the UHF and VHF tuning units permits the set owner to adjust both units by means of the same knob.

The unfamiliar symbols shown under the words *antenna connection* (fig. 4A) represent a double-tuned coaxial line. The line is basically a quarter wave length tuned stub, shorted at one end. The inductance of this stub (as well as the stub used in the second preselector circuit) is varied by means of a ribbon that moves across it. The ribbons are attached to the dial cord and pulley and change the inductive reactance of the

of the line. The circuit arrangement provides an impedance step-up that permits the low impedance of the antenna and the transmission line to be matched to the higher impedance of the preselector tuned circuit. The low impedance input of the line, in other words, is kept from loading down the preselector tuned circuit by the isolating effect of the two C_1 condensers.

The tuner has three sections, to tune the first preselector, mixer and oscillator circuits.

The oscillator output voltage is developed across the oscillator cathode coil, and is fed into the mixer by means of the heater-to-cathode capacitance present in the oscillator tube—an arrangement which will no doubt seem unfamiliar to many servicemen. It is used because it readily provides the very small capacitance desired—about 2.7 mmfd. A very small capacitance is needed between the mixer and oscillator circuits to better isolate the one from the other, and prevent undesired reactions between the two.

Suitable condensers are inserted before and after the mixer crystal, to match its impedance to the RF circuit that precedes it, and the first IF circuit that follows it. The output of the mixer is fed through a double-tuned transformer into a cascode (low-noise) IF amplifier. The amplifier consists of a triode input tube with a very small cathode bias, coupled to a grounded-grid output tube.

Fig. 5—Stromberg-Carlson UHF TV Converter. Separate VHF and UHF antennas may be used.
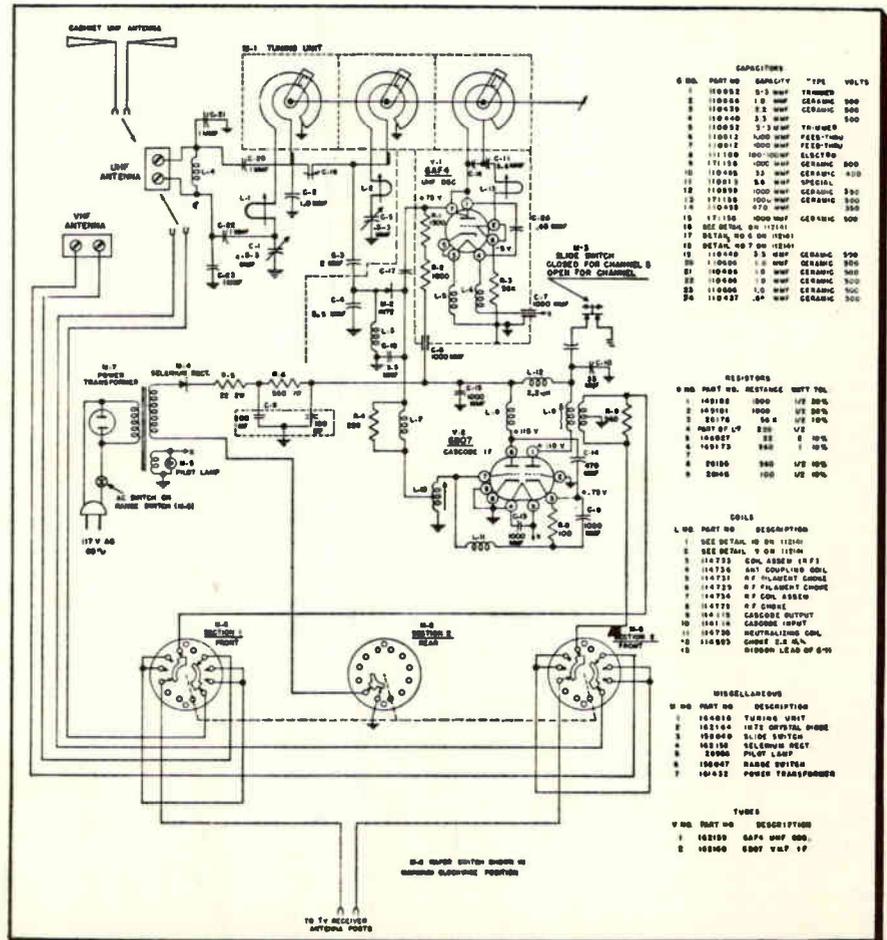
Keyed AGC Circuits

Shortcomings of Simple and Delayed AGC Systems; Need

By Solomon Heller
Technical Editor
Television Retailing

● To better understand keyed AGC, we should consider why such a system is needed—or what defects in simple and delayed AGC systems made a different form of AGC desirable.

Both simple and delayed AGC systems have relatively slow rates of response. That is, the time constant of the AGC condenser and resistor is relatively long. This is an undesirable, but unavoidable feature of these systems, as we shall soon see. Let us first review briefly why the time constant is long. Then we can consider the undesirable effects that can be attributed to this characteristic.

The AGC condenser, in simple and delayed systems, is charged by the horizontal sync pulses to approximately the peak level of these pulses. An AGC voltage is consequently produced that remains unchanged as long as the video carrier and horizontal sync pulse levels remain constant. When the carrier tends to change in amplitude, the horizontal sync pulse levels change correspondingly, causing the AGC condenser's charge to rise or fall. The resultant change in the AGC voltage bucks the carrier's tendency to alter in amplitude, keeping it substantially at its former level.

RC Time of AGC Condenser

The discharge time of the AGC condenser and resistor is relatively long with respect to the interval between horizontal sync pulses. If the time constant is made too long, the AGC system will not respond quickly enough to momentary changes in carrier amplitude brought about by fading, or slow changes in supply voltages, and these changes will therefore affect reception. If the time constant is too short, the AGC voltage will be affected by low-frequency video signals, chiefly the long-duration, low-frequency vertical sync pulses. When such signals are coming in, the AGC system will feed a small portion of them back to the controlled stages, causing the amplitude of these signals to be improperly reproduced with respect to the rest of the composite video signal. Unstable vertical synchronization, improper background shading and other troubles tend to result.

Now, although the discharge time of the AGC condenser is relatively long, its charging time is much shorter.

Short-duration incoming noise pulses are therefore enabled to charge up the fast-charging AGC condenser. These noise pulses take a much longer time to leak off (since the resistance in the discharge path of the AGC condenser is much greater than the resistance in its charge path). The charge on the AGC condenser produced by the noise pulse therefore remains for some time, and the increased AGC bias that results reduces the video detector's video and sync signal output.

The sync signals, which must be of the proper amplitude to produce good holding action even with noise absent, will be reduced in strength at a time when it is especially desirable that they be strong—i.e., in the presence of noise. An impairment of synchronization will therefore tend to occur.

The reader may inquire, why not increase the charging time of the AGC condenser and resistor and get rid of this trouble? The answer is, the charge time must not be increased very much—if it is, the AGC condenser will not charge to the peak of the sync pulse in the time allotted to it, and an accurate AGC response to changes in the strength of the incoming composite video signal will not be possible.

A *small* increase in charge time may be made. In some circuits, such an increase is obtained by the insertion of a

Fig. 1—A) Reducing noise response of AGC rectifier by inserting resistor (R-1) in charging path of AGC condenser. B) Noise reduction by means of filter.

resistor in series with the cathode of the AGC rectifier (see fig. 1A). In another method used to minimize noise, a filter is inserted into the AGC network, as shown in fig. 1B.

A basic defect of simple and delayed AGC systems, then, is their susceptibility to noise. A second basic defect of these systems lies in their inability to counteract rapid changes in carrier amplitude, such as those caused by low-flying airplanes.

When an airplane cuts in between a TV transmitter and a receiver (see
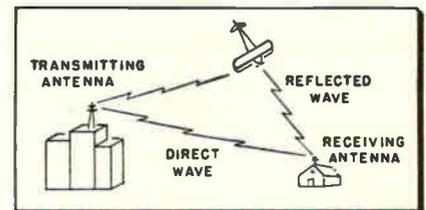
Fig. 2—Reflection of a transmitted signal from an airplane in motion may cause two signals varying in phase to be received at receiving antenna.

fig. 2), signal reflections from the airplane merge with the direct-transmitted signal. Since the airplane is in constant motion, the phase of the reflected signal is constantly changing with respect to the unreflected one. The two signals will, in consequence, sometimes aid, and at other times buck each other, in varying degrees, causing the net amplitude of the merging signals at the receiver antenna to vary from instant to instant. This flutter is too rapid in frequency to be counteracted by a slow-acting simple or delayed AGC system, and undesired symptoms, such as fluctuations in picture contrast and impairment of synchronization, therefore result.

Action of AGC Keying Tube

An AGC circuit is evidently needed that can respond to fast changes in the amplitude of the carrier, and is not very susceptible to noise. Such characteristics are present in a keyed AGC circuit (see fig. 3).

V-305, the AGC *keying tube*, is cut off except when horizontal sync pulses are present at its input. Such a condition is attained by placing its plate at DC ground potential, and tying the cathode to a point about 150 V positive towards ground, making the plate negative to cathode. Horizontal flyback pulses tapped off across the width control are fed through C-428 to the plate

in TV Receivers

Fig. 4—A) Positive-going flyback pulses at plate of AGC tube. B) Positive-going composite video signal at grid of AGC tube.

of V-305. These pulses, which are generated by the horizontal amplifier during retrace time, are sufficiently positive to cause the instantaneous voltage present at the plate of V-305 to exceed the cathode voltage, and thus permit conduction. Conduction takes place, then, when positive-going flyback pulses are at the plate of V-305, and positive-going horizontal sync pulses are at its grid (see fig. 4).

The control grid of V-305 is biased by the flow of plate current from the video amplifier—V-306—through R-318. The bias of V-305 is close to cut-off except when the horizontal sync pulse is present. The positive-going horizontal sync pulse developed in the plate circuit of the video amplifier, and the grid circuit of V-305, decreases the bias of V-305 very considerably, *assisting at the grid, the conduction that the flyback pulse is promoting at the plate*. During the rest of the horizontal cycle (the interval between horizontal sync pulses), a large negative grid-bias is present that helps keep V-305 cut off.

At the control grid, or input to V-305, the composite video signal is present. No part of this signal is, however, permitted to pass through the tube and produce an AGC voltage except the horizontal sync pulse. The advantage of this arrangement lies in its exclusion of the noise associated with video signals from the AGC line.

The AGC voltage is developed by the flow of current through R-437, R-436, R-435 and R-434. Since AGC current flows only during horizontal sync pulse time, or for about 5% of the time of one horizontal cycle, *the noise associated with the remaining 95% of the cycle is eliminated*. The AGC system's suscepti-

bility to noise is therefore very radically reduced.

Another of the advantages of this circuit lies in its fast response. The time constant of the AGC condenser and resistor is very small—about two-thousandths of a second—which makes it possible for the AGC system to buck fast changes in carrier amplitude, such as those produced by airplane reflections.

The reason that the time constant can be made so low lies in the fact that the AGC rectifier no longer has to filter out video signals and vertical sync pulses—the rectifier does not conduct when these signals are present at its input. In simple and delayed AGC system, on the other hand, these signals are present at the output of the rectifier, and have to be filtered out by using a sufficiently large AGC condenser, which means a long AGC time constant, and a slow-acting circuit.

Filtering the AGC Voltage

The keyed AGC circuit has to filter out only the horizontal sync pulses. For this purpose, the fast time constant present is quite suitable. The reason that the horizontal sync pulses must be filtered out (in *all* AGC systems) is that the AGC voltage is based on a relatively large number of horizontal sync pulses, not individual pulses themselves. If the AGC time constant was so short that individual horizontal sync pulses were able to change the AGC voltage, the latter would not be a pure DC voltage, but would contain

a horizontal sync pulse ripple. The feedback of such an improperly-filtered AGC voltage to the controlled stages would tend to impair horizontal synchronization, and introduce other troubles as well.

The use of a string of resistors, instead of one resistor, in the plate circuit of V-305 is for the sake of supplying an AGC voltage to the RF amplifier different from that applied to the controlled video IF amplifiers. Some of the resistors, in conjunction with their associated condensers, are employed to filter the flyback pulses out of the AGC line.

The composite video signal applied at the grid of the keyed AGC tube is not only positive-going—its DC level has been restored as well. All the sync pulses therefore line up at the same level, and as long as the video carrier remains constant, the AGC voltage produced by V-305 will remain the same. When the amplitude of the video carrier tends to change, the sync pulse level of the composite video signal will change with it, affecting the bias and conduction of the AGC rectifier proportionately, and causing the AGC output voltage to buck the change.

Let us say, for example, that the video carrier tends to increase. The grid signal input to V-305 will increase, the horizontal sync pulse level will rise, and V-305 will conduct more. The AGC output voltage will therefore increase, and the gain of the controlled stages will drop, tending to maintain the video carrier at its former level.

Fig. 3—Representative keyed AGC circuit, used in Admiral 24D1, 24E1, 24F1, 24G1, and 24H1

Servicing Keyed AGC

Representative Troubles in Typical Circuits.

Fig. 2. (A) Hor sync waveform at AGC tube grid. (B) Flyback waveform, AGC tube plate.

We outlined the operation of the keyed AGC circuit shown in fig. 1.

Troubleshooting in this circuit will be facilitated if a scope is available. When the circuit is operating normally, the composite video signal will be seen at the grid of V-305. If the scope frequency setting is advanced to fifteen or thirty thousand cycles, horizontal sync pulses should be observed (see fig. 2A). Their normal peak-to-peak amplitude in this circuit is 45 V.

A 350 V peak-to-peak flyback pulse waveform resembling the one shown in fig. 2B should be seen on the scope screen when the scope leads are connected between the plate of the AGC keyer and ground.

Defects in the AGC circuit, *or in other circuits that affect the AGC circuit,* can kill both picture and sound. A defective video amplifier, for example, can eliminate the sound signal. With the video amplifier operating normally, its plate current produces a voltage drop across R-318 (as well as other resistors in series with R-318) that makes the grid of the AGC tube 130 V positive to ground. The cathode of the AGC tube is 150 V positive to ground. The bias of V-305 is therefore —20 V.

If the video amplifier becomes inoper-

ative, and its plate current stops flowing, it will no longer produce a voltage drop across R-318. The upper end of R-318 will therefore be as positive as its lower end, instead of being less positive, as it is under normal conditions. The grid voltage of V-305 will therefore also be more positive. The excessive conduction of V-305 that results will produce an excessive AGC voltage that will cut off the RF amplifier as well as the controlled video IF stages.

Since the sound signal is taken off at the plate of the 2nd video IF amplifier, it will be more readily eliminated by a rise in AGC voltage than if it were removed at the mixer plate. The picture will also be killed, when the sound is cut off.

Fig. 1. (above) Representative keyed AGC circuit, used in Admiral 24D1, 24E1, 24F1, 24G1 and 24H1. Fig. 3. (below) Keyed AGC circuit used in GE Models 17C110 and 17C111.

Faced by such symptoms, in a receiver of this type, the alert serviceman will try substituting a new video amplifier, as well as front-end and 1st video IF tubes, before he starts more elaborate circuit tests.

If the AGC circuit becomes completely inoperative (due, say, to a defective AGC tube) the sound volume will increase, while the picture disappears. This rather surprising circuit characteristic may be analyzed as follows:

Video amplifier V-306 is direct-coupled to video detector V-304A. The grid return resistor of V-306 is R-314. R-314 is also the load resistor for V-304. Therefore the bias of video amplifier V-306 is determined by the voltage developed across R-314. This voltage depends on the current through R-314, which in turn, depends on the signal input to the video detector. If the signal input to V-304 becomes excessive—as it will when the AGC bias is lost—the video amplifier bias developed across R-314 may become so negative that V-306 is cut off, killing the picture.

At the same time, the loss of AGC bias in the RF amplifier and 1st video IF stages will increase the sound signal level. Therefore, if the sound volume seems above normal, and the picture is absent, a quick replacement of the AGC tube would seem the best-advised service procedure, when a receiver containing the circuit described is encountered.

In fig. 3, the keyed AGC circuit used in GE models 17C110 and 17C111 is shown. The flyback pulse is coupled to the AGC keyer through a transformer, instead of a condenser, as in the previous circuit. The grid of the Hartley-type oscillator employed to generate the horizontal deflection voltage is attached through R-363 to the AGC line. This
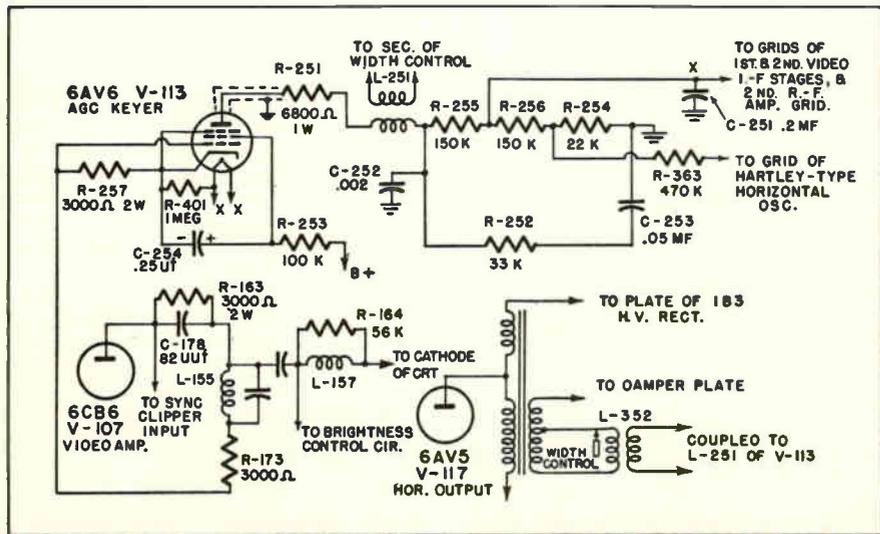
Circuits in TV Sets

Symptoms They Produce. Trouble-shooting Procedures.

connection is probably made to stabilize the AGC circuit action.

C-252, R-252 and C-253 filter out the flyback pulses from the AGC line. The plate lead of V-113 is shielded, probably to prevent induction of the high-amplitude flyback pulse into nearby circuits. In other respects, the circuit is similar to the preceding one.

To check whether the AGC circuit is operating, V-113's grid may be shorted to cathode, and the AGC bias produced between point X and ground measured. This bias should be —30 V or more. If it is, the keyer and horizontal deflection system are probably working OK.

The grid is shorted to eliminate the video signal input applied to the keyer. The possibility of trouble in the stages preceding the keyer is thus isolated. If the AGC voltage measured with the grid shorted to cathode is normal, but is not normal when the grid is unshorted, trouble in the video amplifier or some stage preceding it is indicated. Trouble in the grid circuit of the keyer is also a possibility.

When the AGC circuit is inoperative, negative pictures are likely to result, due to the overloading of various receiver stages. One of the more obscure things to check for in such a case is a defect in the width control. When the flyback pulses at the plate of the keyer are missing, or have insufficient amplitude, an open, partial short or complete short may be present in either the width control, or the winding coupled to it. Resistance checks with the width control primary and secondary disconnected will verify whether any defect is present here.
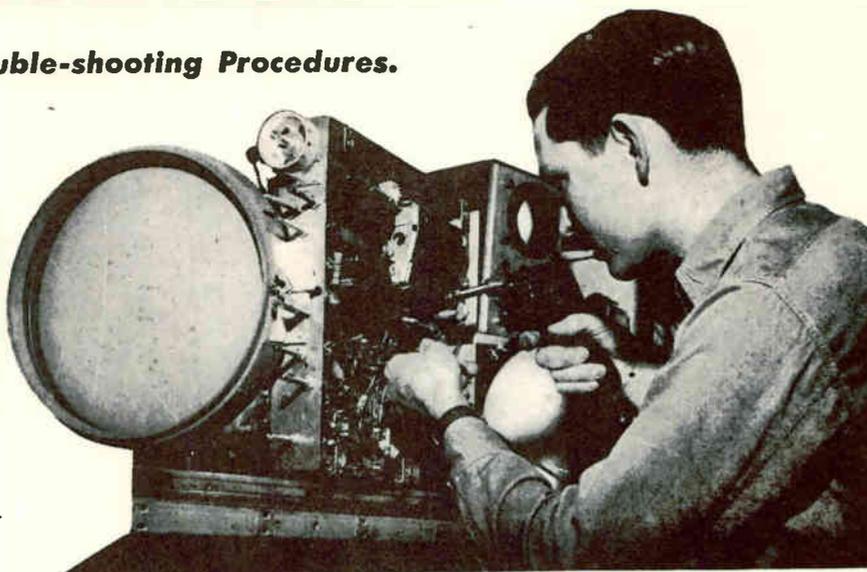
Scope tests at different points in the AGC line will reveal the trouble when flyback pulses are not being filtered out of the AGC feed-line. The 15,750-cycle pulses will be measurably apparent on the scope screen in such a case, instead of being absent.

Other defects, foreign to simple and delayed AGC circuits, but quite chummy with the keyed AGC network we have been describing, may be cited.

Distorted picture and sound, due to damping tube trouble is one of them. The AGC tube's AC plate voltage is taken off across the width control, which is in the damper circuit. If the damper tube becomes gassy, the irregular, highly non-linear conduction that it produces will change the voltage waveform appearing across the width control. Since this voltage is fed to the AGC tube's plate, the AC plate voltage of V-305 will be incorrectly shaped,

constantly changing at an irregular rate, and incorrect in amplitude. The AGC-controlled stages will therefore be fed an improper control voltage, possibly causing distortion in both picture and sound.

Proper operation of the keyed AGC circuit requires that the horizontal sweep be in synchronism with the incoming composite video signal. Under such conditions, the flyback pulse appears at the plate of V-305 at the same time that the horizontal sync pulse appears at the grid, and conduction for a very short interval, within fairly precise time limits, results.

When the horizontal sweep is *not* in synchronism with the incoming signal, however, plate and grid pulses on V-305 will no longer be in step, and the AGC tube may conduct at times other than the correct intervals, causing the AGC bias to vary rapidly, instead of remaining stable.

Improper AGC bias can therefore be the result of a fault in the horizontal deflection system of the receiver, particularly the horizontal AFC circuits. The obvious conclusion is, make sure that horizontal synchronization is ok, before trouble-shooting the AGC circuit proper. Say for instance that the sound signal is imperfect, and horizontal synchronization is also poor. Knowing the circuit, the serviceman would correct the horizontal sync trouble before he works on the sound symptom, because he knows that the sync trouble can be the daddy of the sound defect, via the AGC system.

A third keyed AGC circuit is shown in fig. 4. In this circuit, delayed and keyed AGC features are combined. The AGC amplifier is highly biased in the presence of weak incoming signals, and is practically cut off, in spite of the flyback pulses at the plate. The only negative AGC bias developed is due to the conduction of V-105B, the delay tube. The plate of this tube is fed to a posi-

Fig. 4. Keyed AGC circuit used in Crosley Models S11-447MU, SL-459MU, CH321-4.
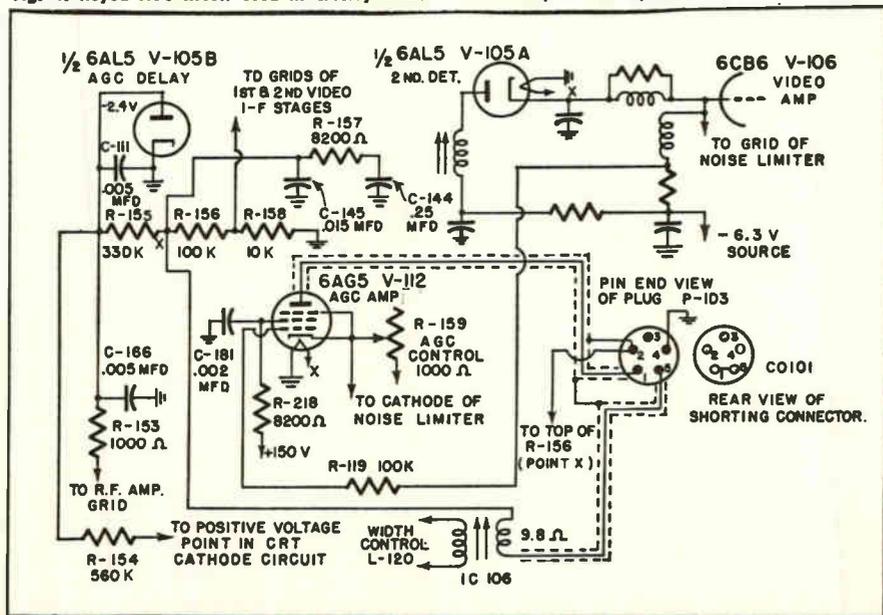
Cascode Amplifiers

Development of the Low-Noise, High-Gain Circuit. Triodes vs Pentodes in

● The cascode amplifier is becoming a standard feature of VHF and UHF television tuners. This circuit is a series-arrangement of two triodes, the first of which is operated as a grounded-cathode RF amplifier, the second as a grounded-grid RF amplifier. Readers who do not "dig" these terms will be supplied with an electronic pick and shovel later on in this article. An understanding of the operation of cascode tuners is essential to the technician, since he may have to service them. Your editor has not yet seen a clear and thorough analysis, from the serviceman's point of view, of how a cascode amplifier works. This article will provide, or attempt to provide, such an analysis.

Before we wade into the swamps of cascode theory, we should inspect our maps—i.e., review some preliminary considerations. One of the basic demands made of children and RF amplifiers is that they introduce as little noise as possible. The reason for this (in the case of RF amplifiers) is that the signal/noise ratio of the TV receiver is established primarily in the first tube. The minimum signal that the TV receiver can do business with depends on the amount of noise introduced in this stage. The larger the noise level here, the greater must be the signal amplitude to override it. Improving the signal/noise ratio—i.e., minimizing the noise introduced in the first tube—is therefore as advantageous
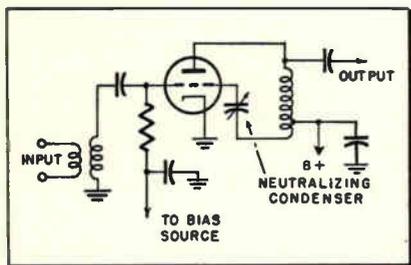
Fig. 1—Grounded-cathode RF amplifier. In some cases, a cathode bias resistor and bypass condenser are also present.

as increasing the power output of the TV transmitter, and far less expensive—at least to the transmitter people.

From the standpoint of minimizing noise, use of a triode as an RF amplifier would seem preferable to the employment of a pentode. This is true because the random division of cathode current in a pentode between plate and screen produces a shot-noise effect about three to five times greater than it would be if the screen were attached to the plate, and the tube functioned as a triode. This undesired noise is called *partition noise*.

Now triodes, although they have the virtues of introducing little noise compared to pentodes, tend to be unstable when used as high-frequency amplifiers. This is due to the large amount of feedback between plate and grid in these tubes. Some form of neutralization is therefore required when a triode is used in a conventional circuit as an RF amplifier, to prevent oscillation. Even with neutralization, how-
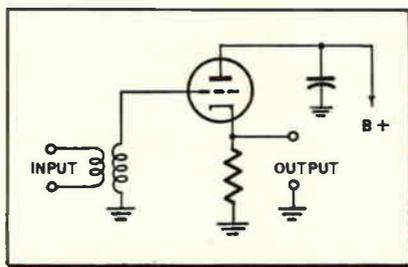
Fig. 2—Grounded-plate, or cathode-follower circuit. Gain of the stage is close to 1, except where the cathode or load resistor is very low (considerably less than 4000 ohms), in which case the gain drops substantially below 1.

ever, triodes tend to be unstable, and this fact limited their use in TV tuners (prior to the introduction of the cascode amplifier). Pentodes were most often used instead, because they were more stable, particularly in tuned input circuits, and did not require neutralization (the shielding effect of the screen grid in a pentode reduces the plate-to-grid capacitance very greatly).

Midnight oil—or the daytime equivalent thereof—continued to be expended by engineers on the problem of getting a triode to behave better. To more readily understand how the triode was finally made acceptable to the polite society of the TV front end, we should review the different ways in which a triode can be used for RF amplification.

A triode can be employed in one of the following 3 ways as an RF amplifier: 1—grounded-cathode amplifier. 2—grounded-plate stage. 3—grounded-grid amplifier. For any given tube, approximately the same noise factor will be introduced in all three set-ups.

The grounded-cathode circuit (fig. 1) derives its name from the fact that cathode of the tube is at AC ground potential (by connection direct to chassis, or through a cathode bypass condenser to chassis). This circuit can brag of high gain. When it is used as the second of two RF amplifiers, it doesn't load the first one down, (except under special circumstances) because its input impedance is high. However, its requirement of a neutralization ad-

justment which generally turns out to be critical and unstable in conventional high-frequency circuits has kept it sitting on the bench.

The grounded-plate amplifier (fig. 2) is a cathode-follower circuit. Its maximum gain is 1, so it has about as much right to be called an amplifier as a janitor has to be called an engineer. Since this circuit usually introduces a loss, rather than a gain, it is only useful in special applications where gain is not vital. It can be included out, as the saying goes, as far as RF amplification is concerned.

In the grounded-grid amplifier (fig. 3) the grounded grid shields the plate from the cathode in just the same fashion that the screen grid of a pentode shields the plate from the control grid. A triode set up in this way will operate without going into oscillation, since the input and output circuits are effectively isolated from each other. A disadvantage of the grounded-grid system, if it is used by itself for RF amplification, lies in the fact that the AC plate current of the tube flows through the source of the input signal, loading down the source and reducing
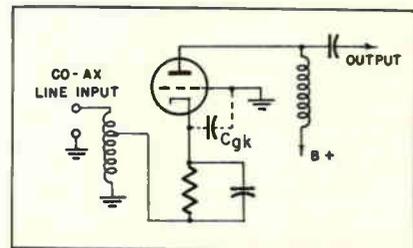
Fig. 3—Grounded-grid amplifier. The cathode-to-grid capacitance (C_{gk}) shunts the input circuit. The input impedance (across the input terminals) is very low in this circuit.

the gain. Another disadvantage is that the very low input impedance varies inversely as the transconductance of the tube. When the transconductance changes—due, say, to a variation in the AGC bias applied to the RF amplifier—the input impedance changes with it; the matching of this impedance to the transmission line and antenna is therefore upset, tending to cause reflections and loss of signal.

Now that the subject of triode amplifier set-ups has been reviewed, we can go on to the cascode amplifier. The cascode amplifier (fig. 4) consists of two triodes which, in combination, provide the amplification of a single pentode; the stability of a pentode; and the low noise factor of the first triode. Quite a package, especially as the two triodes may be provided by a single dual-triode tube. Reception in fringe

in TV Front Ends

RF Stages. Grounded-Cathode, Grounded-Grid and Grounded-Plate Circuits
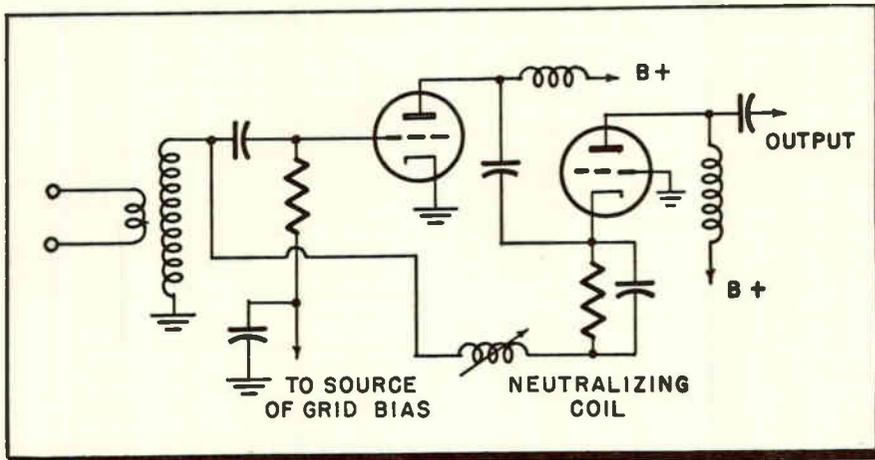
Fig. 4—An early non-commercial cascode amplifier (used in an experimental tuner).

areas can be considerably improved by the use of a cascode RF amplifier.

The second stage of the cascode amplifier is a triode like the first, because the signal/noise ratio is, to an appreciable extent, affected by the noise generated in the second stage of the receiver; it is therefore desirable to make the noise level in this stage as low as possible.

Two triodes can be connected in cascode in any of nine possible ways. The set-up shown in fig. 4 was chosen, because it provided optimum noise factor, stability and gain. The reader will probably recognize that the system comprises a grounded-cathode triode followed by a grounded-grid triode.

Neutralization of the first triode is effected by feeding an out-of-phase signal from the cathode circuit of the second tube to the grid of the first tube, through a neutralizing coil. The grounded-grid second triode requires no neutralization.

The heavy loading of the first triode by the second one (due to the connection of the first triode's plate circuit across the second triode's low-impedance cathode circuit) reduces the first one's gain to a point where feedback dangers are reduced; use of a neutralizing coil further helps to eliminate the possibility of feedback. Thus a grounded-cathode triode with a fairly good gain can be used for RF amplification—something which couldn't be done when the grounded-cathode triode performed in a solo role. The second triode not only keeps the first one behaving like a lady—it also contributes to the gain of the system.

The circuit shown is an early one, and could not be used in commercial TV tuners, because it would have required the switching in of a different neutralizing coil for each channel (due to the frequency-sensitive characteristic of this coil). A later version of the

cascode tuner is the *direct-coupled driven grounded-grid circuit*, illustrated in fig. 5. This cascode amplifier circuit is used in the front ends of "21" series Admiral receivers and other late model sets.

This circuit provides a number of advantages. First, the direct-coupling (signal current of the first tube flows through the second tube as well) permits several coupling network components to be eliminated. The distributed capacitance to ground at the output of the first triode, and the input to the second one is thus reduced, increasing the gain of the system at the lower channels. (The circuit capacitance can be tuned by means of a series coil to increase the gain on the higher channels.) Second, direct-coupling, by extending the cut-off of the characteristic curve, reduces the danger of cross-modulation by around 800%. AGC bias is applied to the first triode to also help avoid cross-modulation. This fuss over cross-modulation is made because a sharp cut-off tube, instead of a remote cut-off one is used, and such a tube is apt to be as chummy with cross-modulation as a chassis is with its cabinet. (A remote cut-off tube isn't employed to avoid the problem because the signal/noise ratio obtained with it would be lower than with a sharp cut-off tube.)

The double-triode used in the cascode amplifier circuit is generally a 6BQ7 or 6BK7. This new tube type has a very high transconductance, which provides a good signal/noise ratio. Its input conductance—which depends primarily on its input capacitance—is very low, resulting in a relatively small shunting of the antenna. A good voltage gain in the antenna input circuit is thus obtained.

The damping resistor in shunt with the grid coil of the first triode prevents excessive changes in bandwidth and input impedance that would tend to result from variations in AGC bias. The resistor also keeps the termination of the transmission line fairly constant from channel to channel, preventing the setting up of standing waves in the line. L101B, the antenna coil secondary, resonates with the inter-electrode and stray capacitance of the first triode's input circuit, in series with C102, a variable trimmer. AGC bias is applied through a resistor which, in conjunction with C115, acts as a

Fig. 5—Cascode tuner used in Admiral 21W1 and 21Y1 chassis. A shield is present between the two sections of the tube. Voltages indicated are measured with the 6BK7-Q7 tube removed from its socket. In the most recent version of this circuit, the bias network ratio of the grounded-grid stage has been changed to further remote the tube cutoff, and the grounded-grid (as well as the grounded-cathode) stage has been capacitatively neutralized.
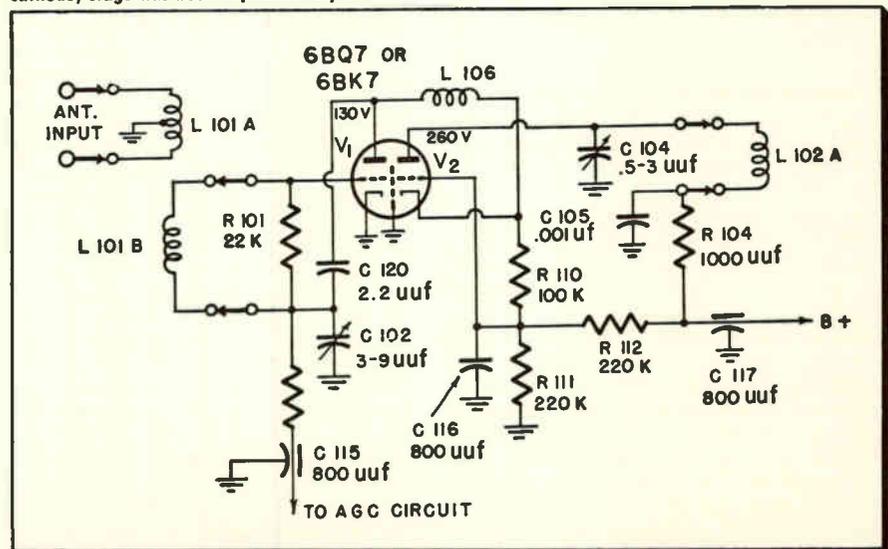
Troubleshooting Hints On

Case Histories from the Service Bench on Difficult or Unusual Set Failures

Locating Short in Auto Radio Power Supply

The fuse in a battery eliminator blew when an auto receiver was connected to it. Since fuse-blowing was not the complaint cited by the set owner, another fuse was inserted, and the set was tried out once more. The second fuse promptly joined its buddy.

The battery eliminator was checked while disconnected from the set (after a third fuse had been inserted in it). Its terminal voltage was correct.

The resistance of the set's "A" power supply wire (see fig. 1) to ground was then checked. The reading was ½ ohm. This seemed too low.

All the tubes were removed from their sockets. The pilot light was taken out of its holder; and the speaker field leads disconnected from the 6 V DC feed line. The resistance reading now measured between the "A" wire and ground was 18 ohms, which seemed a reasonable total for the chokes and coils remaining in the circuit.

The tubes were then replaced one at a time, with the ohmmeter left connected between the "A" lead and ground. The resistance reading dropped as each tube was inserted, but reasonably so. Ditto for the insertion of the pilot light. When the speaker field "hot" wire was re-connected, however, the resistance measured by the meter dropped sharply to ½ ohm.

A visual inspection of the lead showed it was shorted to ground at the point of its origin—i.e., the tube socket terminal to which it was connected. The short was possibly due to excessive strain on the wire, when the speaker assembly was removed from the receiver case.

Removal of the short restored the set to its original state of disrepair. Location of an intermittent tube a short time later brought the receiver to normal operation.

Clicking Noises on GE Model 515F

Clicking sounds were audible in this radio receiver from time to time. A loose socket connection was suspected, for this reason: Removing a tube from its socket and reinserting it again quickly, causes a click to be heard. Conversely, when a click is heard, isn't it likely that a tube is being, in effect, removed and reinserted into its socket, due to a loose connection?

Conventional tube-wiggling tests did not help in localizing the trouble. Tape was wound over a pair of long-nose pliers to insulate them, and various wires and components on the different sockets were then tugged at. When one particular component lead was tugged, a click resulted.

Special-type sockets are used in this GE set, with component connections brought to special connectors above the

chassis, and a socket cover mounted over these connectors. The cover on this one suspect socket unit was removed by bending in two lugs which held it in position. A connection that looked as if it might be cold-jointed was noticeable. It was carefully resoldered. No further clicks were heard.

Using 1,000-Ohm-Per-Volt Meter

High-resistance and vacuum-tube type voltmeters are widely used in servicing TV and FM receivers, and necessarily so. What about the orphaned
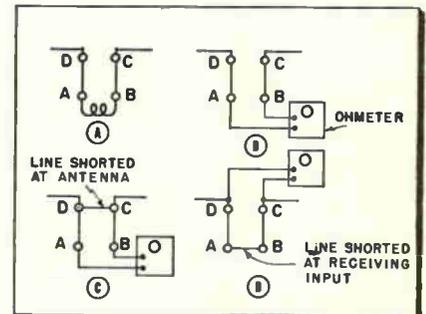
Fig. 2—Using 1000-ohm-per-volt voltohmmeter to check antenna system. a) Normal connection of antenna and line to receiver input. b) Receiver input disconnected. Checking line for short-circuit. c) Checking line for open-circuit. d) Checking line for open with ohmmeter attached at antenna side of the line.
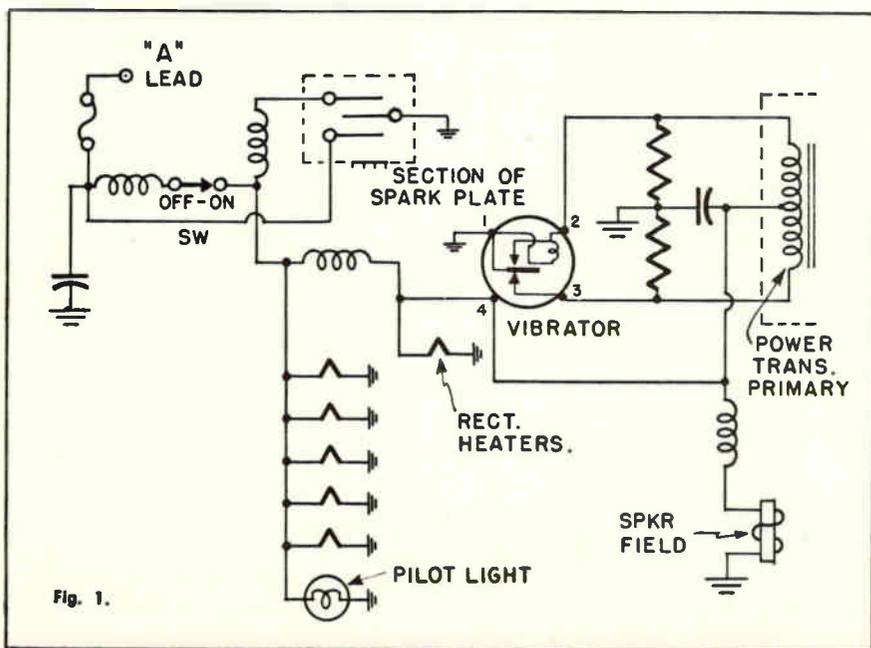
1000-per-volt voltohmmeter, though—can't it be used for anything in TV servicing?

An excellent use for it is in checking antenna systems. It is small enough to be highly portable, and needs no power, like a VTVM. It can be used just as well on a roof, as in a house, to check for an open or short in a transmission line (see fig. 2).

Providing Elbow Room In the TV Front End

When trying to get into the front end of a TV receiver, to make resistance or voltage checks, or perform some repair, look for a removable plate on the chassis near the front end, before you try to disassemble the latter. Some receivers have such a plate. When it has been unscrewed and swung aside, components in the front-end section become more accessible.

In cases where a turret-type tuner is present, removal of a suitable number of strips will make almost any front-end unit easy to get at.

Fig. 1.

TV / Radio Sets

Show the Way to Speedier Repair Work

Brightness Control Trouble

The picture illumination could not be reduced to zero by manipulating the brightness control, on this Regal TV receiver employing a 630 chassis. Similarly, with the contrast setting at minimum, the raster could not be darkened by turning the brightness down. The picture looked out of focus. It couldn't be made sharp by adjusting the focus control.

Trouble in the brightness control circuit was suspected. To localize it, the CRT was disconnected from its socket, and the voltages from CRT cathode connection to ground, and grid connection to ground, were measured at the socket.

The cathode-to-ground voltage was zero. The grid-to-ground voltage was about +10 V. Rotation of the brilliance control while the voltages were being measured didn't appreciably change these readings. A positive grid bias of 10 V was thus present at all brightness control settings. Normally, the bias should go from a negative maximum of 40, 50 or possibly even 100 V, to 0 V, or a very small positive voltage.

A leaky coupling condenser going to the grid of the CRT was suspected. C-141 in fig. 3 was checked, but showed no signs of a leak. C-142, the condenser in the input to the DC restorer was then checked, since it could also be causing the symptoms present. This condenser showed a 200-megohm leak when resistance-checked while cold. With C-142 disconnected (at its "cold" side), the voltage measured from its open side to ground read only +½ V; when C-142 was connected across its source of voltage, however, its leakage current increased, and it transferred a much more positive voltage to the grid of the CRT.

Set operation was restored to normal when C-142 was replaced.

Shocking News

Servicemen who don't judge books by their covers, should not gauge an insulation merely by its thickness. Thickly-insulated wires are sometimes judged to be capable of talking back to high voltage, and used as emergency HV connectors. When the serviceman touches the outside of the wire—intentionally or inadvertently—is he surprised!

There was a case where a long, thick wire was carelessly placed on a shelf overhanging the work-bench. One (insulated) end of the wire came into contact with "hot" surface of a metal-type cathode-ray tube. The other (insulated) end brushed lovingly against the serviceman's ear. The serviceman's remarks on that occasion were quite interesting, especially as he had one hand on the chassis, and had never been properly introduced to 15 KV before.

Arcing OZ4

The B+ voltage in an auto radio was normal for a while, then dropped down to a very low value. No short-circuits could be found by resistance checks.

A new metal OZ4 was substituted. The same symptoms appeared. Furthermore, the new tube's emmission read very low on the tube tester, after it had been in the set a short time.

A glass OZ4 was substituted for the metal one, so the insides of the tube could be watched, and power was applied for a very short time. When arcing was noted, power was immediately turned off. By arcing, we mean that the gas glow in the tube was unusually bright, and the area of glow was irregularly shaped.

It was reasoned that the tube might be conducting in both directions, instead of in one direction alone, due to excessive inverse voltage. An opening in one of the buffer condensers was the logical fault to suspect, since such an opening would greatly increase the inverse voltage peaks between plate and cathode of the rectifier. The two buffer condensers present were therefore replaced by new, identical units. No symptoms were present after this.

Fig. 3.

Noise-Elimination Circuits

General Theory of Noise Inverters. Inverter Circuit

By Solomon Heller
Technical Editor
Television Retailing

● Difficulties of maintaining synchronization in the presence of noise pulses —particularly when the incoming signal is weak—have led to the introduction of special noise-reducing circuits. These have been variously referred to as noise cancellers, noise inverters, etc. Their function is to improve the signal-noise ratio for vertical and horizontal sync signals. We are going to analyze a representative group of such circuits in this series of articles.

The noise inverter used in the new Bendix T14 chassis is shown in fig. 1. Before we analyze it in detail a brief consideration of the theory of noise inverters may prove helpful.

Noise is undesired in sync circuits because it will, when its amplitude is large with respect to the sync pulses, tend to produce incorrect triggering of the deflection oscillators. Now, it has been found that heavy impulse noise does not impair the operation of conventional sync circuits *as long as the noise is inverted in polarity*. If noise associated with, and appreciably larger than, the sync pulses is separated from the latter and turned upside down, it will be *negative-going*, when the sync pulses are *positive-going*. Such noise pulses will, in consequence, be made different from the sync pulses in one very important respect—polarity. They will therefore no longer be able to bamboozle the sync circuits into treating them as sync pulses. A noise inverter performs such an inverting (as well as amplifying) operation on noise pulses.

In a simple clipper circuit, excessively large noise pulses are merely limited in amplitude to the level of the sync tips (see fig. 2). Noise left after clipper action will still have the same polarity and amplitude as the sync pulses, and may therefore produce incorrect deflection oscillator triggering. In this respect, a noise inverter circuit is superior to a conventional noise-clipping circuit. It should be noted that noise inverters (as well as conventional clippers) have no effect, unfortunately, on noise that is smaller in amplitude than the sync tip level.

The noise pulses to be inverted should have a source which does not limit their amplitude, since they must be large enough, when they reach the sync separator input, to more than cancel their oppositely-polarized replicas that are present there (see figs. 3, 4). (This fact also explains the need for amplification in the noise-inverting circuit). It is also desirable that the sync signals come from a source which *does* limit in the vicinity of the sync-tip level, to obtain the benefits of the noise reduction inherent in such limiting. It is therefore customary in most noise inverter circuits to use the video detector as a signal source for the noise inverter. This stage is capable of delivering large amounts of noise before limiting.

There is an important disadvantage to connecting the noise inverter into the video detector output circuit, namely, additional capacitance is unavoidably introduced here, tending to impair the receiver's gain and high-frequency response. This disadvantage is overcome in the Bendix circuit by using the (unbypassed) screen grid of the video amplifier (instead of the video detector output circuit) as the signal source.

The inverted noise is fed to the sync separator only, since it would be undesirable to have it reach the picture tube, where it would appear as *white* noise, instead of the more usual and less conspicuous *black* noise.
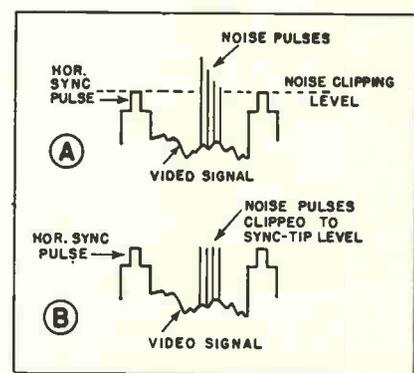
Fig. 2—Effect of simple clipper circuit on excessively large noise pulses.

Let's consider the action of the Bendix T14 noise inverter in detail. The inverter consists of a hi-mu twin triode and its associated circuit (fig. 1). Most of the screen-grid current of video amplifier V13 flows through V14A to the 155 V B+ point (for reasons to be explained soon). A much smaller part of the screen current flows through R65, which is in parallel with V14A. The impedance of V14A in parallel with R65 is very low. Consequently, the voltage changes across this impedance will be very small, when screen current variations due to signal changes occur. No screen bypass condenser is therefore needed; such a condenser is required only when the presence of a large screen dropping resistor tends to introduce substantial screen-grid voltage variations (degeneration). The incorporation of a video amplifier screen bypass condenser would, in fact, interfere with the circuit action, since it would short out or attenuate the screen signal that is fed to V14B.

The video amplifier tube is normally near cutoff on sync tips, since its control grid connects through L7 to the video detector output, and the DC negative voltage put out by the detector is maximum at sync pulse time. When a noise pulse appreciably larger than the sync tips enter the video detector, the
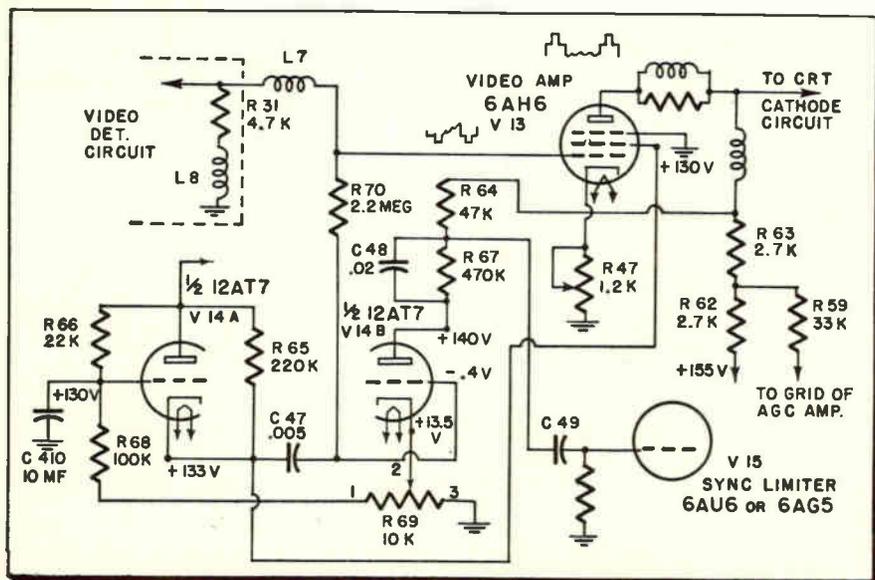
Fig. 1—Noise inverter circuit, Bendix T14 chassis. V14A and V14B comprise the noise inverter. Arrow leading from V14A plate goes to a +155 V terminal.

in the TV Sync Stages

Used in Bendix T14 Chassis.

large resultant negative grid voltage cuts the video amplifier off.

Before we consider further what happens when the video amplifier cuts off, let's investigate some of the things that are going on while it is functioning normally. R65, the screen dropping resistor for V13 (the video amplifier) is connected in parallel with V14A, the first noise inverter triode. Since V14A normally conducts (in the absence of excessively-large noise pulses) its plate-to-cathode impedance acts like a
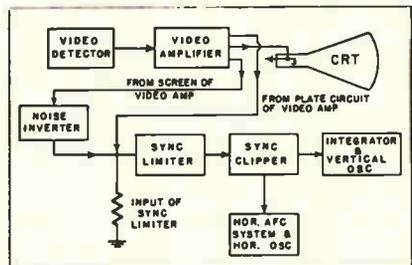
Fig. 3—Block diagram of noise inverter and associated circuits in Bendix T14 chassis.

resistor in parallel with R65. V13 thus has, in effect, two screen dropping resistors. Its screen voltage at any moment will depend on how much voltage is being dissipated across these two resistors in parallel at that moment. The greater the voltage used up across the resistors, the less will be left from the 155 V supply to feed the screen.

Now, the screen voltage constantly tends to change, since the screen is not bypassed to ground for video signals. Such (degenerative) changes would reduce the output of the video amplifier, if they were permitted to take place. They are prevented from occurring by the action of V14A.

When the video signal tends to increase the screen current and thus lower the screen voltage, the cathode voltage of V14A will be lowered the same amount, since the V14A cathode is connected to the V13 screen. When the cathode voltage of V14A drops, or goes *less positive*, it is the same as saying that the cathode is going *more negative*. V14A therefore conducts more. Its plate-to-cathode resistance *decreases* in consequence. The total resistance of V14A in parallel with R65 therefore decreases, tending to produce a lower voltage drop across the network, and thus tending to *increase* the V13 screen voltage. V14A's action thus opposes the tendency of this screen voltage to go down. A similar but reverse action occurs when the V13 screen voltage tends to go up. V14A's plate resistance increases at this time, producing a larger drop across V14A and

R65 in parallel, tending to pull the screen voltage *down*, the same amount it tended to go *up*. The video amplifier's screen voltage is thus kept substantially constant in the absence of large noise pulses. Consequently, the video and sync signals transferred to the cathode of V14A, and to the grid of V14B (through C47) have negligible amplitudes. These (positive-going) video and sync signals are not sufficiently large to drive the grid bias of V14B low enough to bring the latter out of cutoff (V14B is normally beyond cut-off because of its low plate voltage and high cathode bias).

Now, when a large noise pulse comes along, the video amplifier cuts off, and its screen (as well as plate) voltage rises to the value of the +155 V supply. V14A also cuts off at this time, since the cessation of video amplifier screen current through V14A brings the cathode and plate of V14A to the same potential, causing conduction in this tube to stop. The screen voltage of the video amplifier abruptly rises at this time from approximately 133 V to the B+ voltage of 155 V.

This sudden increase in voltage constitutes a pulse, which is developed across R65, and fed through C47 to the grid of V14B. V14B is normally so biased by the proper setting of potentiometer R69 that it is slightly beyond cutoff when the tips of the sync pulses appear at its input. In the presence of a noise pulse large enough to cut the video amplifier off, the positive voltage pulse that is produced across R65 in the manner just described, is large enough

to drive V14B into conduction.

When V14B conducts, the noise pulse present at its input is amplified and inverted. The large negative (inverted) noise pulse developd at its output (across R64) is fed through C49 to the grid of the sync separator, V15. No sync or video signals come to V15 by way of V14B—these latter signals are applied to V15 only by way of the video amplifier, through R64.

The large negative noise pulse at the V15 input cancels the positive-going but otherwise identical noise pulse that is fed to the V15 input through R64. Some negative-going noise voltage is left over, but is not harmful, since only noise of the same polarity as the sync pulses can upset the sweep oscillators.

The setting of R69 is important. If R69 is set so that the bias on V14B is too low, the inverter may respond to and invert the sync pulses, thus preventing proper synchronization and causing an erratic jumping of the picture. If the bias is made too great, the noise inverter will fail to function on noise pulses that are only moderately larger than the sync tips, permitting these pulses to get through to the sync circuits and impair synchronization. The correct setting of R69 is one where the bias of V14B is placed sufficiently beyond cutoff so that this tube does not quite invert the sync pulses when the set is operating in sync.

The problem of "lockout" must be taken into account when a noise inverter circuit is employed in a receiver using a keyed AGC system. "Lockout"
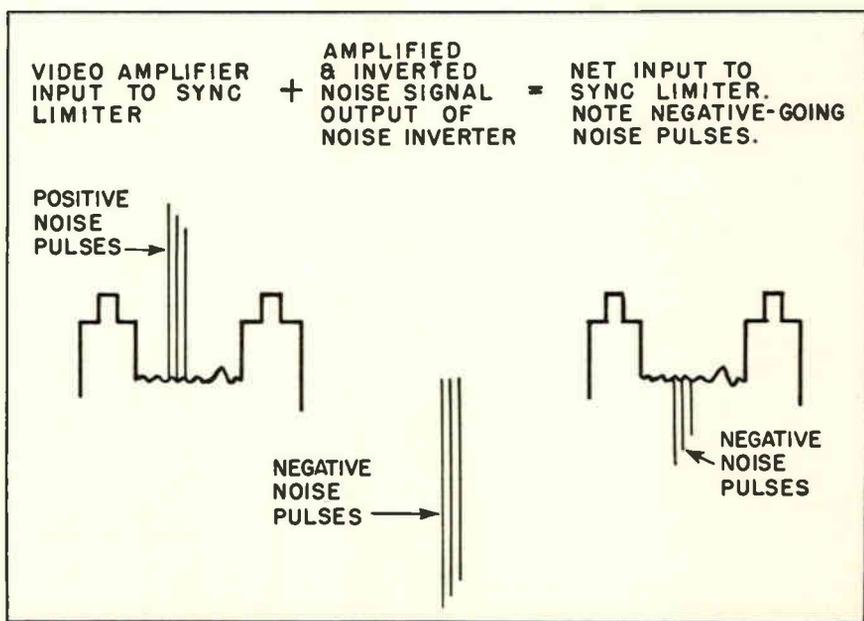
Fig. 4—Effect of mixing positive and negative noise pulses at input to sync limiter.

Sync Noise *Elimination* in

The noise inverter used in the Philco TV-90 receiver is so closely linked with the gated AGC system employed (see fig. 1), that both circuits will be described in detail.

The AGC gate tube, V13, functions like other keyed AGC tubes. A regulated source of grid bias is supplied to V13 by attaching its grid into the series-connected video amplifier—1st sound IF circuit. The composite video signal fed to the V13 grid is direct-coupled from the plate of video amplifier V7A.

video signal is also fed to the grid of the noise inverter (through C601).

The noise inverter is designed to conduct only when large noise pulses are present at its input. At other times, it is cut off. To obtain these conditions, the noise inverter is operated at a low value of plate voltage and high bias. R607 and R608 make up a voltage divider in the inverter plate circuit that reduces its plate voltage to the desired level of approximately 34V. A voltage divider in the cathode cir-

the noise inverter remains cut off (due to its low plate voltage and high bias). The composite video signal applied to its input is positive-going. Noise which can prematurely trigger the sweep oscillators is also positive-going. When video, sync and noise pulses are normal in size, they do not have the requisite amplitude to drive the grid of the inverter positive enough to produce conduction. A harmful noise pulse, however—i.e., a noise pulse whose polarity is the same as that of the sync pulses, but whose amplitude is much greater—will reduce the bias on the inverter enough to permit conduction.

When the noise inverter conducts, the noise pulse that drove it to this drastic step is amplified and inverted, and appears in the plate circuit in negative form. The noise inverter output is fed to the grid of the sync separator, where it mixes with the composite video and noise signal that is fed to this point from video amplifier V7A (See Fig. 2). The large negative-going noise signals from the inverter are more than sufficient to cancel the smaller positive-going noise signals from the video amplifier. In this way noise whose polarity is the same as that of the sync pulses is eliminated.

To prevent the noise inverter from conducting during sync pulse time (an undesired condition that would cause inverted sync pulses to be applied to the sync separator, upsetting synchronization) a circuit called a *gated leveler* is employed. The tube used—V14A—is ½ of a 12AU7. The circuit operation may be described as follows:

When the receiver is first turned on, there is no DC voltage present between grid and ground of the noise inverter. Video and sync signals are transferred through C601 to the grid of the in-
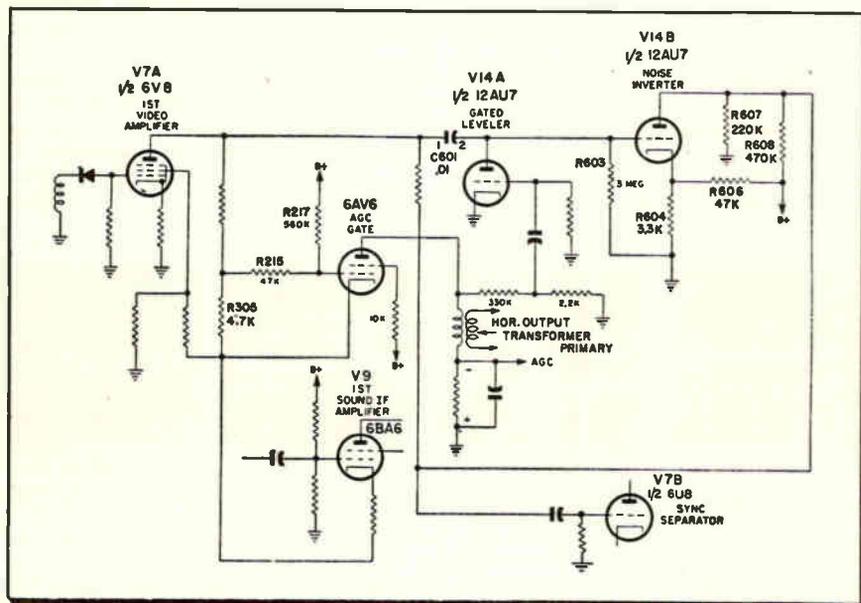
Fig. 1—Simplified schematic of noise inverter, AGC and associated circuits in Philco TV-90 chassis. Although the 6AV6 AGC gate tube is referred to as V13 throughout the article, its designation as V13 in the sketch was inadvertently omitted. (based on a Philco sketch)

A 10K resistor is connected into the screen grid circuit of V13. This resistor is protective in function. If it weren't present and the 1st sound IF tube became defective (open filament, or cathode emission failure) the bias on the AGC gate tube would be greatly reduced or eliminated, permitting it to conduct heavily. In between sync pulses, when no pulse voltage is applied to the V13 plate, excessive current would flow through the video amplifier and the screen circuit of V13. The 10K resistor limits such a current (when failure of the 1st sound IF tube tends to produce it), protecting the circuit components. In other respects, the circuit is so similar to other keyed AGC circuits we have already described that it doesn't seem to warrant further discussion.

Some composite video signal is taken off in the plate circuit of V7A and fed to V7B, the sync separator. This is ½ of a 6U8 tube. Composite

cuit—R606 in series with R604—places a voltage of approximately 6.6 V between cathode and ground.

When normal-sized video, sync and noise signals are present at its input,

Fig. 2—Block diagram of noise inverter, AGC and associated circuits in Philco TV-90. (based on a Philco sketch)
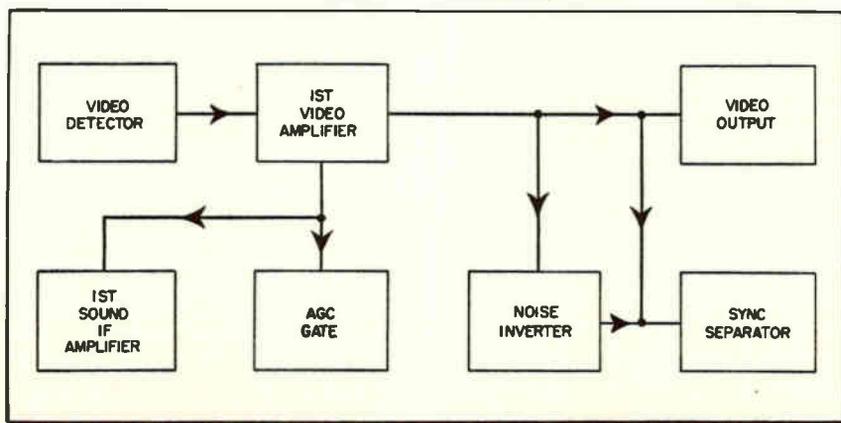
TV Receivers

and AGC Gate Circuits Analyzed.
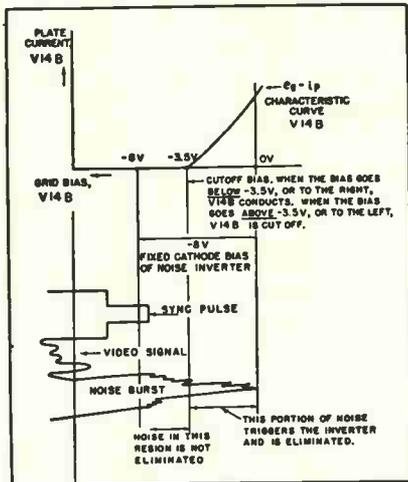
Fig. 3—Explanation by means of characteristic curve sketch of how noise several volts in excess of the sync tips triggers the noise inverter and is eliminated.

verter. These signals vary above and below the DC zero voltage level, but do not cause an appreciable DC voltage to be developed—that is, not for the first few cycles of incoming signal.

The positive swings of the incoming signal cause the plate of V14A to become positive with respect to the cathode, and conduction takes place in this tube. Electrons flow into plate 2 of C601 (and leave plate 1), charging the condenser. When the sync tip has passed, these electrons begin to leak off through R603 to ground. A negative voltage is thus developed between plate and ground of V14A. Since the cathode is grounded, the plate-to-ground voltage is the same as the cathode-to-ground voltage.

After several cycles, the charge on C601 has increased until it is approximately equal to the level of the sync pulses. The negative plate voltage of V14A is consequently much larger than the positive peaks of incoming video signals. V14A therefore cuts off in the presence of video information,

Fig. 4—Circuit conditions in the video amplifier, if the AGC gate tube was not connected into the latter's plate circuit, would permit a 15-volt separation between the sync tips and the B level. (based on a Philco sketch)
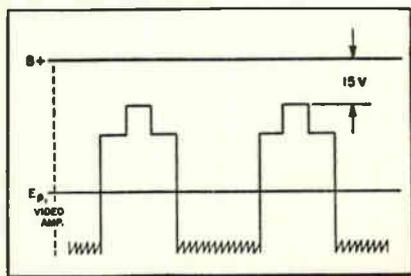
since these positive signals do not have enough amplitude to overcome V14A's negative plate voltage.

In between sync pulses, a small amount of C601's charge leaks off; the relatively long time constant of C601 and R603 does not permit much of the charge to be dissipated, so most of the V14A's negative plate voltage is retained, and the tube remains non-conducting at these times. The positive sync tips are slightly larger in amplitude than the negative plate voltage of V14A, since some of this voltage is lost through C601's discharge; conduction therefore takes place in V14A during sync-tip time, and a pulse of current flows that stops when the small charge that C601 has lost in the interval between sync tips has been replenished.

Across R603, thus, a negative voltage is continuously present; it is substan-

tially a DC voltage, and its amplitude is approximately equal to that of the sync tips.

Now the noise inverter tube has a fixed cathode bias of approximately 8 V. The cutoff voltage of the tube is approximately 3.5 V. This means that the tube is 4.5 V beyond cutoff. Grid signals developed across R603 must, to produce conduction, overcome the 4.5 V negative bias developed in V14B's cathode circuit, as well as the negative voltage built up in its grid circuit (across R603). Only incoming noise pulses that are a number of volts larger than the sync tips (see fig. 3) can overcome the sum of these two bias voltages. Such large noise pulses will trigger the inverter, and cause it to operate.

The question may crop up, what happens to noise pulses that are larger than the sync pulses, but not large enough to trigger the inverter? According to Philco engineers, this condition rarely occurs; even if it should, the sync separator has a certain immunity to such relatively low-amplitude noise, and therefore sync stability will not be impaired by it.

The noise inverter circuit must be

supplied with noise pulses of sufficiently large amplitude, since the negative noise pulse it delivers must be more than large enough to cancel its positive noise pulse counterpart at the sync separator input. A special voltage divider network has been incorporated into the grid circuit of V13, the AGC gate tube, to insure this. Before we discuss the need for this divider, and the manner in which it operates, we should first consider what would happen if it weren't present.

When the receiver is first turned on, no AGC voltage exists, since it takes a certain length of time for this voltage to develop. The above-normal receiver gain present during this interval causes an excessively large signal to be developed in the video detector output; the large negative DC voltage that is, in consequence, applied to the 1st video amplifier grid cuts the video
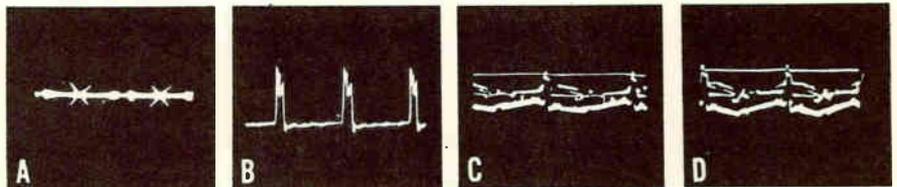
Fig. 5—Waveforms and their amplitudes in noise inverter and AGC circuits of the Philco TV-90. A) Noise inverter cathode (pin 8). Waveshape and its amplitude vary with noise. B) Gate-pulse plug (pin 4). Waveform is 500 V peak-to-peak; frequency, 15,750 CPS. C) AGC gate grid (pin 1). 22 V peak-to-peak, 60 CPS. D) Noise inverter plate, junction of R605, C602 and C603 (fig. 6). 23 V peak-to-peak, 15,750 CPS. (courtesy Philco)

amplifier off. Plate current cessation in this tube causes its plate voltage to rise to the B level. The AGC gate tube grid, which is connected into the video amplifier plate circuit, is thus also brought to the B voltage level.

The cathode of the AGC gate tube has a fixed voltage of 125 V. This volt-

(Continued on page 46)

Fig. 6—Test points referred to in text, are shown in these portions of the actual schematic of the Philco TV-90.

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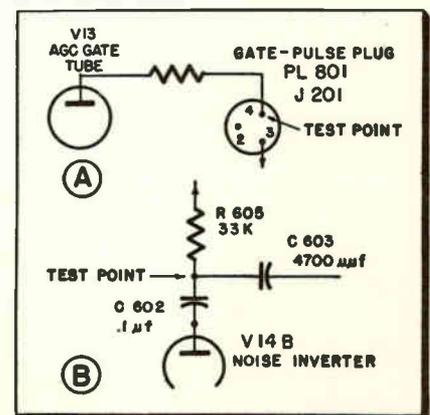
UHF-TV Frequencies & Wavelengths

Compiled by J. M. De Bell Jr., W. Budd and M. Casey, Allen B. DuMont Labs. Inc., Clifton, N. J.

Channel Number	Visual Frequency Carrier	Aural Frequency Carrier	Wavelength Centimeters	Inches
14	471.25		63.660	25.063
		475.75	63.058	24.826
15	477.25		62.860	24.748
		481.75	62.273	24.517
16	483.25		62.079	24.441
		487.75	61.506	24.215
17	489.25		61.318	24.141
		493.75	60.759	23.921
18	495.25		60.575	23.848
			60.030	23.634
19	501.25		59.850	23.563
		505.75	59.318	23.354
20	507.25		59.142	23.284
		511.75	58.622	23.080
21	513.25		58.451	23.012
		517.75	57.943	22.812
22	519.25		57.778	22.747
		523.75	57.279	22.551
23	525.25		57.116	22.487
		529.75	56.630	22.295
24	531.25		56.471	22.233
		535.75	55.996	22.046
25	537.25		55.840	21.984
		541.75	55.376	21.802
26	543.25		55.223	21.741
		547.75	54.770	21.563
27	549.25		54.620	21.504
		553.75	54.176	21.329
28	555.25		54.030	21.272
		559.75	53.595	21.100
29	561.25		53.452	21.044
		565.75	53.027	20.877
30	567.25		52.887	20.822
		571.75	52.470	20.657
31	573.25		52.333	20.604
		577.75	51.926	20.443
32	579.25		51.791	20.390
		583.75	51.392	20.233
33	585.25		51.260	20.181
		589.75	50.869	20.027
34	591.25		50.740	19.976
		595.75	50.357	19.826
35	597.25		50.230	19.776
		601.75	49.855	19.628
36	603.25		49.731	19.579
		607.75	49.362	19.434
37	609.25		49.241	19.386
		613.75	48.880	19.244
38	615.25		48.761	19.197
		619.75	48.407	19.058
39	621.25		48.290	19.012
		625.75	47.942	18.875
40	627.25		47.828	18.830
		631.75	47.487	18.696
41	633.25		47.375	18.652
		637.75	47.040	18.520
42	639.25		46.930	18.476
		643.75	46.602	18.347
	640		46.875	18.455
43	645.25		46.494	18.305
		649.75	46.172	18.178
44	651.25		46.065	18.136
		655.75	45.749	18.011
45	657.25		45.645	17.970
		661.75	45.334	17.848
46	633.25		45.232	17.808
		667.75	44.927	17.688
47	669.25		44.826	17.648
		673.75	44.527	17.530
48	675.25		44.428	17.491
		679.75	44.134	17.376

Channel Number	Visual Frequency Carrier	Aural Frequency Carrier	Wavelength Centimeters	Inches
49	681.25		44.037	17.337
		685.75	43.748	17.224
50	687.25		43.652	17.186
		691.75	43.368	17.074
51	693.25		43.274	17.037
		697.75	42.995	16.927
52	699.25		42.903	16.891
		703.75	42.629	16.783
53	705.25		42.538	16.747
		709.75	42.268	16.641
54	711.25		42.179	16.606
		715.75	41.914	16.502
55	717.25		41.826	16.468
		721.75	41.566	16.365
56	723.25		41.479	16.330
		727.75	41.223	16.230
57	729.25		41.138	16.196
		733.75	40.886	16.097
58	735.25		40.802	16.064
		739.75	40.554	15.966
59	741.25		40.472	15.934
		745.75	40.228	15.838
60	747.25		40.147	15.806
		751.75	39.907	15.711
61	753.25		39.827	15.680
		757.75	39.591	15.587
62	759.25		39.513	15.556
		763.75	39.280	15.465
63	765.25		39.203	15.434
		769.75	38.974	15.344
64	771.25		38.898	15.314
		775.75	38.672	15.225
65	777.25		38.598	15.196
		781.75	38.375	15.108
66	783.25		38.302	15.080
		787.75	38.083	14.993
67	789.25		38.011	14.965
		793.75	37.779	14.874
68	795.25		37.724	14.852
		799.75	37.512	14.769
69	801.25		37.441	14.741
		805.75	37.232	14.658
70	807.25		37.163	14.631
		811.75	36.957	14.550
71	813.25		36.889	14.523
		817.75	36.686	14.443
72	819.25		36.619	14.417
		823.75	36.419	14.338
73	825.25		36.353	14.312
		829.75	36.155	14.234
74	831.25		36.090	14.209
		835.75	35.896	14.132
75	837.25		35.832	14.107
		841.75	35.640	14.031
76	843.25		35.577	14.007
		847.75	35.388	13.932
77	849.25		35.325	13.907
		853.75	35.139	13.834
78	855.25		35.077	13.810
		859.75	34.894	13.738
79	861.25		34.833	13.714
		865.75	34.652	13.643
80	867.25		34.592	13.619
		871.75	34.414	13.549
81	873.25		34.354	13.525
		877.75	34.178	13.456
82	879.25		34.120	13.433
		883.75	33.946	13.365
83	885.25		33.889	13.342
		889.75	33.717	13.274
		900	33.333	13.123
		920	32.609	12.838
		940	31.915	12.565
		960	31.250	12.303

Wavelengths vs. frequency for the UHF-TV band
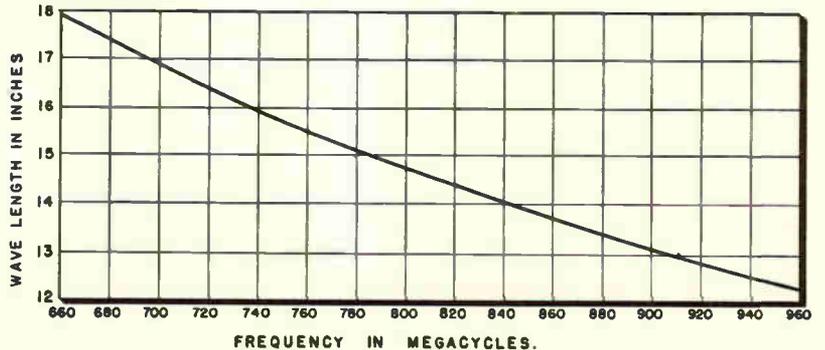
Eidophor Projector for Theatre TV

New system employs unique light valve principle to produce large-screen pictures approaching the quality of motion pictures

A new system for large screen color TV projection—Eidophor—has recently been introduced in the U. S. by Twentieth Century-Fox Film Corp. Essentially of the same size and shape as conventional motion picture projectors, the device provides ample illumination to satisfy the needs of even the largest theatres. See Fig. 1.

Credit for the discovery of the novel principle used in the system belongs to Dr. Fritz Fischer of Switzerland's Federal Institute of Technology, who died suddenly in 1947. The development of the basic black-and-white system, initiated 12 years ago, has been carried out by Dr. Hugo Thiemann of the Swiss Institute and Dr. Edgar Gretener A. G. of Zurich.

Twentieth Century-Fox, which holds the world-wide rights for the manufacture and distribution of the projectors, has adapted Eidophor for color through its joint efforts with CBS. Engineering development by Twentieth Century-Fox has been under the direction of Earl I. Sponable, co-inventor of the sound-on-film process currently used throughout the motion picture industry.

Operating Technique

Operation of the Eidophor system is illustrated in Fig. 2. Light from the arc lamp (1) passes through the aperture plate (2), color wheel (3), condenser lens (4) and strikes the mirror bar system (5). This plane mirror is tilted at 45° to the direction of this initial light beam, and has open slits between and about as wide as the parallel mirror bars. Consequently, half of the light passes through (5) and is lost, while the other half is reflected down on the spherical mirror (7). Assuming for the moment that the thin oil surface, or Eidophor liquid, covering (7) is not disturbed, the incident light on area (8) will be reflected back to the parallel mirror bars of (5) and on to (1) along the same path as the original incident beam. On the other hand, if the liquid surface is deformed by an electron beam from gun (6), the light impinging on (7) will be deflected so that the reflected beam does not strike the mirror bars

HOW GOOD IS EIDOPHOR PICTURE QUALITY?

A recent demonstration using a 525-line raster, 8 MC bandwidth and field-sequential color projected on a 15 x 11.5 ft. screen, gave the editors of TELE-TECH the following impressions:

- Overall quality was splendid and approached that of best motion picture projection.
- Brightness was about equal to motion pictures.
- Definition was excellent.
- Color fidelity was very good, with only slight color "hangover" which would not normally be noticed by lay observers.
- Contrast ratio of 1:200 was quite adequate.

of (5) but rather passes through the slits and then through the projected lens (10), to the directing mirror (11), onto the theatre screen (12).

Definition is determined by the number of mirror bars, which project parallel lines of light on area

Fig. 1: Eidophor system comprises: (1) Projector; (2) Projection light beam hood; (3) Color wheel; (4) Auxiliary services, vacuum pump and cooling system; (5) Projection lamp; (6) TV receiver circuits
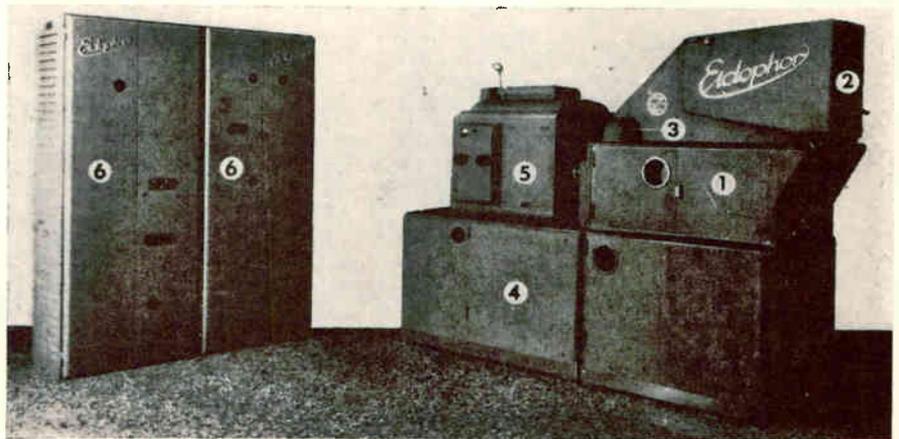
Fig. 2: Operational diagram shows arc source, color wheel, lenses, mirrors and electron gun

1. ARC LIGHT SOURCE.
2. APERTURE PLATE.
3. COLOR WHEEL.
4. CONDENSER LENS.
5. MIRROR BAR SYSTEM.
6. ELECTRON GUN AND DEFLECTION SYSTEM.
7. SPHERICAL MIRROR WITH THIN LAYER OF EIDOPHOR LIQUID.
8. ELECTRON BOMBARDED LIQUID AREA THAT MODULATES LIGHT BEAM.
9. KNIFE EDGE DETERMINING THICKNESS OF LIQUID LAYER.
10. PROJECTION LENS.
11. DIRECTING MIRROR.
12. THEATRE SCREEN.
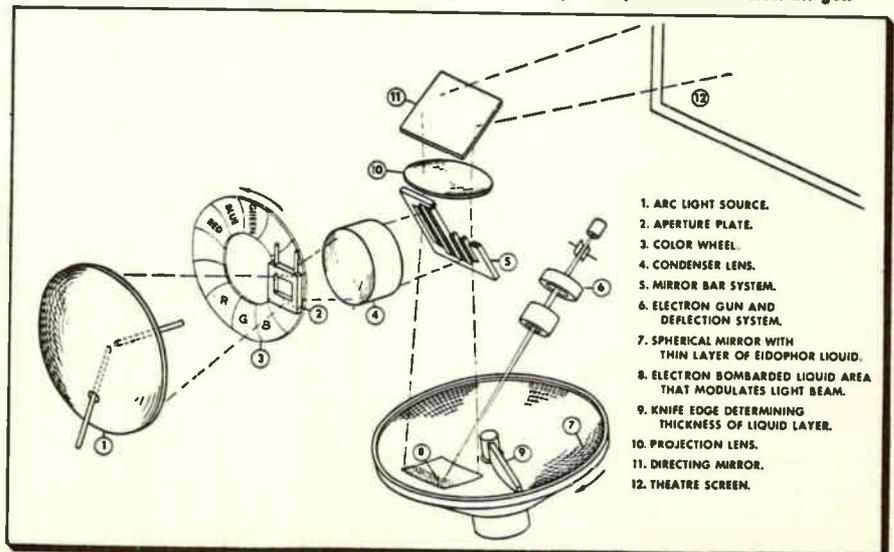
Lightning Protection

Common grounds, parallel conducting paths, and damage from high current surges. Protection of
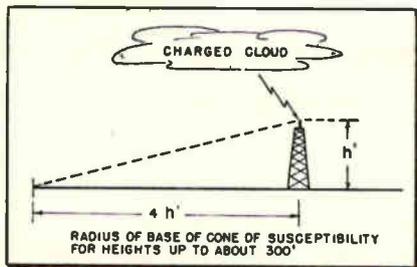
Fig. 1: Probable annual incidence of lightning strokes (I) to a radio tower. Computation: I = Annual no. thunderstorm days (D) × Stroke factor (S) x Susceptible area (A). Example: D = 35, S = 0.28, h = 250 ft., A = 16πh² = 0.113 sq. mi. I = 35 x 0.28 x 0.113 = 1.1 strokes.

By D. W. BODLE,
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EQUIPMENT in fixed stations of a mobile radio system is susceptible to damage from lightning strokes to either the antennas or the connecting power and land communication facilities unless special protection is provided. The problem, however, is not alone one of protecting the station equipment but consideration must also be given to the protection of the connecting facilities to insure their continuity of service.

Fixed stations located in rural areas present a more difficult lightning protection problem than the urban installations, but the protection practices employed in each case are basically the same. Stations in sparsely settled areas are generally more exposed not only to strokes to the antennas but also to destructive surges that enter the station equipment and tower lighting circuits from the connecting power and communication facilities. These connecting facilities are usually of aerial construction and as a rule are not as well grounded as in more built-up sections. In urban areas several factors tend to reduce the incidence of lightning trouble such as other high structures that divert strokes from the antenna, and water mains, gas pipes and other underground metallic structures which provide good station grounding. The connecting facilities in urban areas are frequently underground and have adequate conductivity to dissipate heavy stroke currents.

Lightning Damage

Lightning strokes directly to antennas are not uncommon. The grounded structure type of antenna does not require protection, but with the coaxial type a discharge gap between the "whip" and the "skirt," or some form of ¼ wave shorting stub connected to the coaxial lead-in close to the base of the antenna, should be provided to prevent arcing between the inner and outer conductors. Such a shorted stub, tuned to ¼ of the wavelength of the station's operating frequency, will not attenuate normal transmission appreciably, but will introduce a considerable loss to spurious signals such as lightning surges. The coaxial lead-ins commonly used on poles and towers have relatively high dielectric strength. Therefore, arcing is more likely to occur at the equipment end of the lead-in in the patching line or in radio equipment.

For example, ⅜ in. diameter air dielectric line has the lowest breakdown strength of the lines customarily used and will withstand a surge potential of about 7000 peak. The ⅞ in. diameter line and the solid dielectric lines will withstand materially higher voltages. A discharge gap in the antenna will divert a large portion of the stroke current to the coaxial "outer" and the voltage between the inner and outer conductors at the antenna will be that of the arc drop in the gap. However, as the current flows down the outer conductor to ground, the gap drop is supplemented by another potential that builds up between the inner and outer conductors. This voltage is approximately equal to the product of the resistance of the coaxial outer and the surge current flowing in it and is maximum at the terminal end of the line. When the coaxial outer is paralleled by other conducting paths such as a metallic tower structure or a wire when the line is supported on a wooden pole, the combined conductivity is usually enough to hold the voltage between the inner and outer conductors to

Fig. 2: Station grounding arrangement used by Bell System for one-story building with separate tower
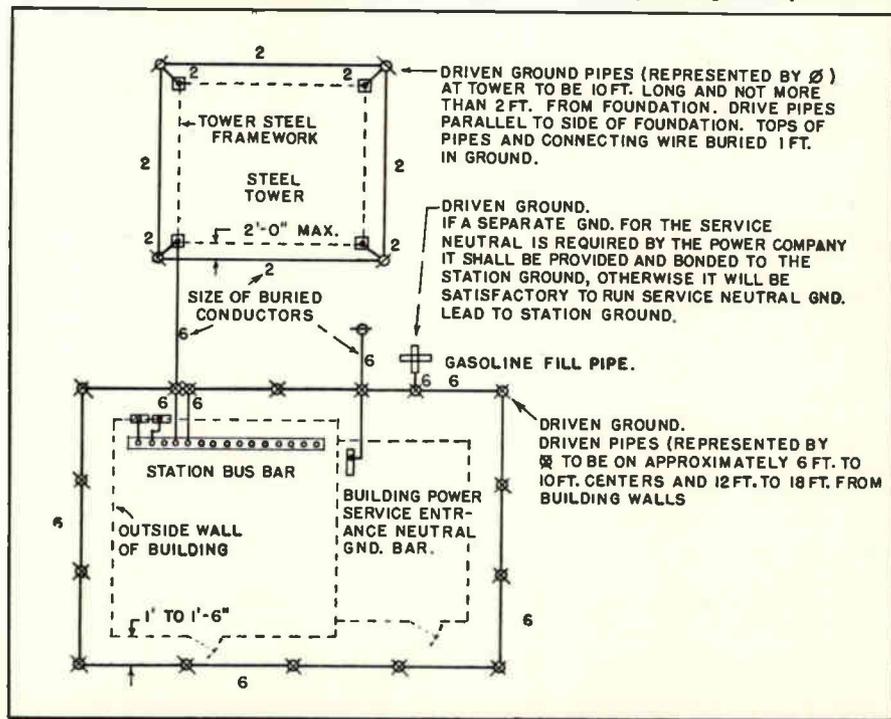
for Fixed Radio Stations

discharge gaps provide three important means for avoiding equipment connecting facilities must also be considered to preserve continuity of service

below the breakdown strength of the line and the connected equipment.

In addition to the problem of dielectric failure, stroke currents subject coaxial lines to magnetic forces directed radially inward which tend to crush the line. The likelihood of crushing may be substantially reduced by providing parallel conducting paths as discussed later, thereby reducing the current in the coaxial "outer."

Surge voltages may also appear between the conductors and conduit of the tower lighting circuit by virtue of stroke current in the conduit. However, it is unlikely that insulation breakdown or lamp damage will occur except on very large stroke currents because of the conductivity of the metallic conduit and other conducting paths in parallel with it.

Sizeable surge currents in the antenna structure may result from a stroke to ground relatively close to the tower. However, the resultant voltage will, in general, be of lower magnitude than those caused by direct strokes to the antenna or tower and do not constitute a serious protection problem.

Exposure to Direct Strokes

Strokes directly to the station grounding system are unlikely for the buried wire of the grounding system will usually be within the cone of protection of the tower.

The power and communication facilities serving stations in rural areas are usually exposed to direct lightning strokes and also to lightning surges from the rise-in-potential of grounds at other points on the systems such as in customers premises, flash over from guys, etc. Field investigations have established that surges of such origin may damage station equipment and tower lighting. Since rural power lines are generally not as well grounded as urban lines and also the communication circuits may be more exposed, these facilities in themselves present a considerable protection problem to insure continuity of service.

The results of recent field measurements indicate that the annual
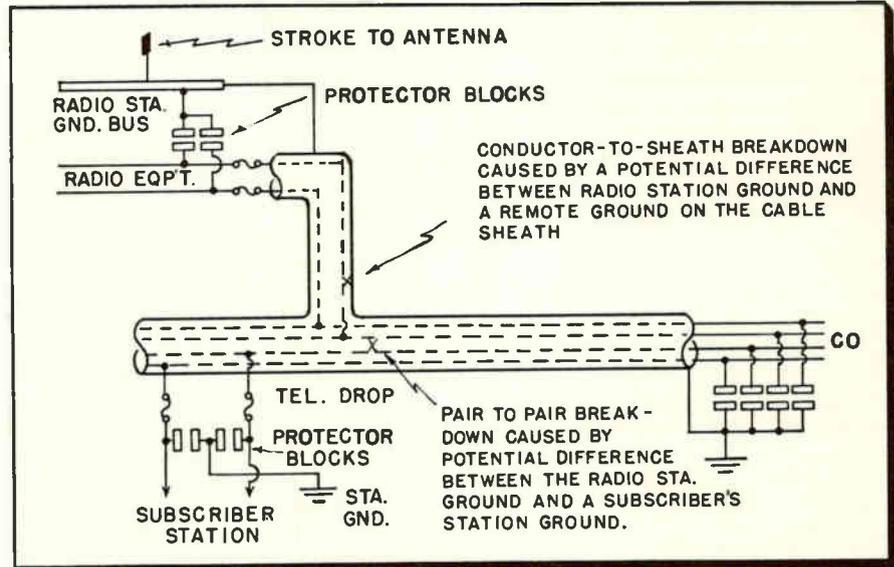
Fig. 3: Failure in telephone cables serving radio station with standard lightning protection only

incidence of strokes to ground is about 9/sq. mi. in areas having 30 to 35 thunderstorm days per year as shown on an Alexander isoceraunic map. In areas having 50 to 60 thunderstorm days annually the incidence of strokes to ground is in the order of 20/sq. mi. A radio antenna, however, is not just an exposed point, but is susceptible to strokes that would normally strike the earth within a considerable area around it. The probable annual rate of strokes to a radio antenna 250 ft. high in an area having 35 thunderstorm days annually is in the order of one stroke per year (Fig. 1). This approximation is based on the assumption that there are no objects such as tall buildings, trees or power lines projecting through the cone of protection of the tower. The presence of such projecting objects will divert strokes from the tower and lower its stroke incidence. Because a tower is located on a hill it may not necessarily have a higher stroke incidence, especially if there are other hills in the vicinity; however, the stroke incidence may be somewhat higher if it is on an isolated hill or the approach of the storms is over lower altitude terrain.

Magnetic link measurements secured during a period of approximately two years on a 250 ft. metal

antenna tower located in an area having 40 thunderstorm days per year indicate that the tower sustained four direct strokes. The following table gives the magnitude of stroke currents recorded:

Measuring Period	Peak Amp. to Gnd.	
	Tower	Coax. Line
July-Dec. '49	9100	200
Jan.-Dec. '50	7700	1900
Jan.-Dec. '50	38000	6000
Jan.-Aug. '51	19000	200

During the period of these measurements it appears that the incidence of strokes to the tower was between one and two per year, which is in good agreement with the theoretical case previously discussed. In a period of one year the station was off the air several times during lightning storms because of tube filament damage and operation of fuses in the radio power supply circuits. Coincident with failure of radio equipment, lamps in the tower lighting burned out and the commercial power line serving the station was disabled on several occasions for periods ranging from 20 min. to 12 hours. Since the instances of station trouble exceeded the number of direct strokes to the tower, it appears that some lightning surges entered the station over the connecting facilities. After some modi-

fication of the existing protection and the addition of arresters on the branch circuits, lightning troubles at this station are no longer a problem.

Protection Methods

The following protection methods have been successfully employed in the protection of land based stations:

1. Apply common grounding to all equipment, metallic structural members and facilities entering a station.

2. Provide a discharge gap in the antenna or a ¼ wave shorting stub in the coaxial lead-in cable close to the antenna.

3. Provide a conducting path in parallel with the coaxial line to reduce voltage between inner and outer conductors.

4. Install lightning arresters on the secondary service leads and lower voltage protectors on branch circuits feeding electronic equipment.

5. Provide discharge gaps on the communication circuits to equalize potentials and conduct surge currents to ground. In cable areas when conditions are severe, additional protection may be secured through the use of higher dielectric cable or conductors in parallel with the cable sheath.

6. For stations without standby facilities install adequate power line protection to help insure continuity of service.

Public metallic water pipes provide adequate grounding from a protection standpoint, but in locations where this means of grounding is not available it is necessary to construct a station ground system. Experience indicates that when setting up the requirements for a "made" ground it is preferable to specify only the dimensions of the buried network and its general configuration rather than its resistance value. Because of the wide variations in soil conditions, the cost of securing a ground of specified resistance may be unduly high and the money can be more profitably spent on supplementary protection on the connecting power and telephone lines.

Common grounding will reduce potential differences between the various metal components of the station. It is well therefore to provide a station ground bus to facilitate the common grounding of such things as the arresters on the power and communication circuits, the outer conductors of coaxial lines, conduit, equipment cases, gas and oil pipes, plumbing and metallic members of the building structure. The antenna tower, if metal, should be connected to the station ground. The tower conduit and coaxial cable outer conductor should be securely bonded to the tower at the top and bottom and also at frequent intervals in a manner to provide good electrical connection. Fig. 2 shows a characteristic station grounding arrangement employed by the Bell System.

Some antennas have incorporated in their design a star shaped discharge gap having an operating value of about 4000 peak v. to prevent flash-over in the coaxial line and connected circuits. A star gap has proven to be an effective protection device. However, it appears that in some recent antenna designs employing multiple arrays, the star gaps are being omitted because of mechanical complications. This makes it necessary to substitute other methods of protection such as the ¼ wavelength shorting stub installed at the base of the antenna. Surge measurements using a 52 ohm solid dielectric line and a current wave of 6 x 15 µsec (peak current attained in 6 µsec, decaying to ½ peak value in 15 µsec) indicate that a ¼ wavelength shorting stub is a satisfactory alternative. The following table gives a comparison of the residual voltage across the load termination for various surge currents applied to the antenna whip.

Surge Current Pk Amp.	Without Gap or Stub	With Gap	With 11 in. Stub	With 55 in. Stub
1000	9000	190	240	310
5000	*	800	1200	1550
10000	*	1600	2400	3100

* Above breakdown of coaxial connectors.

The desirability of some form of antenna protection is quite apparent, for without it the voltage across the load would be in the order of 9000 v./1000 amp. surge current. The star gap gave a reduction in voltage across the load termination in the order of 50 to 1 compared with about 35 to 1 with the stub. The gap is therefore preferable to the stub when it is practical to incorporate such a gap in the antenna design.

Susceptibility to Crushing

Small diameter air dielectric line is particularly susceptible to crushing, so it is desirable to provide a parallel conducting path to divert an appreciable amount of surge current from the outer conductor. When the line is supported on a metal tower, frequent bonding to the structure will provide sufficient parallel conductivity to prevent crushing of the coaxial outer. With lines supported on wooden poles, a conductor should be fastened to the side of the pole opposite the line and bonded to the coaxial outer at both the top and bottom of the pole. Since the division of the current is determined chiefly by the self impedances of the conductor and the coaxial line, copper

Fig. 4: (L) Impedance of power conduit helps protect equipment

Fig. 5: (R) Power circuit without interconnected neutrals or bridging gap
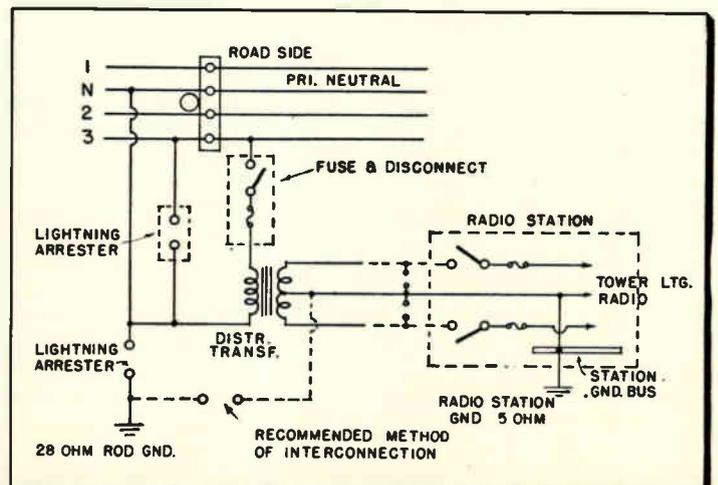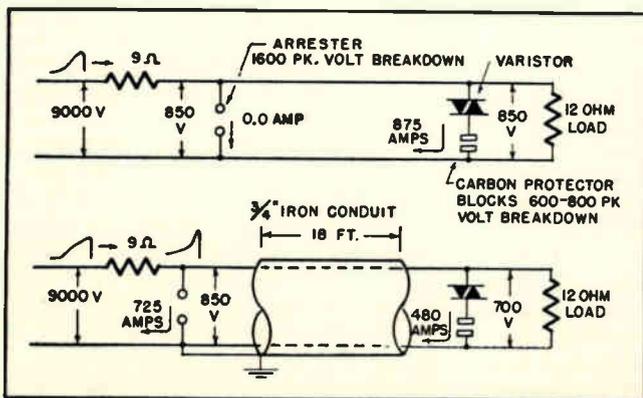
Lightning Protection

wire as small as No. 10 gauge has been used successfully for paralleling purposes. In general, the surge current divides about equally between the line and the parallel conductor and crushing is unlikely to occur except with unusually heavy surge currents.

With the smaller size lines or when the distance between the tower and the station is relatively long, it may be desirable to run the line in metallic conduit. At the tower end, the conduit and the coaxial outer conductor should be commonly bonded to the tower structure and in the building the conduit and coaxial outer should be connected to the station ground bus. The conduit, in addition to giving mechanical support, provides additional conductivity in parallel with the coaxial line, materially reducing the possibility of crushing. However, there have been field reports of lines being crushed by water freezing in such conduit runs so precautions should be taken to prevent the accumulation of water in them.

Land Communication Facilities

Remotely controlled fixed stations are common in a mobile system and consequently the land communication facilities are a vital link in the service. These stations are frequently in isolated locations where the antenna and connecting facilities are highly exposed to lightning. When the communication circuits are brought in by open wire, the protection problem is somewhat less than when small size cable is used. Although open wire will withstand relatively high lightning potentials, protection must be provided to equalize potentials where such circuits enter the station or connect with cable. At the station, all conductors should be connected to the station ground through discharge gaps. When open wire connects with cable, it is well at that point to provide a discharge gap between the sheath and each conductor in the cable. In addition to the gaps, grounding of the sheath at the junction will increase the protection and is particularly desirable in the case of small diameter cables having high sheath resistance.

An open wire line on jointly-used poles with a multi-grounded neutral power line having an operating voltage above 2900 v. rms to ground should be provided with gaps having a breakdown of about 3000 v. rms (.030 in. gap) connected between each open wire conductor and the multi-grounded neutral at intervals

of about ½ mi. In the case of unigrounded and delta systems, since a low resistance neutral is not available for grounding purposes, it becomes necessary to construct protector grounds of sufficiently low resistance so that the voltage drops across these grounds during a power contact will not exceed about 3000 v. rms. However, the cost of constructing these grounds, which may be
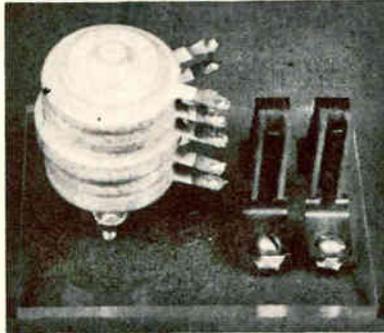
Fig. 6: Two-section varistor assembly and two carbon block discharge gaps provide for low voltage circuits

quite high, is a factor in considering the use of this type of protection. These gaps serve two purposes: first, they limit the voltage across telephone protectors located at other points; and second, they assist in the rapid de-energization of the power line by providing a low resistance path to ground for faulty current.

The protection of small size cable presents a greater problem as it is vulnerable to lightning damage from a rise-in-potential of the radio station ground and also from strokes directly to the cable and associated plant. Current from direct strokes to the antenna will divide between the station ground, the power line and the telephone line in inverse proportion to their surge impedances. As shown in Fig. 3, current entering the station ground will produce a potential with respect to a remote ground such as the protector ground at a subscriber station, and this difference in potential may cause pair to pair trouble. Furthermore, current in the sheath resulting from a heavy stroke to the antenna may cause dielectric failure between the core conductors and the sheath.

It is necessary, therefore, to limit these potentials with discharge gaps connected between the sheath and all cable conductors entering the station. The sheath should be connected to the station ground as discussed previously in the section on common grounding. This will equalize potentials at the station, but with long runs of small diameter cable, it is often necessary to provide equalization at intermediate points. It has been found in practice that adequate protection will generally be provided

by applying discharge gaps to all cable conductors at intervals of about ¼ mi. between the station and a point where the surge current in the sheath has been substantially reduced by shunt paths to ground. Some latitude is permissible in the selection of these equalization points and preference should be given to locations where favorable grounding conditions exist. When a cable is supported on poles with a multi-grounded neutral power system, bonding of the sheath to the common neutral is in most cases more desirable than a made ground. Such interconnection provides additional grounding paths for lightning currents in either system. In situations where the exposure is particularly great and the earth resistivity is high, it may be necessary to use higher dielectric cable or parallel the sheath with wires installed aerially or buried under the cable to reduce the sheath current and thereby the resultant core-sheath voltage.

Power Line Surges

The equipment and tower lighting in stations served by overhead power lines are vulnerable to damage from lightning surges originating on the power system. Experience indicates that in suburban and rural areas, the probability of trouble from this source is sufficient to justify the application of special protection on the service conductors and the branch circuits. The installation of secondary circuit power arresters (1.6-1.8 kv. operating potential) installed on the service conductors either at the weather head or service cabinet have provided satisfactory protection for the miscellaneous power and lighting equipment customarily operated on branch circuits.

With an underground power service in either iron conduit or employing steel clad cable, it is often desirable to install a distribution type arrester (about 3.0 kv. breakdown) on the secondary conductors at the power pole. The ground lead of the arrester should be connected to the conduit or cable sheath and at the station the conduit or sheath should be bonded to the common building ground. This arrangement utilizes the impedance introduced by the metallic covering over the service conductors to reduce the duty on the station arresters and materially raise the level of protection.

Secondary circuit arresters operating at 1800 peak v. will not adequately protect radio equipment. Therefore, a low voltage protector operating at 600-800 peak v. has been used extensively in the Bell System

Servicing Vibrators

Maintenance of Synchronous and Non-Synchronous Types Through

REVERSIBLE SYNCHRONOUS (J-63 or J-65M)

VERTICAL INPUT

4 PRONG INTERRUPTER (J2SP or J22)

TO SCOPE SUGGESTED ADAPTER

NOTE: DO NOT GROUND SCOPE TO EQUIPMENT UNDER TEST

Ⓐ   Ⓑ
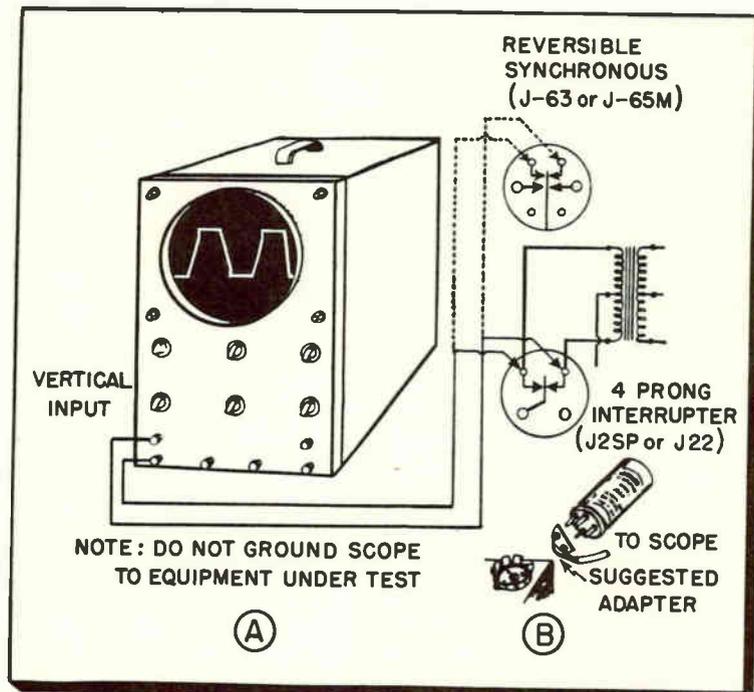
Fig. 1—A) Vibrator connections to oscilloscope. B) Adapter set-up.

• The oscilloscope is a valuable tool in the proper maintenance of vibrators and vibrator power supplies. The understanding and interpretation of the operating waveform of a vibrator will give the servicer important information on the vibrator and its associated components. "The picture tells the story."

The oscilloscope employed may be any standard type having an internal sweep circuit. The vibrator waveform is best observed across the primary contacts of the vibrator. These primary contacts are connected to the vertical input of the scope. This connection applies to both general types of vibrators, the interrupter (non-synchronous) and the synchronous. Fig. 1A is a pictorial diagram that shows the circuit hookup to be made in each case; two common types of auto-radio vibrators are assumed. The proper primary contact connection to other types of vibrators can be ascertained by referring to a suitable vibrator replacement guide.

To simplify the testing of units during operation, a thin adaptor can be readily constructed, as shown in Fig. 1B, with correctly attached leads inserted between the vibrator and socket.

The following oscilloscope adjust-

ments are made, previous to an inspection of the waveforms:

1—The vibrator contact connections are applied to the vertical input of the oscilloscope, and the vibrator power supply turned on.

2—The "synchronization selector" knob on the scope is set to "internal."

3—The sweep frequency range control is set to approximately 30-100 CPS.

4—Initially, the "sync" control should be at zero setting.

5—The "fine frequency" sweep control should be adjusted until two full square waveforms are stopped on the screen.

6—The "sync" control should be advanced until the waveform is stationary on the screen. The final setting is normally at a low level—15% or lower.

Advantages of Waveform Tests

Variation of all other controls to center and focus the waveforms can be made to suit the operator.

A few general comments re waveform analysis may be in order, before we make the analysis proper. Through waveform analysis, it is possible to ascertain the general condition of vibrator-powered equipment. More specifically, we can:

1—Anticipate the remaining life of a vibrator in service.

2—Ascertain the cause of excessive "hash" noise in the receiver, and determine whether it is due to the vibrator, or some other component.

3—Check new vibrators for proper operation.

4—Detect bad buffers or shorted transformers.

5—Observe excessive secondary or load currents.

6—Determine the cause of poor output voltage, localizing it to the vibrator, or its associated power supply, or the rest of the receiver.

Variations in Waveforms

The service engineer must remember that the vibrator is an electro-mechanical device of considerable complexity. Each individual unit in proper operation will show some variation in waveform from the ideals illustrated in fig. 2 and 3. This individuality must be kept in mind when interpreting waveforms. Experience will permit the proper interpretation of vibrator waveforms.

Fig. 2, sketches A-E, illustrate the waveforms obtained in an interrupter or non-synchronous type vibrator. This type of vibrator has contacts operating at the primary low voltage only. Rectification is achieved by other means (than vibrator action). Steady load conditions were maintained during the tests, as indicated by the waveforms.

Normal Waveform

Waveform 2A shows no bounce during contact closures. The broken lines on the diagonal are indicative of good buffer action. A new vibrator with proper buffer will show these breaks under test. As contacts wear, the contact closure is reduced, and the buffer closure will increase, tending to produce a solid line (instead of a broken one).

2B is an illustration of a condition called *single-stepping*. Single-stepping indicates a poor starting action. A vibrator that shows single-stepping on starting voltages of 5.5 V or more is either defective or worn. In service it will fail in a short period through fuse-blowing or poor output. Proper vibrator operation requires full reed-contact operation.

2C shows *contact bounce*. The waveform indicates a worn vibrator, in the case of a used unit. The service result will be lower output voltage and a very high "hash" level.

An extreme bounce like the one

By R. C. Canning, vice-president in charge of engineering, James Vibrapower Co., Chicago, Ill.

With the Oscilloscope

'Scope Waveform Checks. Normal and Abnormal Wave Shapes.

shown in 2C should not be thought of as the result only of dirty contacts—such a condition is occasionally found in a new component, and is due to poor vibrator adjustment. Dirty contacts generally show up as very small-amplitude bounces in the contact waveform. A short period of operation will normally correct this condition when it occurs in a new vibrator.

Unbalanced Closure; Arcing

The *unbalanced closure* indicated in 2D is the result of poor adjustment or, in some instances, a bad buffer. Try another vibrator in the circuit, to find out whether or not the original one is defective. If the trouble lies in the vibrator, the unit may give partial service, but is a poor risk. This is the typical vibrator that "sticks" after short service.

2E indicates arcing at contacts. The trouble can lie either in the vibrator or its associated circuit. Try another vibrator to pin down the source of the fault. If the waveform becomes normal, the original vibrator is defective; if it
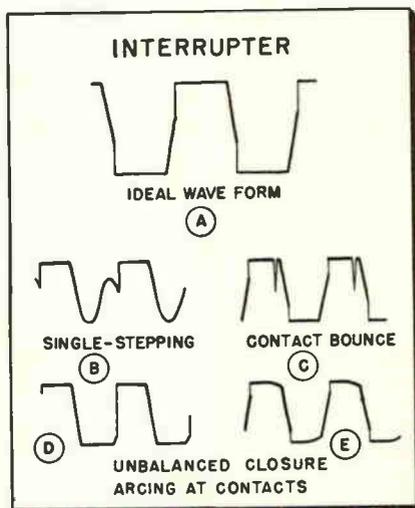
Fig. 2—Normal and abnormal vibrator waveforms for non-synchronous vibrator.

remains abnormal, a component in the associated circuit is to blame.

If circuit trouble is indicated, check the buffer first, then the rectifier, filter and external circuit. If the fault has been traced to the vibrator, the unit should be discarded.

The synchronous-type vibrator has both primary contacts at low voltage and secondary contacts at high voltage. The second set of contacts close slightly after the primary ones, and provide output rectification. The waveform ob-

served across the primary contacts show this secondary contact operation in the form of a small voltage drop when the contacts connect the load. (See fig. 3A).

3A is the ideal wave, and shows no bounce during contact closure. The peaks or horns at the beginning and end of each closure are the secondary rectifier contacts closing later and opening sooner than the associated primary contacts. Note the same broken buffer closure line characteristic of interrupter vibrators. As the vibrator wears, the line becomes longer, and manifests decreasing break. This ideal waveform shows perfect timing of contacts, which results in high output and low "hash" level.

Secondary Spacing

3B shows a condition known as *wide secondary spacing*. The secondary contacts close later, and open sooner, than they normally do. The condition results in lowered voltage output, and a higher level of "hash." Service failure of the unit will not ordinarily occur as a result of this defect. The lower output voltage and "hash" level should be judged for acceptability.

3C represents a condition known as *close secondary spacing*. This condition will result in contact arcing and fuse-blowing in vibrator operation. A synchronous vibrator that produces waveforms lacking horns or tips should be removed from service.

Care in Interpretation

Care should be taken in interpreting the condition present when this waveform appears for a synchronous vibrator. If the secondary load is off (i.e., the set is not warmed up) or circuit trouble is present, the waveform obtained may resemble the one characteristic of a normally-functioning *interrupter* vibrator. The trouble in such a case can be localized by substituting a vibrator in known good condition for the one present, and noting results.

3D—*secondary contact bounce*—illustrates a fault that will result in lower voltage output and high "hash" level. In a vibrator with service, the waveform is an indication of imminent failure due to too low voltage output. The condition is normally caused by reduced secondary contact pressure due to wear. Care should be exercised that small-amplitude ripple, produced by dirty contacts in some new units, is not interpreted as true contact bounce.

3E—*primary contact bounce*—indicates a condition that will result in the

same operating problems as secondary contact bounce.

The following general maintenance notes may prove helpful. A good vibrator for six-volt equipment is designed and tested for the following standards of performance:

1—Low voltage starting—i.e., 5 V or lower.

2—Good waveform at nominal six
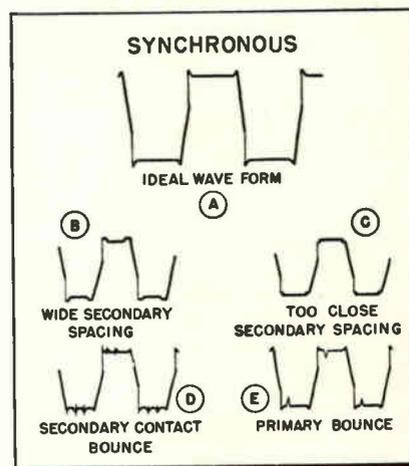
Fig. 3—Normal and abnormal waveforms for synchronous vibrator.

volts, indicating high voltage output and low generated "hash" level.

3—Operation at over-voltage for normal mechanical performance, and, in synchronous units, absence of arcing.

The technician can use these measures of performance as a guide to vibrator condition. New units can be tested for good performance before insertion. Contact dirt, from shelf life and oxidation, can be observed and run off before placing the component in service.

Dating Vibrators

Vibrators should be marked with "date in service" for correct measure of performance. With this data on the unit, hours of service can be readily calculated. Good maintenance for vibrators involves observation of the waveform of the unit in service, when the associated equipment is undergoing bench tests. It is possible to anticipate vibrator failure from normal wearing out through service life data and waveform analysis.

Removal of a vibrator in the last twenty-five per cent of its normal life is far less expensive than its replacement when it fails completely, since a separate maintenance job will be necessary at such a time. (From a booklet published by the James Vibrapower Company.)

Servicing Phono Equipment

● No one will question the fact that many substantial benefits have accrued to the phonograph record user since the introduction of microgroove records—both 45's and 33's. Not only has the consumer been provided with more compact and more durable records, and with more playing time for less money, but also a general upgrading in the quality of recordings is making available greater tonal range, greater dynamic range and less distortion.

The assimilation of the new types has not been without its discomforts, however, both to the user and to the dealer who sells him instruments, records and service.

This is partly due to the fact that we are, in general, dealing with much more delicate equipment, as well as a delicate medium.

A great deal of the trouble can be overcome by educating the user on the little tricks and techniques necessary for living in harmony with his record player. There are also some maintenance demands on the user, which we shall come to.

Gram-Ounce Equivalents

1 gram (metric)	.035 oz. (av.)
6 grams	.21 oz. (about 1/5 oz.)
7 grams	.245 oz. (about ¼ oz.)
15 grams	.525 oz. (about ½ oz.)
22 grams	.77 oz. (about ¾ oz.)
28.35 grams	one oz.

First, there are some facts about which the serviceman needs to be reminded. Some of these things seem small and obvious. But we have discovered from talks in the field and from letters from our readers that many of these small and obvious things are being overlooked.

It seems that in all too many cases the technician working on a complaint plunges immediately into the service notes and starts losing his mind over pawls and pinions and cams, change cycles, set down points, etc., when all along the trouble might be something as simple as a worn needle. It's something akin to tearing a circuit apart

without first checking the tube (which happens to the best of us every now and then).

To get down to cases, one of the most common complaints with microgroove players is groove-skipping and "skating" of the tone arm across the record. When the pickup or needle pressure is properly adjusted to the 6 or 7 grams recommended by the manufacturer, it is truly "as light as a feather." If you doubt this try holding your finger down on a needle pressure gauge so that it stays at seven grams (without resting your hand on anything). Incidentally, if you don't have a needle pressure gauge, you can't do a thorough job on microgroove players and changers . . . but we'll go into this more in a minute.

It might be pertinent at this point to mention why the needle pressure is so light on LP's. In reducing the needle tip radius to 1/3 of the size of 78's (namely from .003 in. to .001 in.), we have reduced the area of the tip to 1/9 (because the area varies as the square of the radius). The pressure per square inch is therefore increased to 9 times what it was on 78's. In other words, in order to obtain a pressure per square inch *no greater* than it was on 78's, we must reduce the needle pressure to 1/9 of what it was on 78's.

Referring back to a pre-LP parts catalog, we find needle pressures of one ounce to 3 ounces, with the average about 2 ounces (56.7 grams). One-ninth of this would be 6.3 grams. Actually, the pressure per square inch on a 6 gram needle is in the neighborhood of 440,000 pounds!

At any rate, even though the pressure per square inch is very high, the 6 gram pressure on the almost infinitesimal .001 tip is very light. As a result, it is relatively easy to cause groove-skipping.

Groove Skipping and Skating

For instance, shutting a slide drawer, or putting a new record on the changer while one is playing are sufficient to cause the needle to jump. If the turntable is not full-floating on springs, and if it is not level, groove-jumping can result if the pitch is toward the center. This is one of the first things you would want to check, as a matter of fact.

Accumulation of dirt on the needle as a result of tracking can permit the needle to skate. Like drawer-slamming and record changing, this is one of the things you must educate the customer about, since this "fuzz" can collect during the playing of one record. This seems to be especially true if (1) no static eliminator has been used on the

record, or (2) if static eliminator has *just* been applied and this is the first run, or (3) if the static eliminator has been on a long time and has lost its usefulness.

Static eliminator, incidentally, is something the writer recommends highly to keep records clean, and consequently quiet.

Trouble From Worn Needle

As for the "fuzz," the customer should get in the habit of attending to it regularly. The writer keeps a small piece of rubber sponge (used to apply static eliminator) handy to the changer, and uses it effectively to brush off the fuzz without danger to the needle. On magnetic cartridges with closely spaced pole pieces, it is a good idea to clean out the pole pieces once in a while, too. One of these days, no doubt, some changer manufacturer will incorporate a little brush on the side of the changer so that the needle rubs past it during the change cycle. Such a "gimmick" can already be observed on the Seeburg "45" juke boxes, which have two such brushes (since the tone arm plays on both top and bottom of the turntable) which are contacted every time a change cycle occurs.

Worn needles will often skip and skate easily. Up until recently, it was difficult to determine if a 1 mil needle was worn except by replacing it. But now, with the flurry of microscopes, a scientific inspection of the point is simple. We believe that every dealer who handles needles (and this should mean every dealer who handles phonographs and/or records) should try to obtain a microscope. In most cases, you can arrange this with your needle supplier, but failing this, you'll find you can obtain one quite reasonably from an optical supply house, some camera stores, and of course, the ubiquitous pawnshop. Bring a needle with you to assure yourself that the power is sufficient for the purpose.

The microscope test is probably one of the most potent merchandising tools yet developed to sell the consumer on the need for a new needle, since it is evident from the appearance of the point under magnification that deterioration of the record grooves can be occurring long before distortion is audible. It is also a powerful selling point for diamond points, since careful watching for needle wear on the less expensive tips will show how often they need replacement.

Not only can a worn needle cause groove skipping, but as mentioned above, it can cause excessive record

for Microgroove Discs

WORN NEEDLE

TURNTABLE NOT LEVEL

IMPROPER NEEDLE PRESSURE

FUZZ COLLECTED ON NEEDLE

1 MIL & 3 MIL NEEDLES REVERSED

STD ← → MG

BENT NEEDLE SHANK

BOTTOM VIEW

END VIEW — TOO LOW
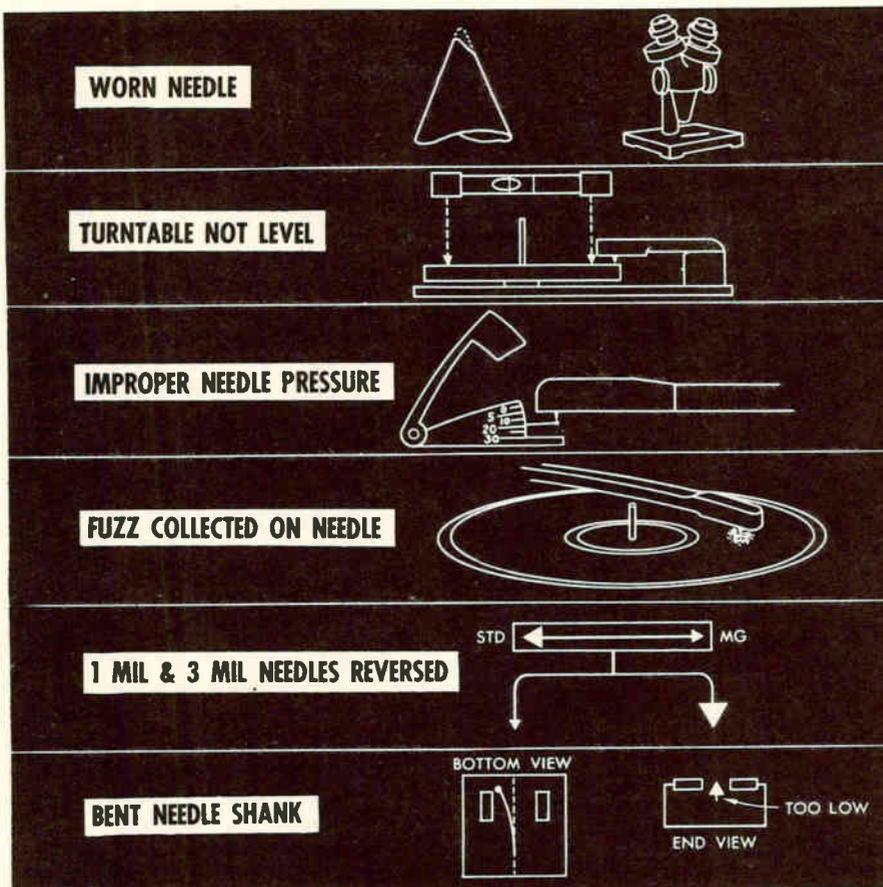
wear and deterioration, and it can cause the needle to get "hung up" in a groove. Both groove-skipping and "stuck" needles can cause irreparable damage to a record, so that the same thing happens every time the needle gets to that point in playing.

In addition to these things, a bad needle can cause distorted sound. Just as we suggested record changer repairs be stalled off until all the small, obvious details are checked, we would also suggest that any examination of the audio circuits in back of the pickup be stalled off until the needle is examined.

Other needle troubles that can give rise to customer complaints are (1): the wrong needle tip may be in use. This could be caused on initial installation of the equipment, or by a subsequent needle change (especially if done by the customer). Not all microgroove needles are marked with a red dot, and it is impossible to tell the size by eye. Consequently, installation instructions of the needle manufacturer (and his color coding, if any) must be closely observed. In this same connection, the

needle may have been improperly or incompletely seated, especially if installed by the customer.

(2) On GE type cartridges, the shank of the stylus may be bent over toward one of the pole pieces, or (3) the needle tip may have become pushed down too far between the pole pieces. These troubles can be corrected by a hand with a light touch. The writer has used a straight pin as a prying tool to effect these corrections (which have sometimes been necessary on new needles).

On conventional type needles with relatively long, delicate shanks, the shank can become bent so that the tip does not ride squarely on the record. It is relatively difficult to correct this unless you have a new needle as a model to work from.

Needle pressure can be too light, which would aggravate skipping, or it can be too heavy, which will accelerate both needle and record wear. Three changers which the writer checked recently *all* ran over 10 grams, with a maximum of 15 grams. Reducing the pressure to a figure somewhat closer

to the design center necessitated an orientation program with the users (who were not hitherto accustomed to the necessity of treating their changer so gingerly) but improved results, and will no doubt increase the life of the needles considerably. In this connection, it probably doesn't pay to be too precise, or that is what many servicemen feel with whom we have discussed the subject. In other words, 6 grams may be OK for the hi-fi fan who wants to have the ultimate in his equipment and is prepared to take a little trouble with it. But for the non-technical customer who would prefer to have his equipment "fool proof," 8–10 grams is probably a better compromise.

Troubles due to variations in the records can be even more troublesome on light weight pickups than with the old type. Slipping is not uncommon with the smaller records, causing an objectionable wow. Non-standard thicknesses and run-out grooves (to cycle the changer) can also cause trouble. Records which are particularly thin and light can fail to fall down properly from the record shelf. As for slipping, the writer has one clear Vinylite 10″ long-playing record which will not play without slipping whether it is the only record on the turntable, or whether it is on top of some others. To correct slipping, the author has found it helpful to put a paper jacket from a 7-inch record underneath the trouble-making record.

This, again, comes under the heading of customer education. And while you're about it, anything you can say to exhort the customer to take good care of his microgroove records will be greatly appreciated in the long run. We have already mentioned the use of a static eliminator. In addition, records should be immediately returned to their jackets after use, to prevent picking up dust, dirt and small particles. Also, it's a good idea to flex the jacket a little, so that the record isn't scraped on the way in. Customers should be warned to try to keep their fingers off the playing surface. Another good idea, we believe, is to discourage them from amusing themselves by playing long-play records at higher speed, or 78's at a slower speed. The latter, with a 3 mil point, will have greatly increased weight on it, since the pickup spends a much longer time riding around the grooves and "rests" longer in one spot.

Attention to the small details of levelling; the right needle, proper needle installation, etc. will pay off in better consumer "public relations" and reorders as a result of word of mouth advertising.

Recording Binaural

Use of LP discs having two recorded bands offers a very compatible and practical binaural record system. Great new market potential indicated for record player manufacturers.

Author viewing binaural cut in process on special recording lathe

By EMORY COOK
Cook Laboratories
Stamford, Conn.

IF the advantages and potential wide sales appeal of binaural sound are to be exercised, the realm of disc-recording, where cost and compatibility factors with existing standards are favorable, offers great possibilities. Let us then review the several ways in which a synchronized double track in disc can be produced:

1. A binaural recording can be made on opposite sides of a disc, playing back both sides simultaneously. This method is not very practical however, because stampers cannot possibly be centered and aligned in the press in the necessary rotational accuracy, and a wholesale redesign of playback turntables would be necessary.

2. Interleaved grooves are another theoretically possible means of binaural disc recording. This method however is costly to record and to playback and further, a great deal of special equipment would be necessitated.

3. A single sideband carrier system has been proposed, but the limitations of this method are such that the frequency range of each "ear" is restricted to a low value that could not be considered acceptable from a fidelity standpoint.

4. To date then, it appears that by far the most compatible and practical system is that of placing two recorded bands on the same side of an LP disc as diagrammed in Fig. 5

As with ordinary recording equipment, the cutting styli move on a radius,—from outside in. Therefore existing recording equipment is easily modified to perform the mastering function. The playback arms may be integrated into a single arm containing two cartridges side by side as shown in Fig. 1.

Compatibility

The confusion of multiple standards has already shaken up the record industry once or twice and another upheaval would probably be impossible. Therefore, both the binaural record and its playback means must be interchangeable with exist-ing standards. Due to the halving of available elapsed time with two channels, the 12-in LP is a natural starting point. With a normal 12 minutes of binaural playing time and a possible maximum of 14-15 minutes, most musical requirements can be met. The method described here produces a record which can be played (one "ear" at a time) on existing equipment, and the binaural reproducing system will likewise play regular records by simply blocking one of the cartridges up off the record.

Accurate Radial Relation

In Fig. 5 is shown the schematic arrangement for playing back the record of Fig. 4. Within the limits of travel in arc of the arm across the narrow band of grooves a high degree of accuracy of radial relation of playback points is obtained. In the practical case the positive error is made to equal to the negative error in terms of wavelengths, —at 1000 cps for instance. The maximum error then measures to be of the order of magnitude of 0.01-in. along the groove longitudinally at the middle of the record corresponding to less than a wavelength at 1000 cps along the groove. The purist might say here that we cannot tolerate a phase error of 180° in the range of maximum directional sensitivity of the human ear, but this is not true, and it is not a matter of "toleration" anyway unless we confine our remarks to the use of earphones as a listening medium. As a matter of fact, earphones can be given no consideration at all commercially. If we think in terms of spaced loudspeakers in a room then a full wavelength error at 1000 cycles can be thought of as corresponding to a motion forward or backward of one of the loudspeakers of about one foot, or a corresponding random motion of the listener in the room (such as turning the head) while the music is playing which is easily possible, in fact probable, without getting up from the chair.

Sound on Discs
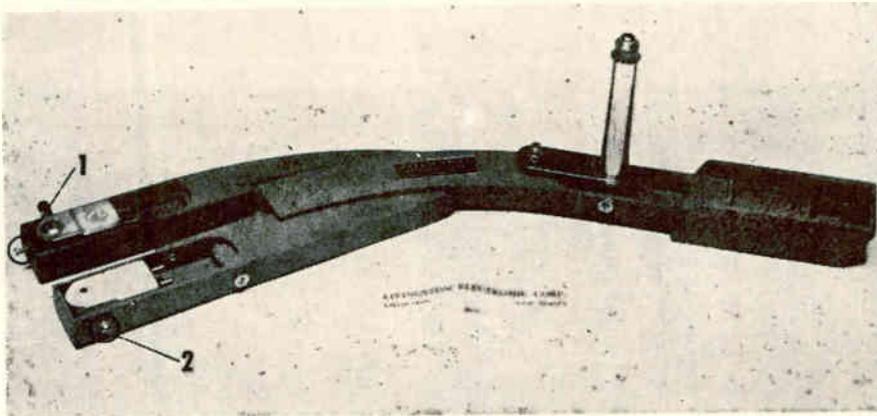
Fig. 1: Close-up of dual cartridge playback arm as manufactured by Livingston Electronic Corp., Livingston, N. Y. (1) and (2) are adjustment screws

A typical modified arm would display a dimension of 10½-in. from pivot to farthest stylus, an offset angle of 27.5° and the standard spacing of $1\frac{11}{16}$-in. The fractional spacing is chosen rather than decimals to facilitate the rough adjustment by using a standard inch rule, where the points will fall into the indentations at the specified dimension.

The radial error is not much affected by the length of the arm, and short 12 in. turntable arms are candidates for conversion.

In order to permit equal tracking pressure of each point of contact, at least one and preferably both of the cartridges must be individually pivoted for the vertical plane, although of course, if one is tempted to put up with the inconvenience, two separate arms may be operated.

Random Production Errors

No record is produced which is actually on center. The magnitude of the combined error in good commercial practice can hardly be reduced under .010-.015-in. The staggered method of interleaved grooves can not operate satisfactorily because of the centering problem alone, since there is a large angle subtended between the two points of pickup. However, the radial method is the least susceptible, in fact practically immune to centering errors such as normally encountered. But there is another and more insidious danger to watch against. In establishing a $1\frac{11}{16}$-in. dimension between points of pickup we must allow a tolerance.

Not only is it quite unthinkable to be able to align recording heads and styli on a lathe to .001-in. tolerance for each and every master, but the metal parts, especially stampers used to mold pressings are basically 0.032-in. copper as regards mechanical strength. In the modern fast cycle press and in handling they become stretched, so that $1\frac{11}{16}$-in. may become distorted around the circle. Furthermore, non-uniform cooling of pressings just removed will produce a small eccentric shrinkage on one side of the record and not the other. All these errors are of course capable of being cumulative to the effect of at least 0.015-in., and therefore we must have a mutual "lost motion" in the $1\frac{11}{16}$-in. spacing figure of ±.015-in. or thereabouts. However, since the record is started with pickups dropped in the spiralling lead-in groove, this does not mean that we shall have trouble getting into the correct grooves; it merely means instead that there is to be a "free" lateral motion of one cartridge with respect to the other. However, the business of "loose pivots," i.e., rattles, in vertically pivoted arms is well known to produce non-linear effects at some mid-frequency. The answer to the problem is the packing of the pivot points with viscous damping, so that the compliance of the cartridge needle is two or three times higher than the viscous compliance for frequencies at and below the undamped lateral resonance.

In bringing binaural into focus as a practical medium, the cost factor is particularly important. A first reaction might be that the cost would be almost doubled but this is not the case. Binaurally, power output per channel can be *less than half* that of an equivalent monaural channel for the same apparent loudness.

Using Twin Triodes

With the use of twin triodes the basic amplifier design may be doubled up (as in push-pull) without much additional cost. Since we certainly need no more than half the output power "per ear" the power supply is the same. The twin cathode, screens and plate supplies may be by-passed through common capacitors, since a moderate amount of crosstalk between channels is permissible. The only serious added cost will be that of the second output transformer, and means for reducing even that appear to be forthcoming.

In the "minimum" design of Fig. 2, there are only 16 one or half-watt resistors, 4 audio condensers and 4

Fig. 2: Minimum binaural amplifier design involves only 16 one- or half-watt resistors, 4 audio capacitors, and 4 tubes not including power supply
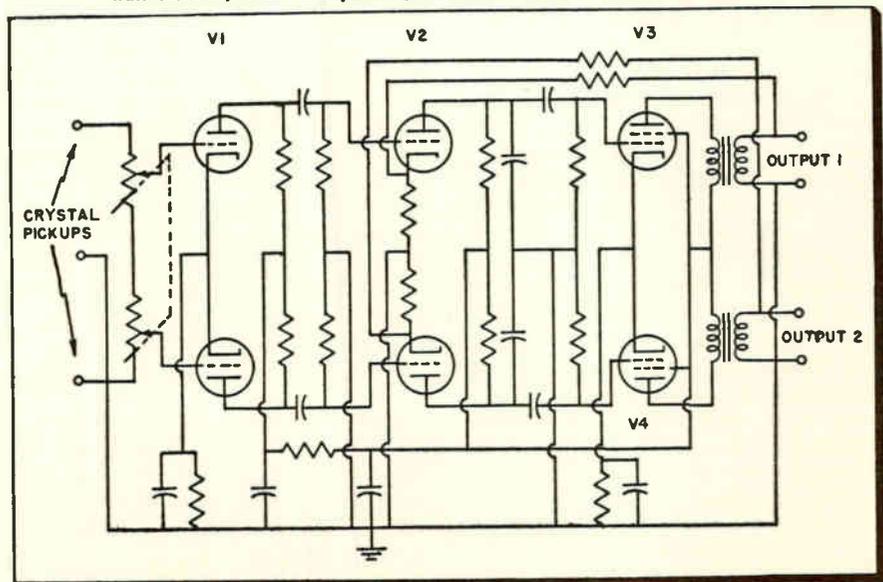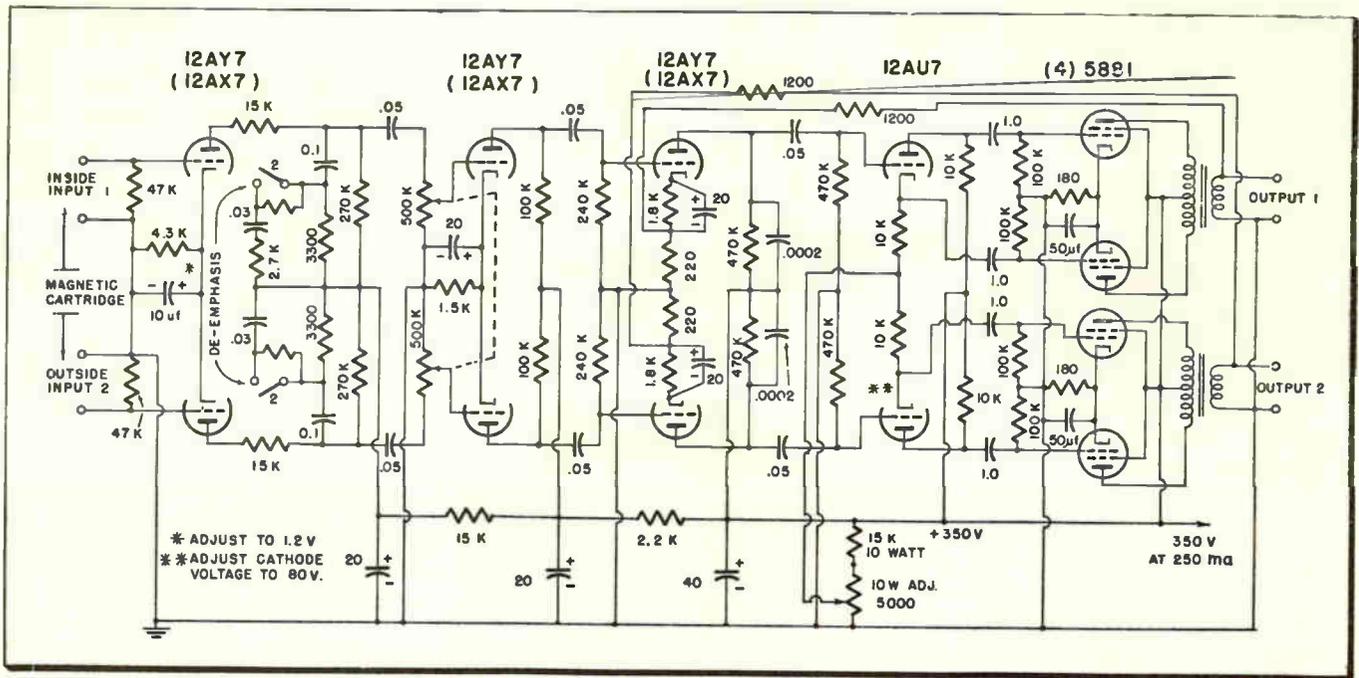
Fig. 3: Complete schematic of high quality binaural amplifying system. Power supply is separate unit

tubes, not including the power supply. No more decoupling or filtering is necessary than with a regular amplifier. The A-B comparison between binaural and monaural on such a minimum system with corresponding small speakers is perfectly astounding, probably because the cheaper monaural systems are so unsatisfactory in themselves. Yet it is hard to see where such an amplifier could cost more than a few dollars extra.

The opposite extreme would be something along the line of Fig. 3, where provision for magnetic cartridges is made, together with phase-splitting so that each output is balanced. Again the increased cost over that of a straight "push-pull" design is very nominal, if one is to

compare it with a regular amplifier using four output tubes as a cost reference.

For equalizing the effective high frequency response of the channels in the room a condenser may be introduced across one or the other of the 220 ohm feedback re-introduction points in the 3rd stage of Fig. 3.

Test & Alignment

In addition to the necessity for an adjustment to permit re-setting the $1\frac{11}{16}$-in. dimension should cartridges be changed, there must also be a "fore and aft" adjustment provided so that there is no time delay error between channels,—so that they operate on the same radius. A means for locating to the required accuracy

of 0.01-in. this longitudinal adjustment can be supplied through use of a test record signal. The Cook Series 30 test record is intended as a temporary standard, and in order to be palatable to non-technical users employs a slowly ticking clock as the source. The clock is fed into both channels in parallel simultaneously, in order to provide a synthetic binaural signal. When played on a binaural arm into a binaural reproducing system which has been adjusted for equal gain per "ear," the cartridges in the arm may be adjusted until the clock sound in the room appears to be neither to the right nor to the left, but dead-center. In order to prevent insofar as possible inadvertent errors, the record

Fig. 4: (Left) Photo of binaural tone arm playing back binaural disc. Fig. 5: (Right) Diagram showing how binaural arm is pivoted
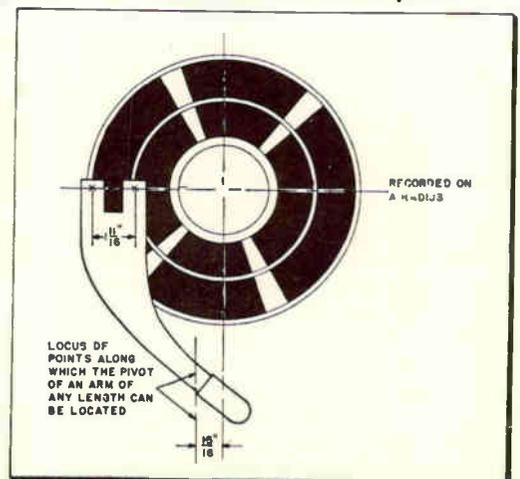
Binaural Sound

is made not in the 12-in. size, but as a 10-in. disc, where the diameter of start of the test grooves corresponds closely to a zero point in the radial error cycle.

No better method than cut-and-try has been discovered yet for cutter alignment on the recording lathe, and such alignment then has to be done in conjunction with a playback turntable whose adjustment has been made on the basis of the Series 30 record as a standard.

The difference in frequency response between inner and outer diameters of pressings is a subject which is well explored and about which much has been written. Additional pre-emphasis is often and may here be applied at inner diameters to compensate somewhat in advance for translation loss. Unfortunately, there is an engineering proclivity toward making hard and fast rules for "shop practice," to cover all such points as diameter equalization and reference pre-emphasis. The trouble is that rules do not take into account the varying character of program material. The method which is satisfactory for a piano — velocity microphone pickup is not applicable to a bright orchestral picked up with a wide-range condenser. With material which is originally bright there is a severe limit on the amount of effective pre-equalization. Fortunately in a binaural system the two channels are not necessarily matched for frequency response, and in Fig. 3 it will be found that in the de-emphasis circuit (plate) of the first stage of the "inside" channel a 2.7K resistor is used to leave pre-emphasis in effect above about 3300 cps.

A general development probably not too far away is the "half-mil" point which can only be associated with cartridges having extremely low motional impedance. When such cartridges become available in manufacture, the inside-outside range and distortion of LP's in general will be vastly improved, and the binaural translation loss factor will be negligible. As for present practice, it has been found generally acceptable to maintain approximately a 50 µs (3300 cps turnover) differential between inner and outer binaural bands in the original recording. Depending upon the program material the outside band might be 50 or 100 µs pre-emphasis, and the inner band 100 µs or 100 µs + 50 µs, correspondingly

Assuming that binaural recordings are pressed in high grade plastic, the most serious surface noise will be that of ticks and pops. Such noise here, however, will take on a random left-right character and as such is distinctly objectionable because of the directional effect. Hence the recorded level must not be lowered in an attempt to permit full "curve" equalization of bright original material.

When experimental recordings were made using 6-in. microphone spacing and earphone playback, phasing was of course necessary. But contrary to what might at first be expected, phasing of playback *speak-*

Fig. 6: Close-up of binaural recording shows the two bands of grooves

ers is unnecessary for material recorded indoors (rather than outdoors.) With any spacing of microphones in excess of ear spacing, phase becomes random in view of the acoustics of both the original room and the playback room. However, in playing back material which was recorded in the open, with no confining walls, phasing may well become desirable, especially if the acoustical environment of the playback speakers is on the "dead" side.

By now, most of us are well aware of the fact that a real distinction exists between standard monaural and binaural systems. Any comparison is unfair at the start because the two media are not comparable on any real basis. The extension of the aural medium by addition of dimension, direction and perspective is important not only for vitalizing the musical catalogs we are building but also for extending useful repertoire into fields such as plays and other documents, where the third dimension communicates enough additional information to make the difference between failure and success.

Of commercial necessity we have had to rule out earphones as the playback mechanism, albeit their rigorous binaural nature. We thus descend into a morass of conjecture relating to position of loud speakers, acoustical reflection characteristics of side and back walls, shape of room, etc., all applied to the room in which playback occurs. Here none but the broadest rules may be drawn, since even mass-produced living rooms are decorated and carpeted differently.

In the case of standardization of recording characteristic curves a basic truth was finally recognized, wherein it is obviously both ineffectual and impossible to standardize the *recording curve*. What we try to standardize is the *playback curve* only. Thus in developing techniques for binaural recording insofar as microphone placement is concerned, the basic truth must always be kept in mind—that playback (on the average) will take place using 2 speakers separated perhaps 12-15 ft. against a wall in a room of corresponding size and fairly random acoustics.

As binaural disc as a medium develops, there will no doubt be a great deal of expert activity in the realm of "where to put the microphone" and "studio acoustics," and there will be many interim pet theories expounded. Without a conclusive amount of experience at this point, we can only suggest a few directions in which *not* to go. For instance, the business of about-facing the band on stage and playing into microphones in opposite corners of the stage wings is extraordinarily unnatural in effect. Wall reflections abuse the reality, and treatment of the walls to inhibit reflections pulls the teeth out of the binaural head. The bright synthetic modern studio acoustic appears definitely out from the binaural standpoint. In general, any studio or hall which has been treated with the idea in mind of creating an "even" frequency distribution of energy per square foot,—the "mix 'em up" philosophy,—is lowest on the binaural scale.

And the one unhappy malpractice which has been in vogue for 20 years of broadcast and recording,—that of the small and odd-shaped, acoustically odd and unnatural control room is absolutely fatal for producing binaural. Note is taken of various broadcast and recording company executives who, for very good reasons, insist on listening to their records in an audition room about the size and shape of an "average" living room with similar acoustics. Yet the records are produced and balanced in a studio control room which is about as far away as one could get from the living room prototype, both in size, shape, proportion, acoustics, and relative position in the room of loudspeaker and listener.

For binaural records, it would be better in these control rooms that earphones be used, for making binaural productions will probably become much more of an *art* than the regular monaural ever was.

Page from an Engineer's Notebook

Parallel-Paired Resistance Values

By CHARLES F. WHITE, Electronic Scientist, Naval Research Laboratory, Washington 25, D. C.

Several excellent nomographs exist for the determination of the value of paralleled resistances but for everyday convenience a simple tabulation proves most satisfactory.

The table gives the nominal resistance for the paralleled combination of two standard ±5% (gold band) RMA value resistors. This series includes the values in the ±10% and ±20% series.

The values for two resistors in the same decade for two resistors in adja-

cent decades are given. Because of the tolerance on the values of the resistors being paired, the actual value obtained physically may deviate by the same tolerance from the tabulated values.

→ R_2 → / ↓ R_1 ↓

R_1	100	110	120	130	150	160	180	200	220	240	270	300	330	360	390	430	470	510	560	620	680	750	820	910	1000
100	50	52	55	57	60	62	64	67	69	71	73	75	77	78	80	81	82	84	85	86	87	88	89	90	91
110	52	55	57	60	63	65	68	71	73	75	78	80	83	84	86	88	89	90	92	93	95	96	97	98	99
120	55	57	60	62	67	69	72	75	78	80	83	86	88	90	92	94	96	97	99	101	102	103	105	106	107
130	57	60	62	65	70	72	75	79	82	84	88	91	93	96	98	100	102	104	106	107	109	111	112	114	115
150	60	63	67	70	75	77	82	86	89	92	96	100	103	106	108	111	114	116	118	121	123	125	127	129	130
160	62	65	69	72	77	80	85	89	93	96	100	104	108	111	113	117	119	122	124	127	130	132	134	136	138
180	64	68	72	75	82	85	90	95	99	103	108	113	116	120	123	127	130	133	136	140	142	145	148	150	153
200	67	71	75	79	86	89	95	100	105	109	115	120	125	129	132	137	140	144	147	151	156	158	161	164	167
220	69	73	78	82	89	93	99	105	110	115	121	127	132	137	141	146	150	154	158	162	166	170	173	177	180
240	71	75	80	84	92	96	103	109	115	120	127	133	139	144	149	154	159	163	168	173	177	182	186	190	194
270	73	78	83	88	96	100	108	115	121	127	135	142	149	154	160	166	171	177	182	188	193	199	203	208	213
300	75	80	86	91	100	104	113	120	127	133	142	150	157	164	170	177	183	189	195	202	208	214	220	226	231
330	77	83	88	93	103	108	116	125	132	139	149	157	165	172	179	187	194	200	208	215	222	229	235	242	248
360	78	84	90	96	106	111	120	129	137	144	154	164	172	180	187	196	204	211	219	228	235	243	250	258	265
390	80	86	92	98	108	113	123	132	141	149	160	170	179	187	195	205	213	221	230	239	248	257	264	273	281
430	81	88	94	100	111	117	127	137	146	154	166	177	187	196	205	215	225	233	243	254	263	273	282	292	301
470	82	89	96	102	114	119	130	140	150	159	171	183	194	204	213	225	235	245	256	267	278	289	299	310	320
510	84	90	97	104	116	122	133	144	154	163	177	189	200	211	221	233	245	255	267	279	291	304	314	327	338
560	85	92	99	106	118	124	136	147	158	168	182	195	208	219	230	243	256	267	280	294	307	321	333	347	359
620	86	93	101	107	121	127	140	151	162	173	188	202	215	228	239	254	267	279	294	310	324	339	353	369	383
680	87	95	102	109	123	130	142	156	166	177	193	208	222	235	248	263	278	291	307	324	340	357	372	389	405
750	88	96	103	111	125	132	145	158	170	182	199	214	229	243	257	273	289	304	321	339	357	375	392	411	429
820	89	97	105	112	127	134	148	161	173	186	203	220	235	250	264	282	299	314	333	353	372	392	410	431	451
910	90	98	106	114	129	136	150	164	177	190	208	226	242	258	273	292	310	327	347	369	389	411	431	455	476
1000	91	99	107	115	130	138	153	167	180	194	213	231	248	255	281	301	320	338	359	383	405	429	451	476	500
1100	92	100	108	116	132	140	155	169	183	197	217	236	254	271	288	309	329	348	371	397	420	446	470	498	524
1200	92	101	109	117	133	141	157	171	186	200	220	240	259	277	294	317	338	358	382	409	434	462	487	518	545
1300	93	101	110	118	134	142	158	173	188	203	224	244	263	282	300	323	345	366	391	420	446	476	503	535	555
1500	94	102	111	120	136	145	161	176	192	207	229	250	270	290	310	334	358	381	408	439	468	500	530	566	600
1600	94	103	112	120	137	145	162	178	193	209	231	253	274	294	314	339	363	387	415	447	477	511	542	580	615
1800	95	104	112	121	138	147	164	180	196	212	235	257	279	300	321	347	373	397	427	461	494	529	563	604	643
2000	95	104	113	122	140	148	165	182	198	214	238	261	283	305	325	354	381	405	438	473	507	545	582	625	667
2200	96	105	114	123	140	149	166	183	200	216	240	264	287	309	331	360	387	414	446	484	519	559	597	644	688
2400	96	105	114	123	141	150	167	185	202	218	243	267	290	313	335	365	393	421	454	493	530	571	611	660	706
2700	96	106	115	124	142	151	169	186	203	220	245	270	294	318	341	371	400	429	464	504	543	587	629	681	730
3000	97	106	115	125	143	152	170	188	205	222	248	273	297	321	345	476	406	436	472	514	554	600	644	698	850
3300	97	106	116	125	143	153	171	189	206	224	250	275	300	325	349	380	411	442	479	522	564	611	657	713	767
3600	97	107	116	125	144	153	171	189	207	225	251	277	302	327	352	384	416	447	485	529	572	621	668	726	783
3900	98	107	116	126	144	153	172	190	208	226	253	279	304	330	355	387	419	451	490	535	579	629	678	738	796
4300	98	107	117	126	145	154	173	191	209	227	254	280	306	332	358	391	424	456	495	542	587	639	689	751	811
4700	98	107	117	127	145	155	173	192	210	228	255	282	308	334	360	394	427	460	500	548	594	647	698	762	825
5100	98	108	117	127	146	155	174	192	211	229	256	283	310	336	362	397	430	464	505	553	600	654	706	772	836
5600	98	108	117	127	146	156	174	193	212	230	258	285	312	338	365	399	434	467	509	558	606	661	715	783	848
6200	98	108	118	127	146	156	175	194	212	231	259	286	313	340	367	402	437	471	514	564	613	669	724	794	861
6800	99	108	118	128	147	156	175	194	213	232	260	287	315	342	369	404	440	474	517	568	618	675	732	803	872
7500	99	108	118	128	147	157	176	194	214	233	261	289	314	344	371	407	442	478	521	573	623	682	739	811	882
8200	99	109	118	128	147	157	176	195	214	233	261	289	317	345	372	409	445	480	524	576	628	687	745	819	891
9100	99	109	118	128	148	157	177	196	215	234	262	290	318	346	374	411	447	483	528	580	633	693	752	827	901
10,000	99	109	119	128	148	157	177	196	215	234	263	291	319	347	375	412	449	485	530	584	637	698	758	834	909

↑ R_1 ↑ / ← R_2 ←

Eidophor

(8). The larger the number of bars, the greater is the number of raster elements in a horizontal line. The system should be capable of more than 1000 of these elements per line, which meets all requirements for the time being. The possible number of horizontal sweep lines crossing the parallel light lines perpendicularly which may be included in a raster is almost unlimited, the system having operated satisfactorily at 392, 525, 625, and 729 lines.

Therefore, to project an image on the theatre screen, it is necessary that the output of a TV camera be fed to the electron gun to cause the electron beam to deform the Eidophor liquid in a proper manner which corresponds, element for element, to the original scene viewed. The fact that the liquid deformations retain the image from which the light is reflected caused the inventor to give it the name Eidophor, derived from Greek sources, meaning image bearer.

Eidophor Liquid

Examination of the criteria governing the Eidophor liquid indicates that the charges deposited thereon should cause the liquid deformations to remain for one picture period, but to decay rapidly after the period is over. The oil is made conductive to make the deposited charges decay according to an exponential time function. The storage time of the picture is controlled by selecting a liquid of proper conductivity, surface tension and viscosity.

The Eidophor liquid constantly carries an average negative charge which exerts a mechanical force on the liquid. If the liquid film were left to itself, it would eventually be pushed out of area (8). To prevent this, the spherical mirror (7) is slowly rotated to renew the image carrier. A radial knife edge (9) allows the passage of a quantity of the liquid, which has a consistency similar to honey, necessary for the production of the picture carrier.

The liquid and electron gun are placed in a vacuum. In order to keep the pressure to about 10^{-5} to 10^{-4} mm Hg, a continuously operating oil diffusion pump is mounted on the projector. A very low vapor pressure is a prime requirement for the liquid. Furthermore, it must be transparent to prevent any influence on the color of the picture. Since the deformations are dependent on the viscosity, which in turn depends on temperature, a refrigeration unit is used to assure constant temperature and picture results. Most important, because the system is very sensitive to even the smallest inhomogeneities (maximum liquid deformations are only a few thousandths of an mm). assembly must be accomplished without allowing any foreign particles to enter the optical system, particularly on the oil surface of the spherical mirror.

Unlike ordinary cathode ray tubes, which employ amplitude modulation, Eidophor uses a kind of velocity modulation. To produce the picture raster, 17-kv electrons from a tungsten cathode deposit a periodic distribution of charge along every picture line, the magnitude of this charge being proportional to the brightness of every picture point. The electrons are confined to a constant intensity beam of rectangular cross-section (width 10 to 20% of height), whose height is the width of one picture line. Since the beam intensity is constant at 70 μa, variations in charge density deposited on the Eidophor liquid are made by modulating the writing speed. That is, the greater the speed, the less charge deposited to deform the oil, and the less the light is deflected to pass through the mirror slits.

The modulation is produced by superimposing a constant frequency ac voltage on the line sweep voltage. Raster element dimensions are determined by the frequency of this superimposed voltage, while the density of the charge deposited is controlled by the amplitude. Modulation velocity potentials of the order of 1 volt are introduced through separate plates.

The results of a recent U. S. theatre demonstration of the projector indicates that one prime advantage of Eidophor is its ability to produce a high definition color picture of comfortable brilliance. In this showing, a 525-line raster and 8 mc bandwidth were used with the CBS field-sequential color system. The projected picture of the live studio pick-up was bright (about 40 lux in the highlights), had good contrast (1:200), and generally was of excellent quality, almost comparable with color motion pictures. It was noted that Eidophor is also adaptable to a simultaneous color system.

The fine results obtainable with the presently developed model appear to warrant early introduction into American theatres. Work is progressing to improve the projector and to develop an associated film system which will take advantage of several desirable qualities in motion pictures which are not realized in conventional filmed TV programs intended for home reception.

Sound, No Raster

zontal hold is varied. If the 15,750-cycle whistle is heard, it means that the horizontal oscillator output tube and transformer are all working. (The whistle comes from the vibration of the horizontal amplifier tube and output transformer). If no spark is present at the HV rectifier plate cap, and whistle is heard, the auto-transformer section of the horizontal output transformer is probably open. In a few sets there is a coupling condenser between the primary and the high voltage secondary that can be at fault also. In any case shop repair is indicated. If the spark is very short but can be pulled out, that is, if we get an insufficient AC spark, the trouble is in the damping circuit. The damping tube should be replaced; if the trouble persists, a shop repair is indicated.

There may be no spark at all at the plate of the horizontal output tube. In that case the trouble may again be in the damping circuit; but before going through the tests just made, the set should be checked for an open fuse in the high-voltage section. This is usually a quarter-ampere, 250-volt fuse located either in the cage, or wired in underneath the chassis. This fuse should be checked and if found open replaced. If the set now works, it should be operated for at least 15 minutes. If the set keeps on working, the customer should be warned that the repair may only be temporary. A thorough shop check is advisable; if the fuse blows again, such a check becomes imperative. In the shop, the easiest method to locate the fault is to short out the fuse and let the smoke indicate the trouble. The set must, of course, not be left unattended. If the spark at the output tube is a DC spark, that is, if it is blue rather than purple and can be pulled out, the horizontal sweep section is defective. This is also the case if no whistle is heard. The horizontal oscillator, the discharge tube and the output tube should then be changed in turn. If the trouble is not cured, an oscilloscope will be of great help in locating the defect

UHF on VHF TV's

stubs across which they move. The effect is similar to the resonating of a piece of twin-lead line at different frequencies, if its length is varied.

Two coaxial stubs, one for each preselector circuit, is employed. The advantages of using this type of tuned circuit include high selectivity, uniform bandwidth, and good shielding against oscillator-radiated signals.

The 6AF4 oscillator uses a section of parallel-wire transmission line for its tuned circuit. The line is shorted at one end. A moveable shorting bar moves across the line, varying its tuning.

The symbols indicate that inductive or link coupling is used between the antenna and first preselector circuit; also between the first preselector and the

second one (mixer input circuit). Coupling between the oscillator and mixer is capacitative.

The cascode first IF amplifier is tuned to a center frequency of 25 MC, and has a broad bandwidth (app. 7 MC). Coupling from the cascode first IF amplifier section to the VHF input is through a ten-inch length of coaxial cable.

Oscillator grid current, rather than grid voltage, is measured in this circuit (as well as in other UHF oscillator circuits). A suitable terminal is provided for opening the UHF oscillator grid circuit at its ground side. When the current flowing in this circuit has been measured with a sensitive enough milliammeter, the grid voltage may be obtained by multiplying the current figure (in amps) by the grid resistance (in ohms). The oscillator grid voltage is not measured directly because the voltmeter, even when it uses a shielded and isolated probe, and is vacuum-tube in type, is apt to detune the oscillator when it is connected at the grid.

Another converter circuit (Stromberg-Carlson UHF Television Converter) is shown in fig. 5. Space limitations and economy factors make the use of a selenium rectifier preferable to a vacuum tube. A power transformer is employed to eliminate the setting up of hum potentials between the converter and the TV receiver. The transformer also isolates the chassis from the line, preventing the chassis from being "hot."

The filaments of the converter's tubes remain on during both VHF and UHF reception; B+ voltages are, however, removed from the converter's filter condenser during VHF operation by a switch in the ground return of the power transformer secondary.

Provision for connecting in a separate UHF antenna has been made at the rear of the chassis.

The converter may be operated on either channel 5 or 6, provided that the channel selected is not occupied by a local station. A switch at the back of the converter chassis makes the desired choice, shifting the tuning of the first IF stage by 6 MC. Since the bandwidth of the pre-selector circuits is 12 MC, the switch from one channel to the other can be made without losing tracking or cutting sidebands.

The tuning units in the antenna and mixer circuits use inductive-type padding to obtain the correct tuning range. The padding is obtained by making the two conductors in the antenna tuning section, and one conductor in the mixer tuning section, extend 7/8 of an inch beyond the tuning unit. The 300-ohm balanced line is coupled through an ungrounded loop into the extended section of the tuning unit.

To help obtain the desired 12 MC bandwidth over the entire UHF band, a combination of capacitive and inductive coupling is employed between the antenna and mixer tuned circuits.

In the oscillator section, a series trimmer helps establish the low-frequency end of the tuning range. The extent of the tuning range, as well as the upper limit of this range, is determined by a series trimmer inductance made up of the grid and plate leads. Varying the

spacing of these leads regulates the adjustment of this inductance.

To avoid "holes" in the bandpass, resistors are used in place of chokes in the plate and grid return circuits. Dissimilar chokes are used in each heater leg for the same reason.

The oscillator tube socket is a special low-capacitance type used to minimize the effect of the grid-to-plate socket capacitance on the tuned circuit. "Warm-up" oscillator drift is minimized by use of minimum plate voltage. Oscillator radiation is reduced not only by complete and careful shielding, but by using a low value of oscillator plate voltage.

The pre-amplifier, or 1st IF amplifier, is cascode in type. The output triode of the double-triode 6BQ7 has a 6 MC bandwidth. A switch on the rear of the chassis selects the desired VHF channel. For reasons of economy, the switch employed is a simple slide unit that regulates the amount of capacitance in series with the B+ end of coil L-9, and thus controls the latter's tuning.

The secondary of L-9 is balanced to ground, to eliminate the pick-up of interference that might occur if a single-ended input to the VHF receiver was used.

Servicing AGC

tive point in the brightness control circuit. The positive voltage fed to the plate is changed to a negative one by the conduction of the delay tube.

-2.4 V is fed to the AGC-controlled RF amplifier in the presence of weak signals. Approximately 0 volts is fed to the controlled video IF stages at this time. (Practically all of the -2.4 V AGC voltage is used up across R-155 and R-156, very little remaining across R-158 to be fed back to the video IF stages.) Thus, some negative voltage is developed and fed to the RF stage, but practically no AGC voltage is supplied to the video IF stages, when weak signals are coming in.

In the presence of medium and strong signals, the positive signal voltage fed to the grid of the AGC amplifier overcomes the negative cut-off bias, and the tube conducts, producing an AGC voltage.

If the AGC delay tube becomes defective, weak signals may not be satisfactorily received, since the reduced bias of the RF amplifier may cause enough signal to be transferred to the AGC amplifier to prematurely bring it out of cut-off and produce an AGC bias at the grids of the controlled video IF stages.

An AGC threshold control is present. It is adjusted with weak signals coming in, and is set to a point where the receiver just begins to overload when the contrast control is advanced to maximum.

Servicing of this circuit is similar to that of the other circuits discussed. A scope can be used to check plate and grid waveforms. If these waveforms are absent, incorrect in amplitude or imperfectly shaped, the circuit points between plate and grid and the source of

each waveform can be scope-checked, to help find the source of the trouble.

When scope tests are inconclusive, DC voltage and resistance tests will prove helpful.

UHF-VHF Circuits

tenna (actually radiated), avoiding standing waves of input circuit noise at the first tuned circuit.

Thus far we have discussed some of the requirements of composite VHF and UHF receivers. Let us now consider UHF reception on standard VHF receivers.

Converter Design Considerations

Of necessity, a UHF converter must operate with a different intermediate frequency than that of the associated VHF receiver, otherwise it would be necessary to make actual wiring changes in the VHF receiver.

Utilization of the double superheterodyne principle is forced upon all designers of UHF converter units in order that the output signal may operate into one of the standard VHF channels. The choice of the channel could be fairly broad, extending from channel 2 to channel 13. This choice determines the frequency of the pre-i-f (or VHF) amplifier; the latter, incidentally, provides separation between the UHF mixer and the VHF receiver, as well as signal amplification.

It has been found that there is an optimum range of frequencies for this pre-i-f amplifier. The frequency must be less than ⅛ of the lowest UHF channel, or the spurious responses from harmonics of the local oscillator may be quite serious. This places the maximum usable i-f frequency below channel 7, and, for the vast majority of conventional VHF receivers, leaves the highest frequency choice as channels 5 or 6, or 76 to 88 MC. As you know, it is necessary to have a choice of two channels so that in a given location, the VHF receiver may be switched to the one, either 5 or 6, which has the lowest VHF interference.

Due to the simultaneous use of two local oscillators, one in the converter, the other in the VHF receiver, very careful shielding of the converter assembly is essential to reduce interference possible from the harmonics of one local oscillator beating with the harmonics of the other, together with harmonics of the intermediate frequencies. In addition, a high-pass filter at the input to the tuner section and a low-pass filter at the pre-i-f output of the converter are desirable.

Sync Stages

age depends on the ratio of the plate resistances of the 1st video amplifier and the 1st sound IF tube, since these tubes are connected in series, and the gate tube cathode is connected into this series line at a point between the two tubes.

With its cathode at +125 V and its grid at B+ potential, V13 conducts heavily, developing an AGC voltage in its output circuit. The gain of the receiver is consequently reduced; the 1st video amplifier comes out of cutoff, and plate current flows through it, reducing its plate voltage, and consequently making V13's grid less positive. V13 now conducts less, and the AGC voltage does not increase as much in this interval as in the preceding one. The action continues until the point of stabilization is reached. At this equilibrium point, the AGC gate tube is operating with its bias just above cutoff.

Under these conditions, the sync tips of the composite video signal fall 15 V below the B level (see fig. 4). Noise pulses with an amplitude of 15 V in excess of the sync tips can therefore be developed in the plate circuit of the video amplifier. (Negative noise pulse peaks at the input of the video amplifier cannot drive the plate voltage above the B level; this level therefore constitutes the upper ceiling for noise pulses.)

This is the state of affairs that would exist if the AGC gate tube was not connected into the video amplifier. Its presence in the circuit, however, changes matters. The cutoff level of the AGC gate tube is a negative 5 V. In other words, if a 5 V. drop appeared across R305, and R215 and R217 were absent (with the upper end of R305 connected to the V13 grid), the AGC gate tube would cut off—an undesired condition, since the receiver would overload in consequence.

Now, the larger the negative-going sync pulse input applied to the 1st video amplifier, the greater becomes the negative bias of the amplifier, and the smaller is the voltage drop across R305. To avoid more than a 5 V. drop across R305, the sync pulse to the video amplifier would have to be so large that the sync pulse output in the plate circuit would fall only five volts below the B level. Noise pulses only five volts greater in amplitude than the sync tips could, in consequence, be developed in the 1st video amplifier output.

The sync pulses must be reduced 10 V further below the B level, to allow noise pulses to exceed them sufficiently in the 1st video amplifier plate circuit. Now, the level of the sync pulses in this circuit is determined by the input to the video amplifier; this is, in turn, determined by the gain of the AGC-controlled stages. By suitably adjusting the level at which the AGC gate tube conducts, the distance from the sync tips to the B level can be made correct.

The result desired is achieved by inserting the R215-R217 voltage divider into the grid circuit of V13. A ten volt drop occurs across R215. This ten volt drop (which tends to make the V13 grid ten volts more positive) is in series with the five volt drop across R305, as far as the V13 grid is concerned. A total negative voltage of almost 15 V. may now be developed across R305, without cutting V13 off and upsetting receiver

operation, since the 10V positive voltage across R215 will buck the (app.) fifteen negative volts developed across R305, reducing the net bias applied to V13 to –5 V (the maximum it is meant to handle). Noise pulses approximately 15 V in excess of the sync pulses can now be developed in the 1st video amplifier plate circuit, and fed to the gated leveller.

In troubleshooting the inverter, a scope is very useful. Connect the scope vertical input between cathode and ground of the inverter. Noise pulses should be seen (fig. 5A), if the circuit is functioning normally, and appreciable noise pulses are associated with the incoming signal. If no noise signals are seen at the cathode, but the contrast of video information on the CRT screen seems normal, try another noise inverter tube. If the noise signals still do not appear at the cathode, volt-ohm-meter checks in the circuit should rapidly locate the trouble.

For a check of the AGC gate circuit, inspect the waveform at pin 4 of the gate-pulse plug (see figs. 5b, 6). This waveform should be an approximately 500 V peak-to-peak pulse with a frequency of 15,750 cycles. The waveform on the grid of V13 (fig. 5c) should be the composite video signal, approximately 22 V in amplitude, checked with the scope frequency setting at 60 cycles.

When trouble is to be isolated in the AGC gate circuit, the remainder of the receiver may be made to function normally by applying a fixed bias to the AGC bus of approximately –7.5 V. Voltage tests can then be accurately made. Keep in mind that the gate tube derives its bias from the voltage divider made up of the 1st video amplifier and 1st sound IF amplifier connected in series. Trouble in either of these circuits can cause the wrong bias to be delivered to V13, upsetting its operation, as well as that of the circuits associated with it.

Cascode Circuits

decoupling network. C120 is a small neutralizing condenser.

Interestingly enough, feedback in this stage is employed, not to prevent regeneration, but to boost the gain. The plate impedance of the first tube is essentially capacitative, causing feedback to be *degenerative* in nature (compared with the *regenerative* feedback that would tend to occur in such a tube if a tuned plate circuit were present). If this degenerative plate-to-grid feedback were not counteracted, reduced gain would result, lowering the signal/noise ratio.

C116 puts the grid of the second triode at RF ground potential—a necessary condition for grounded-grid operation. Since the two triodes are in series across the B supply (see fig. 6), the cathode of the second triode (V-2) is positive to ground—125V positive, to be more specific. The grid of V-2 must similarly be positive, although less positive than the cathode, for
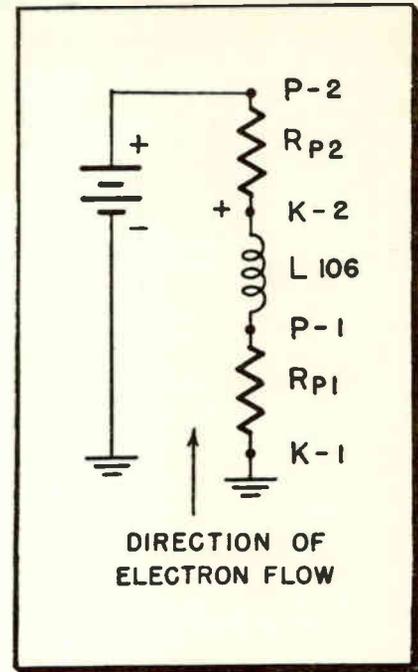
Fig. 6—Simplified, equivalent circuit of the two triodes shown in fig. 5. K-1, R_{p1} and P-1 are, respectively, the cathode, plate resistance and plate of the first triode; K-2, R_{p2} and P-2 are the cathode, plate resistance and plate, respectively, of the second triode. Note that the cathode of the second triode is positive to ground.

proper biasing. Voltage-dividing components R111 and R112 cause a positive voltage to be established for V-2's grid that makes it negative to its cathode by the necessary voltage.

An AGC voltage is applied not only to V-1, but to V-2 as well. If the AGC voltage of V-1 tends to go up, the plate current of both tubes tends to go down (since the same plate current flows through both). The plate resistance of both is thus effectively greater. A larger plate-to-cathode voltage is now developed across the larger plate resistance of V-2. Since V-2's grid voltage is fixed by the ratio of R111 and R112, the increase in cathode voltage increases its grid-to-cathode voltage, increasing the bias. Thus, AGC is effective at V-2 as well as V-1, preventing overloading when strong signals are coming in.

R110 is inserted between cathode and grid of V-2 to reduce the effect of— i.e., "delay"—the AGC applied to V-2 at low signal levels. It is desirable to keep the AGC voltage minimum when the signal input is low, to avoid a reduction of the signal-noise ratio. When the AGC voltage tends to boost the bias of V-2 by increasing V-2's cathode voltage, current flows between V-2's grid (less positive or more negative point) to V-1's cathode (more positive point). This current flows through R111, causing the grid (to ground) voltage of V-2 to go *more positive*. The tendency of the AGC voltage to make the grid go *more negative* is thus partially counteracted. R110 has little effect at high signal levels.

Noise Eliminator

arises when the set is out of horizontal synchronism. The keyed AGC system cannot function correctly in such a case. Adequate AGC bias is not developed, and excessive signal may consequently be applied to the video amplifier. The sync pulses at the input to the noise inverter may be large enough under such circumstances to trigger V14B, causing the sync pulses to be inverted, and thus preventing them from pulling the set into synchronism. To prevent such an undesired action, anti-lockout components are inserted into the circuit.

C48 and R67 form part of the anti-lockout system. When the receiver is out of sync, V14B conducts during sync pulse time, and C48 tends to be charged up by the vertical sync pulses, since these are of sufficiently long duration to do the job. The voltage developed across C48 reduces the plate voltage applied to V14B, as it is opposite in polarity to the B voltage applied to the plate.

The plate voltage is reduced so much, in fact, that V14B stops conducting, and therefore ceases to invert sync. V14B will start to conduct again as soon as enough of the charge present on C48 has leaked off (through R67) to raise the plate voltage to the conduction level. Due to the relatively long time constant of C48 and R67, however, enough time is taken by C48's discharge to permit the receiver to come into sync. When it does so, the sync pulses will no longer be large enough to improperly trigger V14B, since the AGC voltage will be high enough to prevent such an action.

Anti-Lockout Measures

Another anti-lockout measure is provided by connecting R70 between the video detector output and V14B control grid. The negative DC voltage output of the detector becomes quite large when th receiver is out of sync, sinc the AGC the receiver is out of sync, since the AGC system is not biasing the IF controlled stages properly. This large negative bias, when fed back to the V14B grid, will help prevent it from conducting on sync pulses, and thus locking the receiver out. When the set is functioning normally, the negative DC voltage output of the detector is too low to interfere with V14B's operation.

A third anti-lockout measure consists of using such values for C47 and R70, that their time constant will be correct. This can be explained as follows: V14B tends to conduct on sync pulses when the set is out of sync, as described previously. The large-amplitude, long-duration, positive-going vertical sync pulses present at the grid tend to cause grid current to flow. If the C47-R70 time constant is right, the grid current flow will rapidly build up a charge on C47 that will leak off *slowly*. This charge will maintain a negative voltage between the grid of V14B and ground that will bias V14B back. The increased negative bias on V14B (due to grid current flow, long R70-C47 time constant,

and connection of the V14B grid to the video detector output) as well as the reduced V14B plate voltage (due to the long time constant of C48 and R67) quickly cuts V14B off when it starts to conduct on sync pulses, eliminating the possibility of lockout.

Some readers may wonder if a transfer of negative noise pulses through R64 to video amplifier plate resistor R63 may not occur, with undesirable consequences—i.e., production of white noise, as well as attenuation of any positive-going video signals present at the time. The answer is that negative noise voltages are so greatly attenuated by R64, that they are insufficient to overcome the black (positive) noise put out by the video amplifier. In other words, the CRT scanning spot is black when noise is present, just as it would be if no noise inverter were used in the set.

Lightning Protection

on 120 v. ac branch circuits to protect low rated electronic equipment. This protector consists of a .600 in. carbon block discharge gap in series with a silicon carbide varistor.

Fig. 6 shows a two-section varistor assembly and two carbon block discharge gaps which will provide low voltage protection for two 120 v. branch circuits. These components may be arranged in various ways to facilitate mounting in the radio cabinet. The varistor prevents 60 cycle power-follow and the small resistance introduced by it materially extends the life of the gap. These low voltage branch circuit protectors should be installed in the radio equipment cabinet on the line side of the fuses.

In this location the device will not only protect the equipment from dielectric breakdown, but will reduce the possibility of equipment fuse operation on surges.

It is also recommended that time delay type fuses or circuit breakers be substituted for the branch circuit power fuses on circuits equipped with the low voltage varistor protector. Tests indicate that a higher level of protection will be secured if there are at least several feet of iron conduit between the service entrance and the location of the low voltage protector. Considerable benefit can be derived from the impedance introduced from such conduit as shown in Fig. 5.

The power protection just discussed is intended primarily for the protection of the station equipment. At locations where no provision is made for standby power service, it is desirable to consider the adequacy of the protection on the power line itself. The multi-grounded neutral

power circuit usually provides a low resistance path to earth on the neutral and in combination with the station ground provides a grounding system that can be of considerable mutual benefit. Power systems, however, which do not provide some path for surge current between primary and secondary neutrals are more likely to be damaged by lightning. As a result of a stroke to either the power line or the station, a potential will appear between the primary and secondary windings of the distribution transformer serving the station that may damage the windings and interrupt service.

Fig. 5 shows a particular power connection at a radio station where the distribution transformer was damaged by lightning. It may be noted that interchange of surge current between the station ground and power primary neutral grounds would create arcing in the transformer. Interconnection between primary and secondary neutrals or between the primary arrestor ground and the secondary neutral is desirable. In the case shown in Fig. 5, interconnection may be by means of a discharge gap between the primary arrestor ground and the secondary neutral as shown in the figure.

The problem of protecting the fixed stations of a mobile radio system from service interruptions due to lightning is not confined to the station equipment and the antenna system, but consideration must also be given to the connecting power and land communication facilities. The protection methods discussed have been successfully employed in Bell System radio installations and many of the arrangements will also provide satisfactory protection for other types of equipment.

Associated with the technical solution of a protection problem is the matter of cost. The amount of protection applied should be determined through a consideration of the probable savings in plant damage expense and the value placed upon continuity of service.

SHOP HINT

Record-Changer Service

When a record-changer is serviced outside the receiver cabinet, and the female motor plug connector to the line is not available, try the cheater cord of a TV receiver on for size. It often fits. The male end of the cheater cord goes, of course, to the AC power outlet.—*Sol Sukenick, 5160 Arbor Street, Phila. 20, Pa.*

ASSEMBLING YOUR

JUNIOR

EXPERIMENTER'S
ELECTRONIC KIT

PIONEER HOME STUDY RADIO·TV SCHOOL

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

DRAWINGS

For your convenience, the working drawings for this kit are not attached to this manual, but are printed on large, separate project sheets and inserted in the back of this manual. There are six pages with drawings on both sides of each page. Check the drawings against this list.

SHEET 1 BASIC WIRING – POWER SUPPLY

SHEET 2 METRONOME

SHEET 3 AUDIO OSCILLATOR

SHEET 4 CONDUCTIVITY TESTER

SHEET 5 PHONO AMPLIFIER

SHEET 6 CODE PRACTICE OSCILLATOR

SHEET 7 THEREMIN

SHEET 8 BROADCAST STATION

SHEET 9 SIGNAL TRACER

SHEET 10 BABY WATCHER

SHEET 11 RECEIVER

SHEET 12 MASTER PARTS LIST

THE JUNIOR EXPERIMENTER'S ELECTRONIC KIT

The projects in the NRI Junior Experimenter's Electronic Kit have been designed to give you practical experience in the construction of electronic circuits from schematic and pictorial diagrams. You will not only build and operate many types of electronic circuits, but will also learn how each circuit works. Last, but not least, you will get hours of pleasure from experimenting with the finished projects and can keep any one of them, such as the receiver, permanently wired up as proof of your skill.

For those who have a speaking acquaintance with radio and the operation of vacuum tubes, the short technical descriptions telling how each circuit works will be instructive. Even a beginner who knows practically nothing about electronics will pick up many ideas and will be building a good background for further study. The short List of Radio Terms which is a part of this manual will explain the radio words used in describing the work you will do here.

No previous technical knowledge is required to build and operate any of the projects in this kit. You will get satisfactory results if you follow the special hints which are given, and if you do the work carefully. The pictorial diagrams furnished for each circuit should be followed faithfully, since they show how each wire and part is connected. However, you have the opportunity to compare the schematics (wiring diagrams using symbols) with the pictorial diagrams. This will be very helpful if you decide to make a further study of electronics.

The projects need not be built in any particular order. After reading the following brief descriptions of the ten projects you can decide which you would like to build first.

The Receiver uses the superheterodyne circuit. Since the i-f transformer has been adjusted at the factory, the entire receiver can be aligned without the use of special service equipment. This receiver will give far more selectivity than a TRF set, and, under favorable conditions, will enable you to pick up many distant stations. It compares very favorably with similar commercially manufactured receivers.

The Phonograph Amplifier has high gain and can be used to amplify signals from a phonograph. The power supply in this, as in all of the other projects, is of the AC-DC variety.

The Broadcast Station radiates for a short distance signals which may be picked up on your home receiver. If you talk into the loudspeaker, which is used as a microphone, your voice will come out of your receiver — great fun for parties and special occasions! A phono pickup may be used to modulate (put a signal on) the Broadcast Station instead of voice. The Broadcast Station can also be used as a "wireless" baby watcher; for instance, you can put it in the baby's room and go into another. If you tune in the Broadcast Station on a receiver you will hear any sound from the baby.

With the **Code Practice Oscillator** you can easily learn how to send and receive Morse code. By working together, two people can quickly become proficient in both copying and receiving code signals. Since the signals come out over your home receiver, a group can practice at the same time, one person sending, and the others copying the signals.

The Signal Tracer is a practical servicing instrument of the type used by professional radio servicemen. With it you can find the exact point in a defective circuit where the signal stops. In this way, trouble-shooting is cut down to a single section, or stage, in a dead receiver.

The Metronome is an instrument which electronically produces the same effects as the mechanical metronome. The neon lamp flashes on and off giving you a visual standard for tempo, and clicks are produced at the loudspeaker giving you an audible standard. The principle demonstrated by this circuit is used in many commercial and industrial applications. This electronic metronome has no moving mechanical parts, and its speed may be varied over a wider frequency range than the mechanical metronome merely by turning a knob.

The Audio Oscillator is an interesting project which will enable you to produce various audio tones. Audio oscillators are used by servicemen to check the operation of audio amplifiers and loudspeakers and by engineers in sound development work.

The Conductivity Tester and Photo Control shows how a tube may be used for industrial control applications. You actually demonstrate that certain impurities in liquids can be readily detected electronically! The Photo Control feature of this project will show you the basic principles of photoelectric control circuits.

The Theremin is actually a musical instrument. In this basic model you see how the signals from two oscillators beat together to produce an audio note. You can have fun changing the pitch of this note by simply waving your hand near the loop. This circuit also has possibilities for use as an intrusion detector by placing the loop near a passage to be "protected." If any one passes by when the instrument is tuned to "zero frequency" it will make a loud squeal.

When the **Baby Watcher** is completed it may be used in several ways. It can be placed in the room near the

baby's crib so that any sounds or cries will be heard over the program to which you are listening on a receiver in another room. It can also be used to interrupt a program and make side comments, if desired, by talking into the microphone. This cannot be done with the Broadcast Station since, with the latter, you must tune the receiver to a point where no regular station is picked up.

The "baby watcher" may also be used as a concealed microphone so that you can hear conversations without being present!

A LIST OF RADIO TERMS

You can build and operate all of the projects in this kit without any knowledge of electronics, but in order to understand the operation of any of the circuits you will have to learn a few new terms which are peculiar to the science of electronics. As few technical terms as possible have been used in the circuit explanations. Many of the technical terms used are self-explanatory, but, since some technical terms are unavoidable, a list of those used and their definitions is given here. It is not recommended that you attempt to memorize these definitions. Use the list as a reference when you come to a term that you do not understand.

AC (Alternating Current) — An electric current that reverses its direction of flow at regular intervals.

AMPLIFIER — A device or circuit which increases the strength of an electrical signal.

ANTENNA — A device which picks up, or radiates, energy in the form of radio waves.

AUDIO — Any signal varying from 20 to 20,000 cycles per second is called an audio signal.

"B" SUPPLY VOLTAGE — The high voltage direct current usually supplied to the plate and screen of a vacuum tube.

CATHODE — The element in a vacuum tube which throws out electrons when heated by the filament.

CONDENSER — An electronic part which will temporarily store electrical energy. Generally speaking, it will block the flow of direct current and allow the flow of alternating current.

CONTROL GRID — The electrode (part) in a vacuum tube which controls the flow of electrons through the tube.

CONDUCTIVITY — The ability of any material to allow the flow of current (electrons).

CONTACTS — The metal parts of a key or switch which come together when the key is closed.

DC (Direct Current) — Current which flows in only one direction.

DISTORTION — The improper reproduction of sound. If the sound coming out of the speaker does not sound like that which went into the microphone it is said to be distorted.

FILAMENT — The element in a vacuum tube which glows and generates heat causing the cathode to emit (give off) electrons.

FREQUENCY — The number of complete cycles per second an alternating electric current, a sound wave, or a vibrating object, undergoes. A cycle consists of a rise from zero to maximum, a return to zero, a rise to a maximum in the opposite direction, and a return to zero again.

GRID — An element between the cathode and plate of a vacuum tube which governs the flow of electrons (similar to the effect of the control grid).

I-F (Intermediate Frequency) — The frequency produced in the superheterodyne receiver by mixing the oscillator signal with the incoming signal.

KEY — A form of switch used to send telegraphic code by opening and closing the contacts.

LEAD — The wire provided on electronic components to make electrical connections.

LUG — A metal tab to which wires or leads are soldered.

MEGOHM — One megohm equals one million ohms.

MODULATE — To combine sound waves with radio waves so that the radio waves (carrier) will deliver the sound to a distant point.

NEON BULB — A bulb filled with a gas which lights up (ionizes) and conducts current when a certain voltage is applied across it.

OHM — The unit of resistance.

OSCILLATOR — A vacuum tube circuit which generates alternating current energy.

PENTODE — A five-element vacuum tube.

PHONO PICKUP — The device on a phonograph which holds the needle on the record and converts the groove variations into an audio signal.

PICTORIAL DIAGRAM — A diagram which shows exactly where each part is mounted and where the leads are placed and connected.

PLATE — The electrode in a vacuum tube which attracts electrons. The amplified signal is usually taken from the plate.

POLARITY — Parts which must have one lead connected to a positive terminal and the other to a negative or ground terminal are said to be polarized.

POTENTIOMETER — A fixed resistor with a movable tap (slider arm).

POWER SUPPLY — The section of any electronic equipment which converts the power from the wall outlet to plate and filament supply voltages.

RECEIVER — A device which converts radio waves into sound.

RESISTOR — An electronic component which impedes the flow of electric current. Its value is expressed in ohms.

RHEOSTAT — A variable resistor.

RF (Radio Frequency) — A signal whose frequency is above the audio range, and which can be radiated from an antenna.

SCHEMATIC DIAGRAM — A diagram which uses symbols to represent components and connections. It is used to

show the operation of a circuit rather than the placement of parts and connecting wires.

SCREEN GRID – An electrode mounted between the control grid and the plate of a vacuum tube.

SELECTIVITY – The ability of a receiver to receive a station without interference from another station.

SUPERHETERODYNE – The circuit used in most modern receivers in which a local oscillator mixes (or beats) with the desired signal. This produces a frequency (I-F) which is easier to amplify than the station's frequency. The I-F is then converted to audio signals in the usual way.

TIN – To coat with a thin layer of solder.

TRANSFORMER – A device with coils of wire so arranged that electrical energy may be transferred from one coil to another without direct electrical connection between the coils.

TRF (Tuned Radio Frequency) – The circuit used in early receivers in which signal amplification is obtained by using one or more tuned rf amplifiers.

TRIMMER – The small screwdriver-adjusted condenser on top of a tuning condenser or mounted in an i-f transformer can.

TRIODE – A three-element tube.

VOLUME CONTROL – A potentiometer which controls the amounts of audio signal fed into an amplifier.

HOW TO IDENTIFY PARTS

The master parts list on sheet 12 of the working drawings identifies each part, shows the value, gives the identifying code if used, and shows the schematic symbol for the part.

Check the parts in your kit against this list to become familiar with them. Handle all parts carefully to avoid breakage. *Do not remove the tape on the top of the i-f transformer can or adjust the preset screws under the tape.* Leave the plates of the tuning condensers fully meshed. This protects the moving plates from damage until this part is mounted on the chassis.

Paper Condensers – The fixed paper condensers all have the same general appearance. On them you will find the name of the manufacturer, the manufacturer's part number, and the fact that the condenser was made in the USA. None of these facts are of any electrical significance. The important markings are the capacity in mfd. (microfarads), the working voltage and the polarity. By polarity in a paper condenser we mean the identification of the lead which goes to the outside of the two foils with which the condenser is wound. This lead is identified by a heavy black ring around one end of the condenser or by the word "ground" or "outside foil" printed at the end of the condenser. Watch the pictorials for the polarities of paper condensers. Where polarity is of any importance, the ground end marked with a heavy black band must be connected to ground. You need not be concerned with "working" voltage which means the highest voltage that may be applied safely to a condenser. All the condensers you receive have an ample working voltage rating.

Fixed Resistors – Radio men identify the ohmic value of resistors by the resistor color code. The colors for each resistor used are given in the parts list and the complete code is reproduced here.

How To Read Resistor Values With The Color Code

All carbon resistors are produced and color-coded under standards set by the RETMA (Radio Electronic and Television Manufacturers' Association). Under these standards the user is assured of a wide range of values and of a universal color-coding system that permits easy

identification of any carbon resistor. To determine the value of a resistor, hold it with the color bands reading from the left end, as illustrated, and refer to the chart.

Band A		Band B		Band C		Band D	
Color	Value	Color	Value	Color	Value	Color	Tolerance
Black	0	Black	0	Black	0	None	± 20%
Brown	1	Brown	1	Brown	X10	Silver	± 10%
Red	2	Red	2	Red	X100	Gold	± 5%
Orange	3	Orange	3	Orange	X1,000		
Yellow	4	Yellow	4	Yellow	X10,000		
Green	5	Green	5	Green	X100,000		
Blue	6	Blue	6	Blue	X 1 Million		
Violet	7	Violet	7	Violet	X 10 Million		
Grey	8	Grey	8	Gold	÷ 10		
White	9	White	9	Silver	÷ 100		

The first band (A) shows the first figure of the resistor value, the second band (B) shows the second figure, the third band (C) indicates the number of zeros to add. The fourth band (D), which is not included on all resistors, merely indicates tolerance: silver for ± (plus or minus) 10%, gold for ± 5%. If the (D) band is omitted, the tolerance is ± 20%.

Here is an example: A band yellow, B band violet, C band yellow, D band silver = (4) (7) (X10,000) (± 10%) or 470,000 ohms, ± 10% tolerance.

Remember that all resistors must have *three* colors to show their ohmic value, and that a fourth color, if present, merely shows the tolerance of the resistor. None of the circuits you construct in these projects are critical as to resistance tolerance ratings, and you can ignore any silver or gold tolerance markings on any resistor. If you find a resistor with markings such as, black, orange, and silver, grouped together, you will know that the last color means a tolerance of plus or minus 10% and that there should be another color in addition to black and orange. The other band *is* present but is often not visible as a

band since it has the same color as the *body* of the resistor. Resistors usually have brown bodies. Thus the resistor in question would actually be *brown*, black, and orange, and from the color code has a value of 10,000 ohms. Whenever a band seems to be missing, assume that it is the same color as the body.

CONSTRUCTION HINTS

Tools — Only three tools are needed - a soldering iron, a screwdriver and a pair of pliers. Although you can get along with only these tools, your work will be easier if you have several sizes of screwdrivers, a pair of long nose pliers, side cutting pliers and ordinary automobile pliers. All the needed tools can be obtained inexpensively from the 10-cent store.

Solder Lugs — Bend up the small ends of all your solder lugs about 45° (half of a right angle). *Do this now!*

Mounting Permanent Parts — The large parts are located in the same position for each project. With the exception of resistors, paper condensers and tubes, all these parts are to be permanently mounted in position.

A flattened view of the bottom of the chassis with the parts mounted is shown on the Basic Wiring diagram. The front of the chassis is at the top of the drawing. The chassis holes and cut-outs which will be used are lettered. You should letter the corresponding holes on your chassis with a soft lead pencil or marking crayon. DO THIS NOW! The markings may be removed later with an ordinary eraser if desired.

Identify the output transformer T3 and cut its red and blue leads so they are about 5½ inches long. With a sharp knife cut off ¼ inch of the *insulation* from the end of the red and blue leads. Do not cut or nick any of the wires with your knife. Twist the wires coming out of the blue lead to make a solid strand. Do the same for the red lead. DO THIS NOW!

Now mount all parts that go to the bottom of the chassis as shown in the illustration. All screws not already attached to parts are inserted through the top of the chassis with the nuts below the chassis. To mount the screw at hole Z, put a fibre bushing in hole Z from the top of the chassis, insert the screw through the bushing, slip a fibre washer over the screw on the bottom of the chassis, and put the solder lug and nut on the screw. Neither the screw, the nut, nor the lug, should touch the metal chassis.

Some of the screws and nuts may be brass while others may be cadmium plated. Their colors are of no importance and they may be used without regard to their appearance.

Tube Sockets — Mount the tube sockets as shown in the pictorial diagram, with miniature sockets in holes R, Q, and J and the larger, octal socket in hole F. Note the solder lug which is mounted under the nut holding the tube socket at hole Q. All tube sockets are held against the bottom of the chassis and the screws inserted from the top. When installing each socket be sure that the large space between lugs 1 and 7 on the miniature sock-

ets, and the keyway on the octal socket are placed as shown in the pictorial diagram. After the sockets are mounted, be sure you have bent the terminal lugs on all the tube sockets down and out. This will give you more space between the ends of the lugs. None should be bent far enough to touch the chassis. The four lugs which are a part of the mounting ring on the octal socket will never be used and should be bent down, out of the way. It does not matter if they touch the chassis.

Output Transformer, T3, and Electrolytic Condenser, C1 are mounted together. One side of the transformer and a solder lug are held through hole E by a screw and nut. A *larger*, 6-32, screw and nut through hole Y hold the other end of the transformer and the mounting strap of the electrolytic condenser. Note that both the transformer and condenser are mounted with the colored leads toward the *rear* of the chassis.

Volume Control R15 — Remove the nut from the threaded portion of the volume control. Push the shaft and the threaded portion at the base of the shaft through hole V, so that the shaft protrudes from the front of the chassis. Hold the control with the lugs in the position shown in the diagram, and, with the pliers, tighten the nut down on the threaded part, which extends through the front of the chassis.

Neon Bulb — Place a rubber grommet in hole V1 and push the bulb through the grommet so that the glass end of the bulb is visible from the outside of the chassis. The base (metal end) should be completely inside the chassis and not touching the rubber grommet.

Grommet — Place a rubber grommet in hole A.

Oscillator Transformer, T2 — Mount the oscillator transformer with the terminals color coded red and black nearest the edge of the chassis. This coil is held in place with screws and nuts through holes K and K1. Note that there is a solder lug under the nut at hole K1.

Terminal Strips — Mount two terminal strips one at hole T and one at hole G as shown in the diagram. These strips are held in place with a single screw and nut.

I-F Transformer, T4, is mounted from the top of the chassis so that the colored leads extend through hole H to the underside of the chassis. The mounting bolts which are already attached to the can of this transformer fit through the small holes on either side of hole H. Tighten 6-32 nuts down on these bolts until they are firm, but do not force them as you may damage the can.

Tuning Condenser Gang, C9 and C10 — This part also has its own mounting bolts attached to it and is placed on top of the chassis. Before mounting the tuning condenser, locate the small solder lugs on the bottom of it

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and bend them up with a pair of pliers so that they will clear the chassis by about one-quarter of an inch when the condenser is mounted.

The **Cardboard Dial Plate** must also be put on the condenser before it is mounted. Fit the large hole over the tuning condenser shaft, and bend the bottom of the dial plate so the small holes fit over the two front mounting screws. Now insert the two front mounting screws through holes X and X_1. The back mounting bolt goes through the large slot in the chassis marked M; place the large metal washer over this bolt and tighten down the 6-32 nut on it. Do not over-tighten this nut or you may warp the chassis.

The Antenna Transformer is shown in the Receiver pictorial. It is mounted on top of the chassis. Mount it with the lugs color coded blue and red, nearest the back of the chassis. This coil is mounted with a single screw and nut through hole I. Place a solder lug under the head of the screw on top of the chassis.

Code Practice Key — The mounting of the Code Practice Key is illustrated on the pictorial diagram of the basic wiring. Mount the key as shown with a 4-40 screw and nut through the second hole from the end of the key and hole Z_1 in the chassis. Align the key so that the head of the screw which holds the knob is directly over the head of the screw in hole Z. When you press the knob these two screw heads should come together, and when the knob is released they should separate.

Knobs — Slip the knobs on the volume control and tuning condenser shafts, and tighten the small set screws. The tuning condenser knob should be mounted so that it points to 550 when the plates are fully meshed.

After all parts are mounted, carefully check your work against the illustration.

The next assembly step is to put in the permanent wiring, but you should first read over the following hints, unless you are experienced in the assembly of electronic equipment.

HOW TO SOLDER

From more than thirty years experience in training men in radio and TV work we have found that poor soldering causes more trouble in construction than anything else. However, it is easy to make good soldered connections if you follow the simple rules for successful soldering. All of the electrical connections in the projects are soldered joints; therefore, it is necessary that you learn to make good soldered connections.

The Soldering Iron — You must obtain an iron which is suitable for radio work. You may use a soldering gun or an ordinary electric soldering iron. The latter is preferable for construction work and should be rated between 60 and 100 watts. The tip, which transfers the heat to the parts to be soldered, should not be over 5/8 inch in diameter and may be considerably smaller. It should taper to a sharp point with flat surfaces or, as they are called, working faces. The heat is transferred from these flat surfaces to the work.

The iron tip must be kept clean and covered with a thin film of solder. Clean the iron from time to time by pushing the tip into a ball of steel wool and turning the handle of the iron. If the tip gets badly pitted file the surfaces smooth, heat the iron, and tin the tip by melting solder on it until a thin film of solder, which cannot be wiped off on a cloth, sticks to the working faces.

CAUTION: Do not touch any part of a hot soldering iron but the handle. The heat developed in the tip can burn your body or clothes!

The Solder — Use the solder supplied with this kit. If you ever buy solder for radio work get only ROSIN CORE solder. Acid core solder must never be used. Do not use flux paste - the rosin core does the necessary work.

The Wires — Each wire which is to be joined must first be coated or, as we say, "tinned" with a thin film of solder. Beginners should pre-tin each lead to avoid the use of excess solder and the possibility of poor connections.

Most radio part leads, lugs, and wires are pre-tinned at the factory, but frequently oxidation covers the solder film and prevents other solder from melting into it. It is the function of the rosin core in your solder to dissolve such films. However, re-tin all leads and other parts to be soldered by rubbing them back and forth on the working surface of the iron while applying a little solder to the tip and lead. When the solder sticks and SPREADS on the lead it is tinned.

The iron must be in its rest, or lying in an ash tray or dish while being used to tin parts. If the part is mounted on the chassis the iron must of course be applied to the part to be tinned. Don't worry if solder drips on the chassis - you can scrape it off. Solder will not stick to the metal of which the chassis is made. Solder which covers holes in solder lugs can be collected on the iron and flipped from it. In any event, the solder will melt when an iron is applied, and you can then push leads through the hole. You should tin all part leads and solder lugs before you begin wiring the circuits. DO THIS NOW!

Now look at output transformer T3. Two leads on this part are of enamel covered wire. If the ends of these leads have not been tinned, scrape about ¼ inch of the enamel off the ends with your knife and tin them. Be careful not to cut or nick the wires.

How to Make Good Soldered Connections — The tinned leads which are to be soldered may be placed through a hole in a tube socket terminal or through a lug hole on a mounting strip. They should be held in place by a slight

bend in the wires in case of temporary connections and by sharply bending or hooking the wire ends in the case of permanent connections which will not be removed. When it is necessary to hold leads together with pliers, touch the iron to the work and the solder at the same time.

When you are ready to solder, apply a WORKING FACE of the iron to the terminal and wires. DO NOT USE THE SHARP POINT AT THE END OF THE TIP. After a few seconds the parts will become hot, and you may touch the end of your solder to the wires and lug. The solder will melt and spread over the wires and lug. Use only a small amount of solder. Remove the iron and let the wires remain MOTIONLESS until the solder cools. If the wires move, just before the cooling occurs, the solder will crack away from the wires and the heating and cooling process must be repeated. Be careful not to damage parts by applying the hot iron for too long.

Permanent and Temporary Connections – All connections in these projects are soldered, but since many of them must be removed time after time you should make them so that they can be easily disconnected.

Where temporary connections are made the wires or leads are allowed to remain their full length. The wire ends are slipped through the holes in the solder lugs and bent only slightly. This bend should be just enough to hold the part or wire in place until it is soldered.

To make a permanent connection cut the wires or leads so that they are about a quarter of an inch longer than is necessary just to reach the lug. Insert the wire through the hole in the solder lug, and wrap it tightly around the lug so that the connection is mechanically and electrically secure, even before it is soldered. These connections are difficult to disconnect and should only be used where they will not be moved.

You must always have a good metal to metal contact in any connection before you attempt to solder it. Make sure that none of the insulation on your hookup wire has extended into the hole in a solder lug when you make a connection. If you solder a connection with the insulation in the hole you may get a joint that looks as if it is soldered, but it will frequently be a poor electrical connection.

HINTS ON WIRING THE PROJECTS

Diagrams – With each project we show both a schematic and a pictorial diagram. Both types are given because each serves a different purpose. The schematic is easier to follow when one is attempting to analyze the function of a circuit, but the pictorial diagram is easier for a beginner to use when constructing equipment. The pictorial diagrams or working drawings are inserted in the back of this manual.

The pictorial diagram shows the exact location of each part, wire, and connection under the chassis. Each part on the diagram is identified with the same designation that is used on the parts list. By carefully following the pictorial diagrams you will be able to build the projects in the minimum time with the maximum accuracy.

The schematic diagrams show how the circuit operates rather than how to build it. In each schematic the parts are shown symbolically. The symbols are shown on the parts list. The lines on the schematic represent paths of current rather than specific wires. When two lines cross directly, a connection is indicated. If one line loops over the other there is no connection. The schematics are to be used when analyzing how the circuit works, not in wiring the circuit.

Building a Circuit – When you build a project turn to the diagrams and instructions for that circuit. Study these carefully before beginning to work. Then gather the components given in the parts list for that project and proceed to wire them in place as shown in the pictorial diagram. AS EACH PART AND WIRE IS INSTALLED MARK OVER IT ON THE PICTORIAL WITH A COLORED PENCIL. This will prevent you from forgetting to install

any parts. AS EACH CONNECTION IS SOLDERED MARK IT WITH AN "X" ON THE PICTORIAL.

After all construction is completed, shake the leads in each connection one at a time and if any are loose re-solder. Next position or, as radiomen say, "dress" the parts, leads, and wiring as shown in the pictorial. Since the leads on most parts are not to be cut, this dressing is necessary to avoid shorts between exposed wire leads.

Place the tubes in the correct sockets as shown on the bottom view of the pictorial diagram. TUBE PLACEMENT WILL VARY IN THE PROJECTS, SO BE CERTAIN THAT THEY ARE IN THE RIGHT SOCKETS FOR THE PROJECT YOU ARE CONSTRUCTING. If any of the tube pins are bent they can be gently straightened with a pair of long nose pliers and the tubes easily slipped into their sockets with only a little pressure. If the tube is moved around slightly you will find that its pins will easily go into the socket holes.

When the circuit is constructed, the parts dressed, and the tubes installed, you can place it in operation, following the instructions given for that project.

If a circuit fails to work after you have constructed it, carefully check your wiring against the pictorial diagram. HAVE YOU INSTALLED ALL OF THE PARTS SHOWN ON THE DIAGRAM? ARE ALL OF THE PARTS OF THE PROPER VALUE? Carefully check the values against the parts list. ARE ALL OF YOUR CONNECTIONS MADE TO THE RIGHT TERMINALS AND PROPERLY SOLDERED? Recheck all soldered joints. ARE ANY BARE WIRES TOUCHING THE CHASSIS OR OTHER BARE WIRES? Check the dress of parts and leads.

After carefully checking all of your wiring reread the section in this manual on the project carefully to see if there are any hints which may help you or if there are any connections to be made that are not shown on the pictorial. Most failures are caused by either a mistake in wiring or poor solder connections.

NOTE: *All* tubes must be installed for each project or none of the tube filaments will light.

When you disassemble a circuit, preparatory to building another, carefully remove all fixed resistors, paper condensers and temporary wiring, leaving only the basic power supply circuit shown on the pictorial diagram for the basic wiring.

When unsoldering connections, use your pliers to straighten any hooked leads, rather than attempting to pull them loose after the solder has melted. Care should be used in applying your soldering iron to connections. Do not let it touch the transformers or paper condensers, because excess heat will damage these parts.

Do not discard the odd lengths of wire. You will find circuits in which they will fit nicely with little or no further cutting necessary.

If excess solder is building up on the tube socket terminals or terminal lugs flip the free solder from your iron and apply the iron to the lug. Some of the excess solder will be drawn on to the iron tip which may be cleaned again by flipping the solder off. Repeat this a few times until the terminal is free of excess solder. It is very important to do this in order to keep solder from building up and causing shorts to the chassis.

Safety First – In these projects one side of the power line connects directly to the metal chassis, just as it does in millions of AC-DC receivers. Servicemen work safely on these sets every day. You will avoid all chance of a shock by following simple safety rules and by understanding how shocks can be caused.

CAUTION: *Failure to follow these safety rules may result in shock:*
1. *Never touch the chassis and ground, such as a water pipe, radiator, concrete floor, etc. at the same time.*
2. *Never work on the chassis with the power cord plugged in.*
3. *Always discharge the filter condenser before working on circuits.*
4. *Never touch two chassis at the same time.*

When a person is electrically shocked, current travels through a portion of his body. In order for current to flow there MUST BE A COMPLETE CIRCUIT. In other words you must touch two things to get a shock. If you touch only one thing at a time it is impossible for you to be shocked when working on these projects. When we speak of touching things we mean any part of your body - not just your hands.

You can stand on one side of a circuit, touch the other side with your hand and get a shock. An example is a chassis. One side connects to the power line and one side of the power line connects to ground. If the line plug is inserted so that the chassis connects to the ungrounded side of the line and you stand on a good ground, you will get a light shock if you touch the chassis. Your shoes are between you and the ground and since dry leather is a poor conductor the shock will be light. The shock will be greater if your feet and shoes are damp with perspiration. It will be very heavy if you touch a grounded metal object such as a radiator, water pipe or a receiver chassis with your bare skin. *Never touch a water pipe, radiator, etc. and the chassis at the same time!*

If you must work on a concrete floor, stand on dry boards, or sit on a wooden stool. Your workbench top should be of wood, bare, or covered with linoleum or any non-metallic material, and there should be no grounded objects nearby which you might touch. Never place the chassis on a grounded object. You might blow a house fuse.

You can avoid shocks from voltages existing in the circuits if you remove the line plug from the wall outlet before doing any work. If you ever touch any parts or terminals under the chassis while power is applied, you will not get shocked if you touch only ONE thing at a time. But do not take any chances, even with relatively harmless shocks - disconnect your equipment from the power line before you work with it. As a further precaution you can discharge the electrolytic filter condensers – AFTER DISCONNECTING THE EQUIPMENT FROM THE LINE – by shorting socket terminal 6, of the octal socket, to the chassis with a screwdriver.

It is a fact that beginners are almost never shocked. People who grow careless and forget or ignore the rules are the ones who are shocked. In working with electricity never let familiarity breed contempt.

HOW TO WIRE THE BASIC POWER SUPPLY CIRCUITS

This circuit is the same in almost all of the projects and should be built first. Before starting any wiring on this or the following projects remove the tubes, if they are plugged into their sockets, and put them to one side out of your way. Close the tuning condenser plates and put something under the chassis so it will be steady when you are working on its under side. A block of wood or a cardboard box will do. In addition to the parts which are already mounted on the chassis, you will need hook-up wire, two 2.2K (2,200) ohm resistors (R3 and R4) colored red, red, and red, and a 150 ohm resistor (R1) coded brown, green, and brown. The parts should be connected and wires installed as shown in the pictorial diagram. Do not make permanent connections at terminal 1 of miniature socket R. In one of the projects these leads will be removed.

Since other wiring will go over the permanent wiring, keep all insulated wires close to the chassis. But be sure that no bare wires or terminals touch the chassis.

Note that a bare wire connects between terminals 8 and 4 of octal socket F. This wire can be obtained by pushing back the insulation on the hookup wire and cutting off as much bare wire as required. Most of the hook-up wire used in the power supply is insulated. Only push back enough insulation at the ends to make a good connection. The thin lines on the pictorial diagram represent bare wire and the heavy ones insulated wire. Make a permanent connection at terminal 8, but a temporary one at terminal 4. In another project this wire will be moved to terminal 1.

Cut the leads of the three resistors fairly short. They should be just long enough to reach the lugs and make a good connection. In the rest of the projects *do not cut* the leads of any of the resistors or condensers. They will be moved from place to place in the circuits, and in some cases you will need longer leads than others. The pictorial diagrams show you how to position (dress) the leads so that they will not short out.

Pull the end of the power cord through the grommet at hole A. Tie a knot in the cord as shown in the pictorial diagram.

Note that in the filament circuit one of the power line leads connects to terminal 2 of the octal socket while terminal 7 of the octal socket connects to terminal 4 of the miniature socket in hole R. The No. 3 terminal of this socket connects to the No. 4 terminal of the socket in hole J. The No. 3 terminal of the socket in hole J connects to the No. 3 terminal of the socket in hole Q. The No. 4 terminal of this socket connects to the chassis by way of a solder lug and also to the center terminal on the socket. Use bare wire here. Put the wire through the hole in the solder lug and the hole in the center terminal.

Bring the wire under and against terminal No. 4 of the socket. Solder the connections now. The remaining power cord lead connects to one terminal of the on-off switch on the back of the volume control. The other terminal of the switch is grounded to the chassis by way of a wire going to the solder lug on the socket in hole Q.

Do not make a permanent connection between the output transformer and terminal 7 of socket R and between the output transformer and terminal 4 of socket F. At terminal 4 of socket F, permanent connections should only be made with the condenser C1A lead. All other leads on terminal 4 should only be temporarily soldered, since they will be moved in some of the projects.

If the enameled leads on T3 are too short to reach the terminals at strip T, loosen the screw and turn the strip around. Use two pieces of wire about 12" long to connect permanently the speaker to these two terminals. Do not mount the speaker on the chassis. It is more convenient to leave it on your workbench.

Carefully check your work. See that you have put in *all* of the wiring shown in the pictorial. If your wiring is correct, you are ready to try out the power supply.

Install the tubes in the sockets. The 35Z5 tube must be inserted in the octal socket F, the 50C5 in miniature socket R, the 12BA6 in miniature socket Q, and the 12BE6 in miniature socket J. Now plug the line cord into the power outlet and turn the volume control switch to the right. When you hear a click the switch has closed. The tube filaments should now light up if they have been properly wired. Turn the switch off and pull the plug out of the wall socket.

To Construct a Tester for the B Supply — Temporarily solder the 100,000 (R9) ohm resistor colored brown, black and yellow, between the shell of the neon bulb base and the solder lug at terminal K1. Solder a wire lead about 8 inches long to the small brass disc on the very end of the neon bulb base (NL), and push back the insulation enough to uncover the free end of the wire. Tin the disc at the end and a spot on the shell before making these connections. Temporarily solder this end of the wire to the terminal strip lug which connects to pin 6 of the 35Z5 tube. Put the plug in and turn on the switch. If the B supply is working the bulb will light. The resistor and test wire may now be unsoldered. DO THIS NOW!

If the tube filaments light and you have B supply voltage you may assume that everything is in good condition.

How the Power Supply Works — The tube filaments are connected in series across the power line. When the switch is closed current flows through the tube filaments, as in a string of Christmas tree bulbs. The tube fila-

8

ments light up, but what is more important, considerable heat is developed. This heat is transferred to the *cathodes* of the tubes. The cathodes, when heated, throw off electrons. This stream of electrons flowing through the tube can be controlled by the signals applied to the tubes.

In the power supply a special type of tube known as a rectifier is used. This tube, a type 35Z5, has no grid and is used only to change the ac line voltage, which constantly reverses in polarity, into pulsating dc which does not reverse its polarity. The 35Z5 is able to change ac into dc because it allows current to flow in only one direction. The 2.2K resistor (R4) and the two 20 mfd. electrolytic condensers (C1A, C1B) "smooth out" the pulsating dc so that a constant voltage is available for use at the electrodes of the other tubes. This rectify-

ing action is continuous, and we always have a source of dc voltage and current available at C1B to operate the equipment.

A defect in C1A or C1B will make the tubes receive their supply in pulses directly from the 35Z5, and a hum voltage will be introduced into the circuits. If the circuits feed into a speaker a loud hum will be heard.

Now that you have successfully completed the basic wiring you are ready to continue with the projects. If you have had no previous experience in wiring we suggest that you start with one of the more simple projects, such as the metronome or audio oscillator. The skill you gain wiring the simple circuits will make the more complicated projects, such as the baby watcher or receiver, much easier for you.

METRONOME

Gather the components shown in the parts list on the pictorial diagram, and carefully study the schematic and pictorial diagrams. Note that the connections to the neon bulb are made by soldering leads to the brass case of the bulb socket and the insulated terminal at the end of the bulb base. Do not let solder from this insulated terminal touch the brass casing, because this would short the bulb and prevent it from working.

When the project has been constructed, install all of the tubes. Note that only the 50C5 and 35Z5 are used, but the other tubes must be in the circuit to complete the filament string and permit the correct current to flow through the filaments of the 35Z5 and 50C5 tubes.

Turn the equipment on and advance the setting of potentiometer R15. When the tubes heat up the neon bulb will start to glow and you will hear signals from the loudspeaker. By adjusting the setting of the potentiometer (R15), you can change the signal from very rapid clicks to clicks which come at widely spaced intervals. The exact time between clicks can easily be changed by adjustment of the potentiometer.

HOW THE METRONOME OPERATES

From the schematic diagram you can see that we have an ordinary audio amplifier feeding a loudspeaker, and that signals are delivered through coupling condenser C3 to the input circuit of the amplifier. You will note that there is a condenser, C4, across the neon bulb, and that the neon bulb connects to the B supply through resistor R14 and the potentiometer. Varying the position of the control varies the B supply voltage fed to the neon bulb. The gas in this bulb has the property of breaking down and conducting current when sufficient voltage is applied to it. When the voltage is not high enough the bulb acts as an open circuit.

Since the condenser (C4) is connected across the neon bulb, the voltage across this condenser is also applied to the bulb. Voltage is applied to the condenser through resistor R14 and the potentiometer. As current flows into the condenser the voltage across it builds up. The speed with which the voltage builds up across the condenser depends upon the value of resistance between the condenser and the voltage source, and on the capacity of the condenser. If the condenser is made larger, more current (and a longer period of time) is required to charge it up. If the resistance is made larger it takes more time for sufficient current to flow into the condenser. If the resistor is made smaller more current flows, and it takes less time to charge up the condenser. Also, if the condenser has a smaller capacity it does not take as long for it to charge.

The voltage across the condenser gradually builds up. When it reaches the striking voltage of the neon bulb, the gas in the bulb will ionize, and the condenser will immediately discharge through the bulb. This causes a variation in voltage to occur across the condenser and this voltage pulse is fed through coupling condenser C3 to the input of the 50C5 amplifier tube. The tube amplifies the pulse, and the pulse is fed to the loudspeaker where it produces a "click." As soon as the neon bulb has discharged the condenser, ionization in the bulb ceases, and the voltage across the condenser builds up again. When the voltage reaches the right value the neon bulb will again discharge the condenser. This charge and discharge cycle will continue to repeat. By varying the position of the volume control, the amount of voltage available to charge the condenser is changed. Consequently, the amount of time required to charge the condenser to the point where the bulb will fire is changed. If the slider of the potentiometer is turned too far towards ground insufficient voltage will be available to fire the neon bulb, and no clicks will be heard from the speaker.

METRONOME
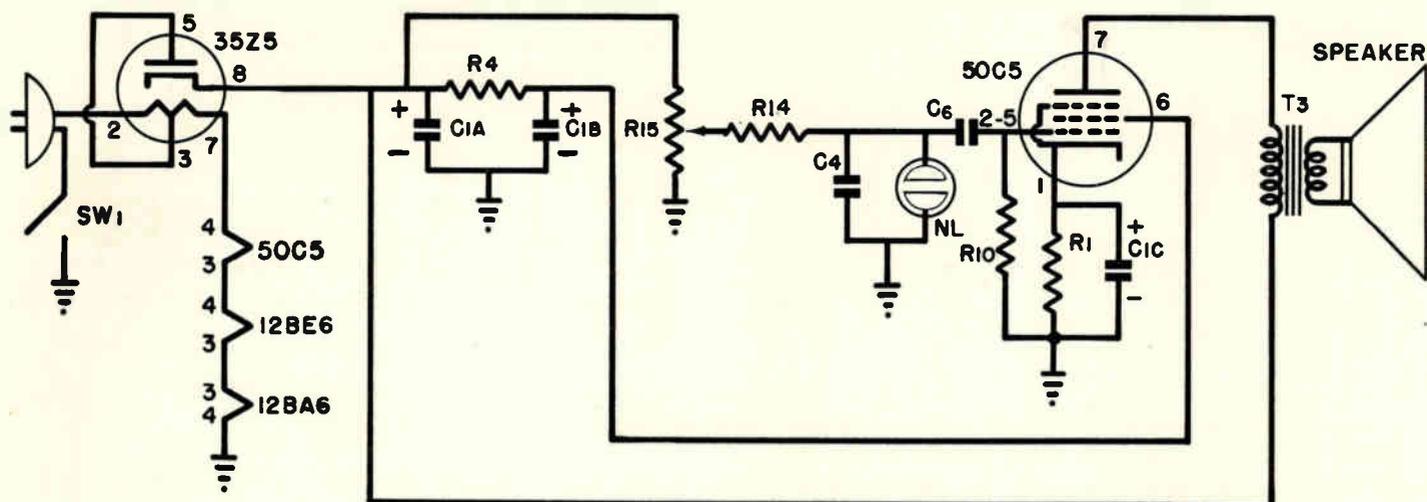
THE AUDIO OSCILLATOR

You will need all of the parts shown in the list under the pictorial diagram. Place these before you on your workbench and carefully check the resistor color coding with that shown in the parts list. Study the schematic and pictorial diagrams carefully, so you will see how the various components are positioned in the circuit. Then, build the audio oscillator, being sure to use a colored pencil to go over the parts and leads shown on the pictorial. Compare your finished work with the pictorial and schematic, and be on the lookout for any excess solder which may have dripped from a tube socket terminal or other soldered connection to the chassis.

Place the tubes in the correct sockets as shown on the pictorial diagram, remembering that this is the bottom view of the chassis. All of the tubes must be installed to complete the filament circuit.

Plug the audio oscillator into the power line, turn on the equipment and wait until the tubes reach operating temperature. When the tubes heat up the neon bulb will glow, and an audio tone will be heard coming from the loudspeaker. By adjusting the slider on potentiometer R15, you will be able to vary the frequency of the audio note.

If too much volume is produced by the loudspeaker you can connect some of your other resistors across voltage divider resistor R10. This will reduce the signal voltage applied to the input of the 50C5.

To get a different range of audio tones try connecting some of your unused paper condensers, one at a time, across condenser C6. Note that the larger values will simply produce a slow clicking noise in the loudspeaker. If you connect another .0005 mfd. condenser in parallel with C6 you will still get an audio signal but at a lower frequency. You can also try connecting condensers in series. Disconnect C6 from the junction of R11, C6, and the neon bulb. To the free end of C6 connect another paper condenser. The free end of this new condenser should then be connected to the junction of R11 and the neon bulb. Since condensers in series have a smaller total capacity, you will note that the audio frequency has now increased. Of course, you should disconnect the audio oscillator from the power line when making any soldered connections. When you wish to place another condenser across C6 you can hold the condenser by its body, letting one lead touch the chassis and the other lead touch the ungrounded lead of C6.

HOW THE CONDUCTIVITY TESTER WORKS

From the diagram you will note that the 12BA6 tube is connected as a triode, terminals 2, 5, and 6 being wired together. Electrons flow from the chassis through potentiometer R15 to the cathode of the tube and across to terminals 2, 5, and 6, which we will simply designate as the plate. They then travel back to the cathode of the rectifier. The cathode of the 12BA6 is at a relatively high potential with respect to the chassis. It acts as a voltage source for the neon bulb. Condenser C2, across the bulb, is charged up by current flow from the cathode of the 12BA6 through resistor R10. When the voltage across the condenser becomes sufficiently high the gas in the neon bulb ionizes and the bulb conducts heavily, immediately discharging condenser C2. The bulb then ceases to be conductive, and condenser C2 charges up again through resistor R10. The rate of charge is governed by the available supply voltage, the value of resistor R10, and value of condenser C2. The cycle will repeat itself as long as the source voltage is sufficiently high. As a result, we have voltage pulses developed across the neon bulb and condenser C2. These are transferred through coupling condenser C4 and the voltage divider, consisting of resistors R12 and R16, to the input of the 50C5 tube. The voltage across resistor R16 is available to drive the grid-cathode circuit of the 50C5. Since these voltage pulses are applied to the input of this tube they are amplified and reproduced by the loudspeaker as clicks, or a buzz.

You will note that, at the start of this discussion, we said the cathode of the 12BA6 was at a high potential with respect to the chassis, because of the large current flow between the cathode and plate of the tube. This current flow, and hence the chassis-to-cathode voltage, may be governed by changing the grid-to-cathode voltage of the tube. By adjusting the slider arm of potentiometer R15 we can change the grid-to-cathode voltage and the current flow through the tube. This, in turn, changes the cathode-to-chassis voltage of the tube which, you will recall, is the supply voltage source for the neon discharge tube. In addition, by connecting a resistor or other conductive medium to terminals X and Y, we can cause a further change in the cathode-to-grid voltage of the 12BA6. For this reason, when a conductive medium such as salt water is between terminals X and Y, the control grid-to-cathode voltage of the tube changes as the voltage between the cathode and chassis changes.

It is apparent from the photoelectric test you conducted that light reaching the bulb will make it discharge at a slightly lower voltage. Therefore, when the bulb is barely discharging the removal of light by shielding the bulb stops its discharge action. When light is again applied, the gas can break down, and the clicks are heard coming from the loudspeaker. Commercial photoelectric tubes are more efficient than the neon bulb, but many of them work on the principle of conductivity through gasses. In commercial equipment the photoelectric tube is generally connected to operate a relay that can turn on an alarm, turn lights on or off, or operate some other type of electrical equipment.

PHONO AMPLIFIER

13
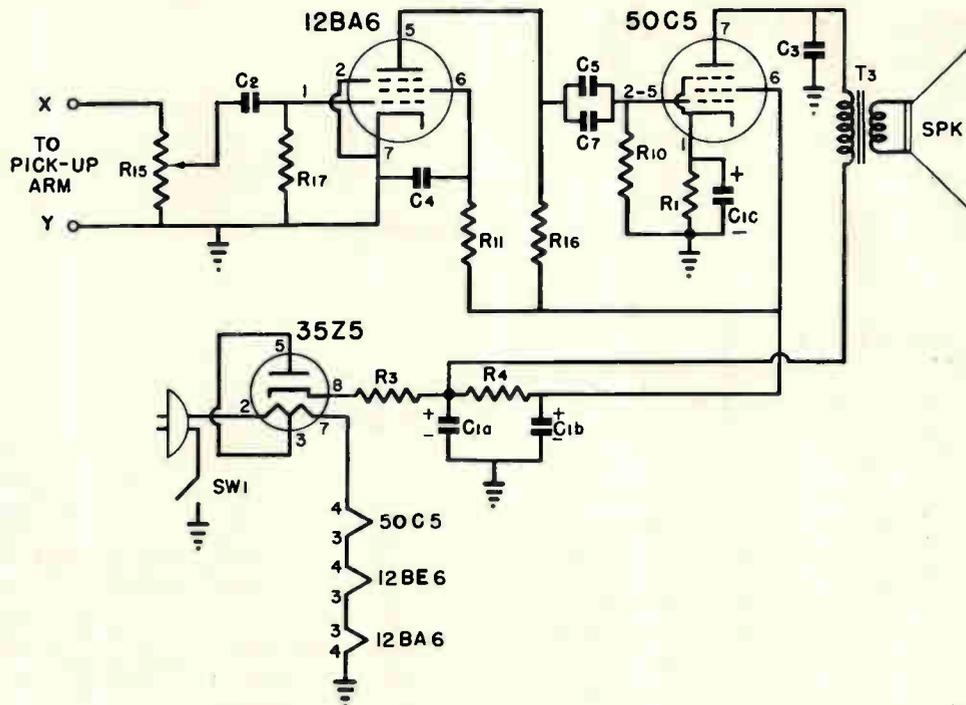
PHONO AMPLIFIER

Assemble the components shown in the parts list. After careful study of the pictorial diagram, you can easily construct the phono amplifier. There is a slight change in the basic wiring. There should be no connection between terminals 8 and 4 of the 35Z5. Terminals 8 and 1 should be connected instead. If the output of a crystal phono pickup is fed into the leads marked X and Y the signals from the phono pickup will be amplified and heard from the loudspeaker. Do not make leads X and Y any longer than necessary to reach your pickup conveniently. The grounded lead of the pickup, which is generally the shield of the cable, should connect to lead Y (the amplifier chassis). The volume control used in the phono amplifier will change the strength of the signals coming from the loudspeaker.

HOW THE PHONO AMPLIFIER WORKS

Electrical signals fed into terminals X and Y produce a signal voltage across the volume control. By varying the position of the control, any amount of the available signal may be fed through coupling condenser C2 so that it appears across the 1 meg grid resistor marked R17. This voltage is applied at the input of the 12BA6 tube, which amplifies the signal. The amplified signal will appear across plate load resistor R16. This signal is applied across the following 1 meg grid resistor, R10, through coupling condensers C5 and C7.

The signal across the grid resistor is applied to the control grid of the 50C5 tube, amplified by this tube, and fed to the primary of the output transformer. The signal current flowing through the primary winding of the output transformer (T3) induces a voltage into the secondary winding which results in movement of the voice coil and attached cone. Sound waves are then produced. Thus we can take mechanical variations which are impressed on the grooves of a recording, change them to electrical variations, amplify them, and then change the electrical variations into sound waves.

THE CODE PRACTICE OSCILLATOR

All of the parts shown in the list below the pictorial diagram will be required. These should be gathered and placed before you on your work space. In this project the 2,200-ohm (R3 and R4) resistors used in the power supply are not employed. Instead wire in the 10,000-ohm resistor (R5) as the filter resistance. Note carefully the connections shown on the pictorial diagram. Pay particular attention to the connections to the oscillator coil. If any of the coil lead connections are reversed the 50C5 will not oscillate.

CODE PRACTICE BROADCAST OSCILLATOR
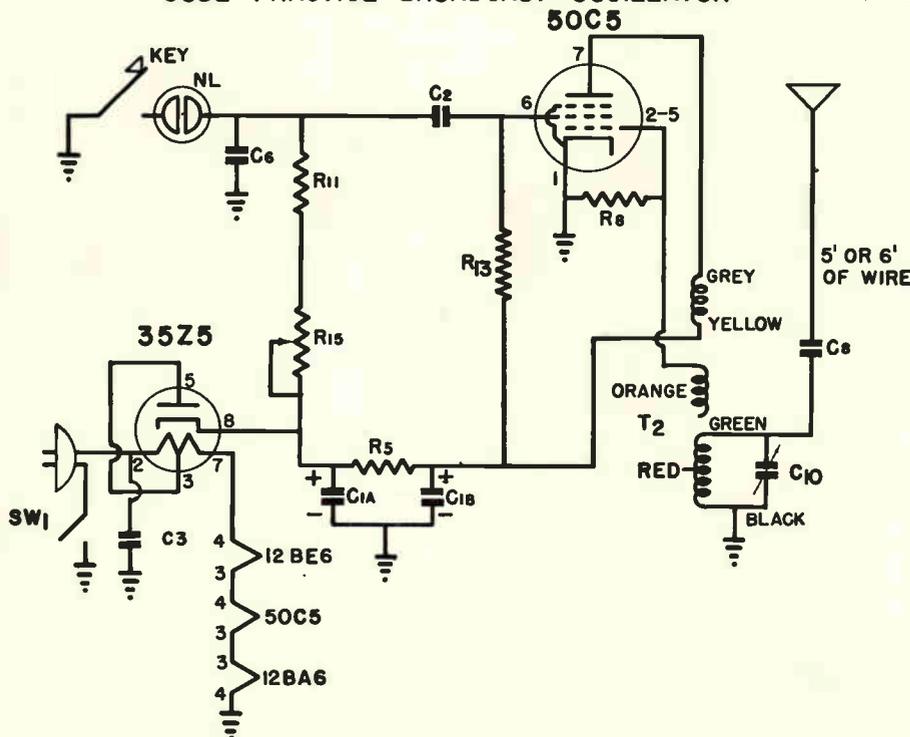
INTERNATIONAL MORSE CODE

FRONT

NL

V1

SW-1 R15

V

X X1

C9

C10 M GREY

X

50C5

C4

12BA6

C2

C1

T3 E RED R

R1

R10 Q

BLACK

GREEN C5 C7

BLUE R4

RED R16

RED G R17

T2 K1

H

Z F T4

Z1 35Z5 I J 12BE6

to pick up arm.

Y X

A

PHONOGRAPH AMPLIFIER

Parts List

R10	1 megohm	Brown	Black	Green
R11	3.3 megohms	Orange	Orange	Green
R16	1 megohm	Brown	Black	Green
R17	1 megohm	Brown	Black	Green
C2	.001 mfd.			
C3	.01 mfd.			
C4	.05 mfd.			
C5	.005 mfd.			
C7	.005 mfd.			

JEEK: PA

SHEET 5

NL

V1

SW-1 R15

V

X X1

12BE6

C9

R11

RED

R1

R

BLACK RED

C10 M K

GREY

12BA6

Q

GREEN

ORANGE

T2

C1

E

Y

T3

C3

R13

C6

K1

YELLOW

BLACK

C GREEN BLUE R5

B RED

A RED

G

H

T4

J

R8

Z

Z1

35Z5

I

C2

50C5

A
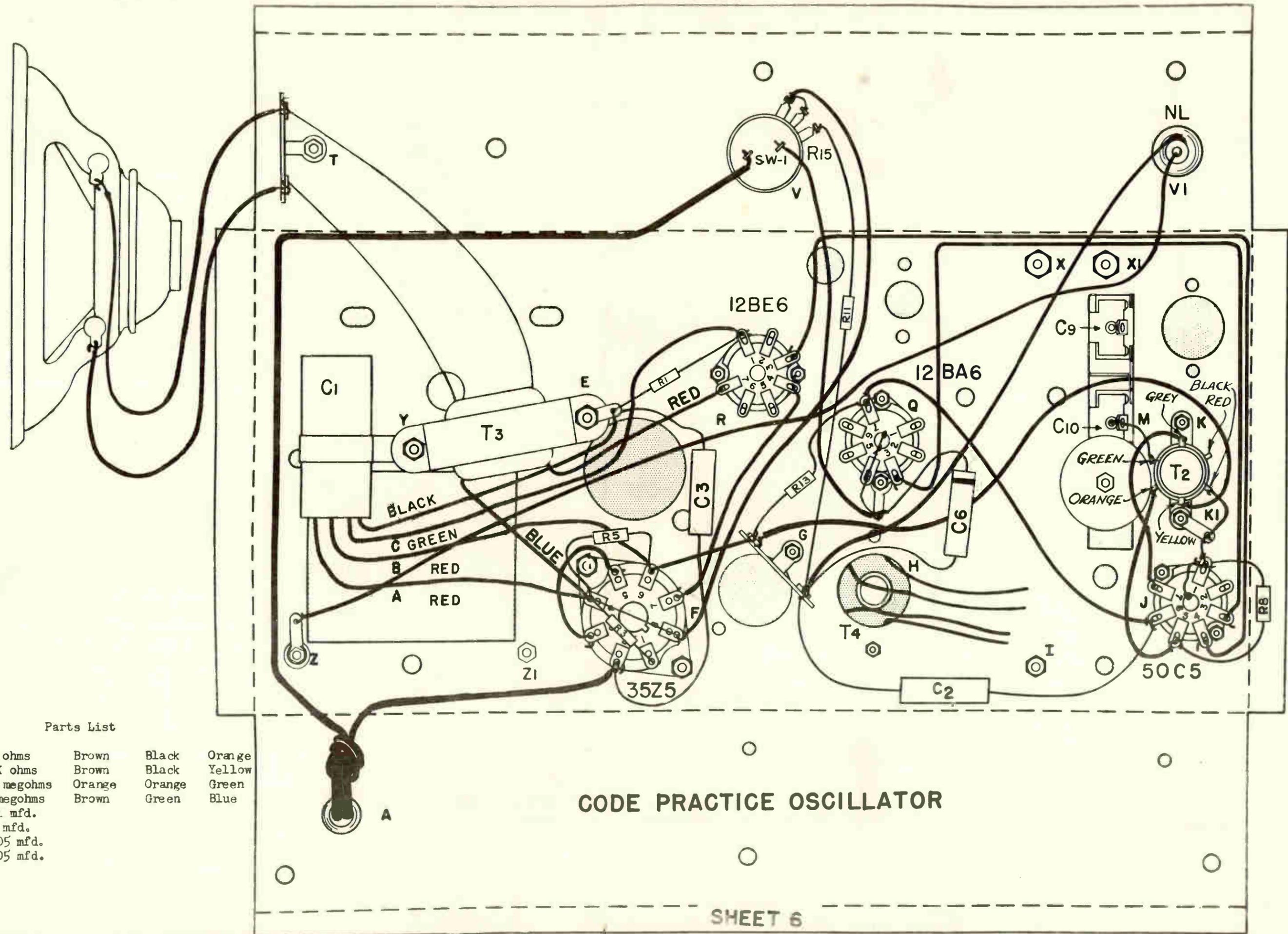
Parts List

R5	10K ohms	Brown	Black	Orange
R8	100K ohms	Brown	Black	Yellow
R11	3.3 megohms	Orange	Orange	Green
R13	15 megohms	Brown	Green	Blue
C2	.001 mfd.			
C3	.01 mfd.			
C6	.0005 mfd.			
C8	.0005 mfd.			

CODE PRACTICE OSCILLATOR

JEEK: PO

FRONT

X Y

NL

V1

R15

SW-1

V

50C5

12BA6

C9

C2

C1

T3

E

R1

RED

R

R16

R12

R10

C10

M

K

GREY

T2

K1

Y

BLACK

GREEN

BLUE

R4

C

B   RED

A   RED

O

G

C4

H

F

T4

I

12BE6

J

Z

Z1

35Z5

A

X   X1

CONDUCTIVITY TESTER

JEEK:CT

SHEET 4

FRONT

NL

SW-1 R15

V

V1

X X1

C9

50C5

C10 M

GREY

12BA6

R1

RED R

Q

R11

K

C1

E

T3

Y

T2

BLACK

GREEN

C

BLUE R4

B RED

A RED

C2

C6

G

H

K1

F

Z

Z1

35Z5

T4

I

12BE6

A
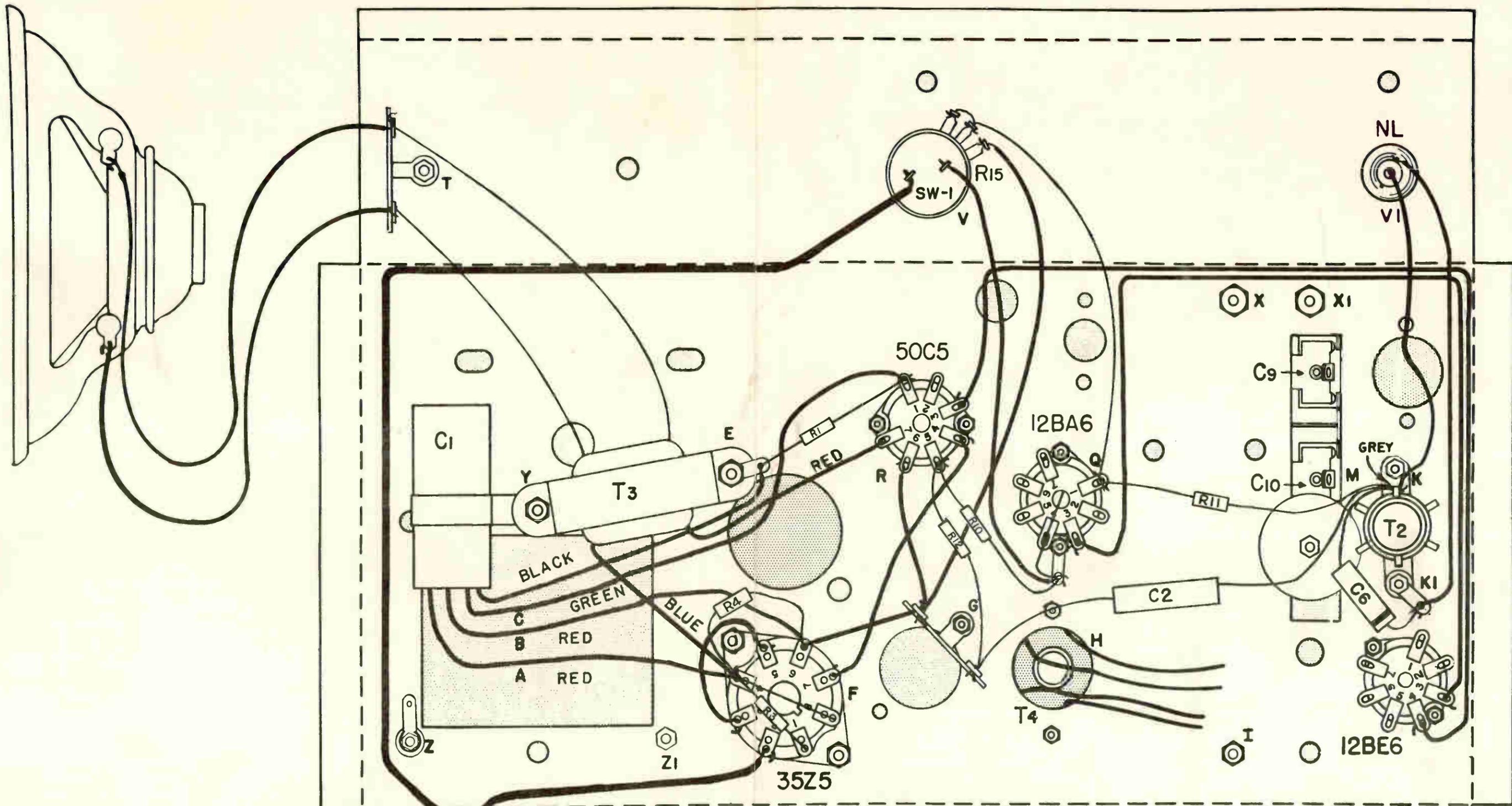
AUDIO OSCILLATOR

Parts List				
R10	1 megohm	Brown	Black	Green
R12	4.7 megohms	Yellow	Violet	Green
R11	3.3 megohms	Orange	Orange	Green
C2	.001 mfd.			
C6	.005 mfd.			
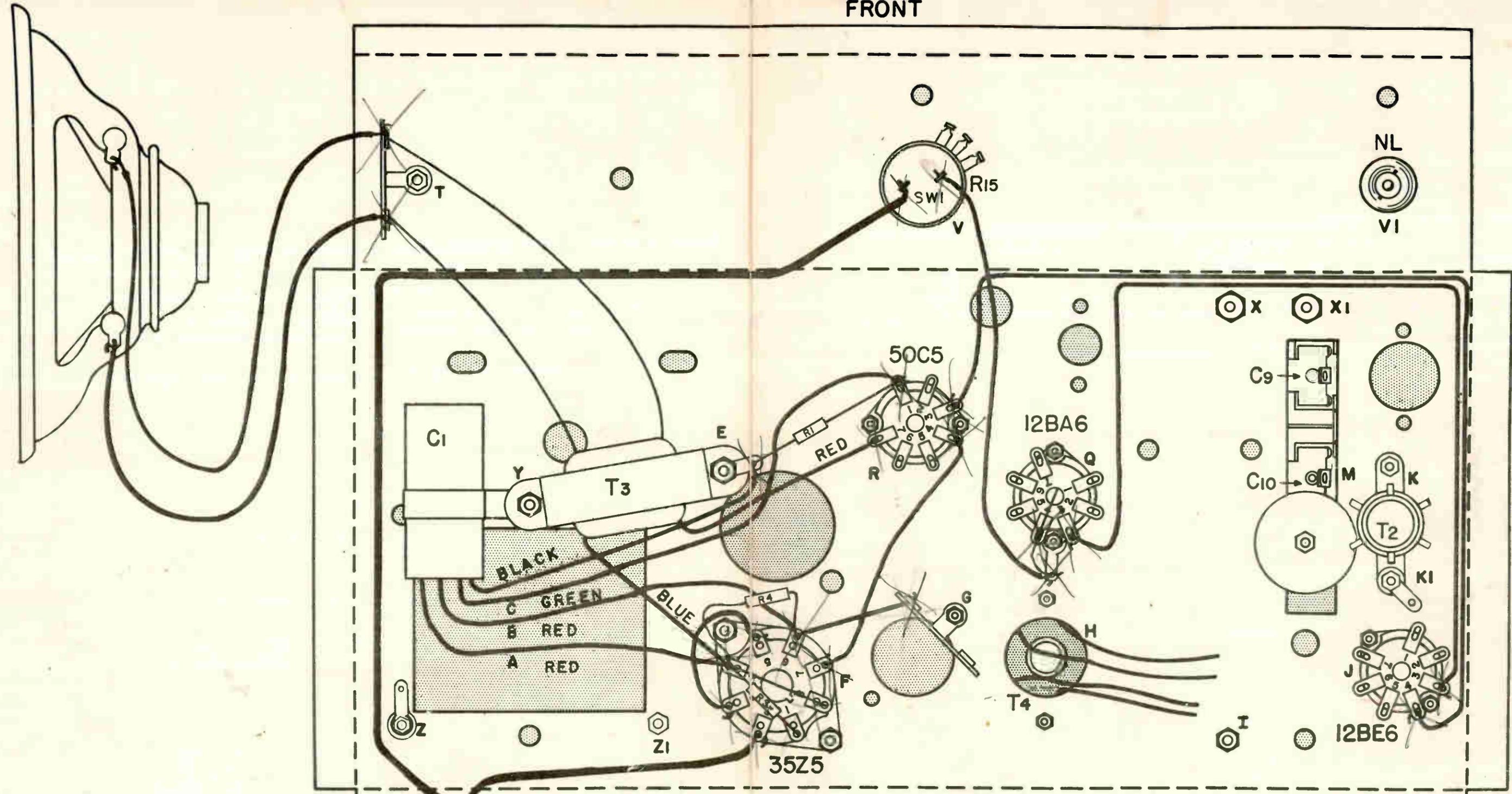
SHEET 3

FRONT

NL

V1

SW1 R15

V

X X1

50C5

12BA6

C9

C10 M K

T2

K1

E

Y

C1

T3

R1 RED

R

Q

BLACK

GREEN

BLUE R4

G

J

C GREEN

B RED

A RED

H

12BE6

Z

Z1

F

T4

I

35Z5

A

Z1

Z

TOP OF CHASSIS

JEEK: PS

BASIC WIRING — POWER SUPPLY

SHEET 1

FRONT

NL

V1

SW-1
R15
V

X   X1

C9

C10   M   K

50C5
R1
RED
R
12BA6
Q
C6
T2
K1

C1
Y
T3
E
R10

BLACK
C GREEN
B RED
A RED

BLUE
R4
G

H
C4

T4
J
12BE6

Z
Z1

35Z5
I

A
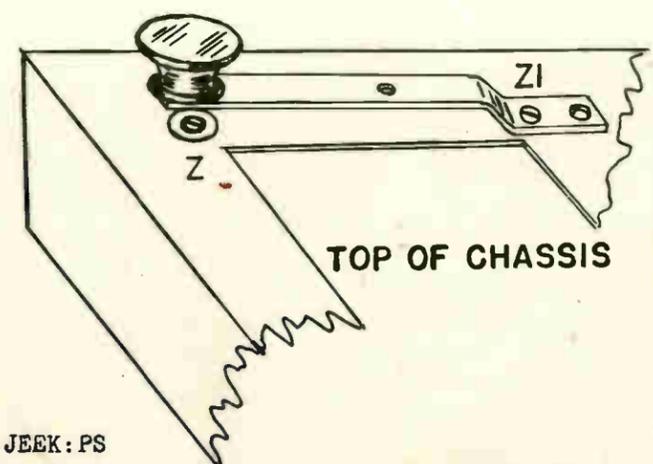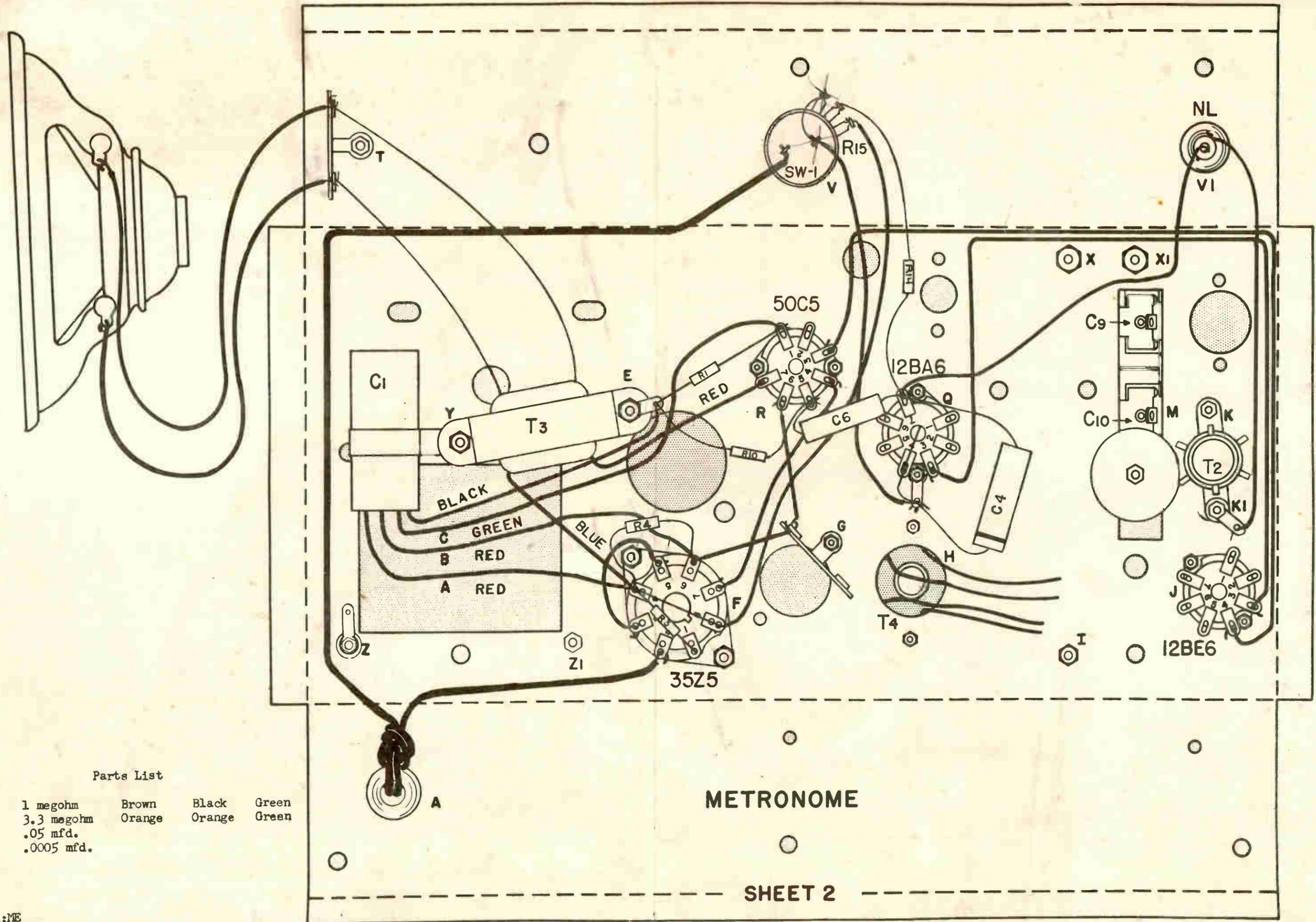
METRONOME

Parts List

R10	1 megohm	Brown	Black	Green
R14	3.3 megohm	Orange	Black	Green
C4	.05 mfd.	Orange	Orange	Green
C6	.0005 mfd.			

SHEET 2

JEEK:ME

RECEIVER
VOLUME CONTROL

NL
V1

X X1

C9

GREY

C10

ORANGE

T2

K

M

K1

C5

C7

R17

50C5

C3 12BA6 Q

C8

C6

R1 RED

R

R19

R5 R11

R16

C4

G

H

R8

12BE6

I

C2

R4

35Z5

F

T4

Z1

C1

Y

T3

M

E

BLACK

BLUE

C GREEN

B RED

A RED

Z

A

T

SW-1 R15

V

BABY WATCHER

Parts List

R5	10K ohms	Brown	Black	Orange
R8	47K ohms	Yellow	Violet	Orange
R9	100K ohms	Brown	Black	Yellow
R16	1 megohm	Brown	Black	Green
R11	3.3 megohms	Orange	Orange	Green
R16	1 megohm	Brown	Black	Green
R17	1 megohm	Brown	Black	Green
C2	.001 mfd.			
C3	.01 mfd.			
C4	.05 mfd.			
C5	.005 mfd.			
C6	.0005 mfd.			
C7	.005 mfd.			
C8	.0005 mfd.			

JEEK:BW

FRONT

NL

V1

SW-1

R15

V

X   X1

50C5

C9

C5

C4

C10   M

RED

R12

12BA6

Q1

C2   T2

C1

E

R1

RED

R

GRD

Y

T3

R10

R16

K

HOT

BLACK

R11

C7

C6

GREEN

BLUE   R4

G

K1

RED

R8   H

R17

RED

Z

F

T4

A

Z1

I   J

35Z5

12BE6

SIGNAL TRACER

FRONT

NL

V1

12BE6

12BA6

SW-1

R15

C7

C9

C10

GREY

C1

T3

E

R10

R

C5

C4

M

K

GREEN

BLACK

BLUE

RED

R9

R11

R16

T2

BLACK

GREEN

RED

R5

G

C2

ORANGE

C

GREEN

YELLOW

K1

B

RED

H

A

RED

R13

T4

R8

Z

Z1

J

I

35Z5

C3

50C5

Parts List

R5	10K ohms	Brown	Black	Orange
R8	47K ohms	Yellow	Violet	Orange
R9	100K ohms	Brown	Black	Yellow
R10	1 megohm	Brown	Black	Green
R11	3.3 megohms	Orange	Orange	Green
R13	15 megohms	Brown	Green	Blue
R16	1 megohm	Brown	Black	Green
C2	.001 mfd.			
C3	.01 mfd.			
C4	.05 mfd.			
C5	.005 mfd.			
C6	.0005 mfd.			
C7	.005 mfd.			

BROADCAST STATION

SHEET 8

JEEK:BS

FRONT
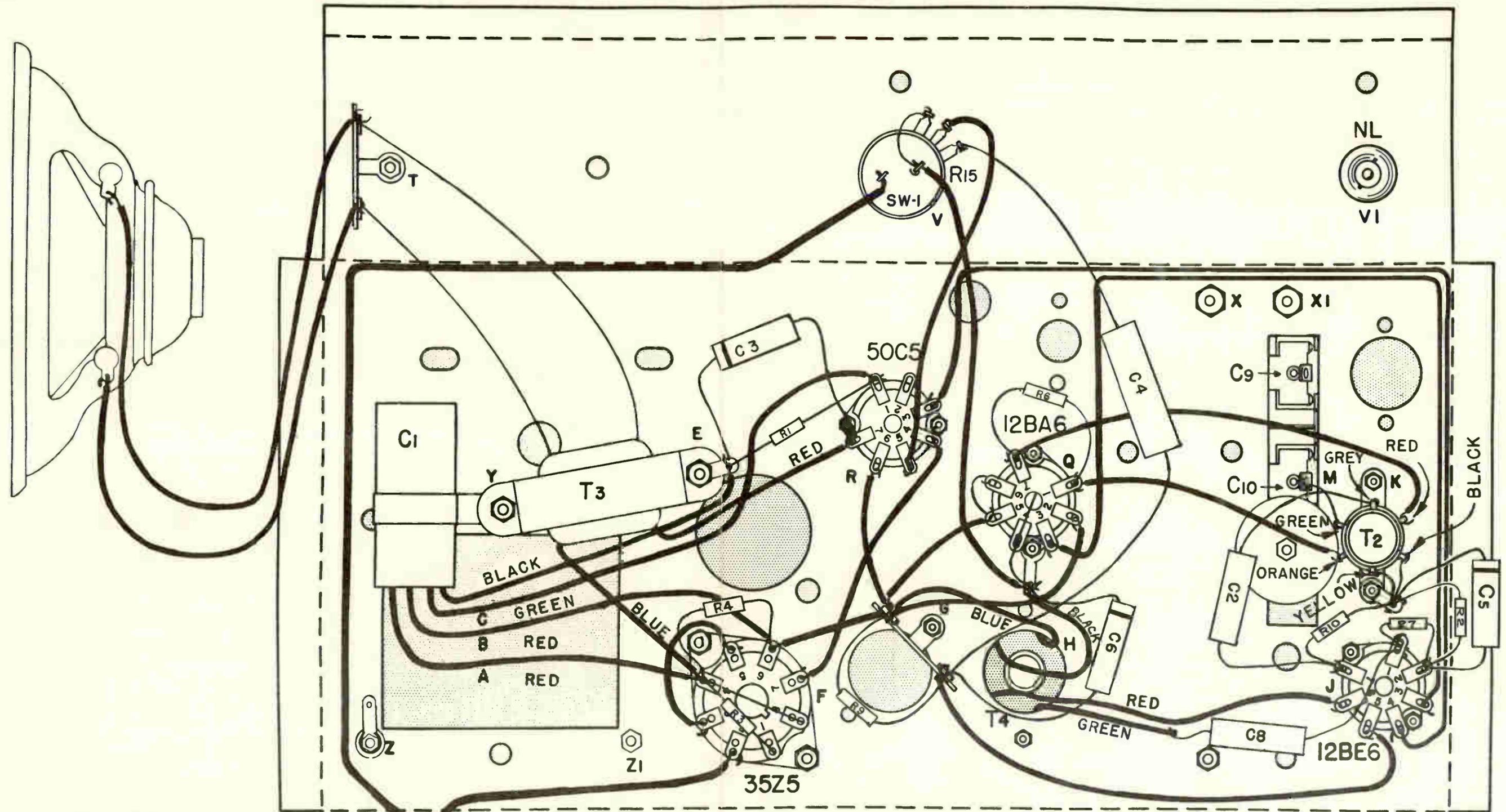
Parts List

R2	470 ohms	Yellow	Violet	Brown
R6	22K ohms	Red	Red	Orange
R7	33K ohms	Orange	Orange	Orange
R9	100K ohms	Brown	Black	Yellow
R10	1 megohm	Brown	Black	Green
C2	.001 mfd.			
C3	.01 mfd.			
C4	.05 mfd.			
C5	.005 mfd.			
C6	.0005 mfd.			
C8	.0005 mfd.			

THEREMIN

SHEET 7

JEEK:TH

FRONT

NL

V1

50C5

12BA6

C7

X   X1

C9

C10   M

GREEN

ORANGE

K   RED

T2

K1

BLACK

C1

T3

E

R1

RED

R

R14

R10

Q

C4

G   C6

R11

H

GREEN

BLACK

RED

BLUE

J

R6

BLACK

A RED

B RED

C GREEN

BLACK

BLUE

R4

F

Z

Z1

35Z5

RED

T4

C5

I

12BE6

A

RECEIVER

TOP OF CHASSIS   BLACK   GREEN

RED

C8   I

BLUE ANTENNA
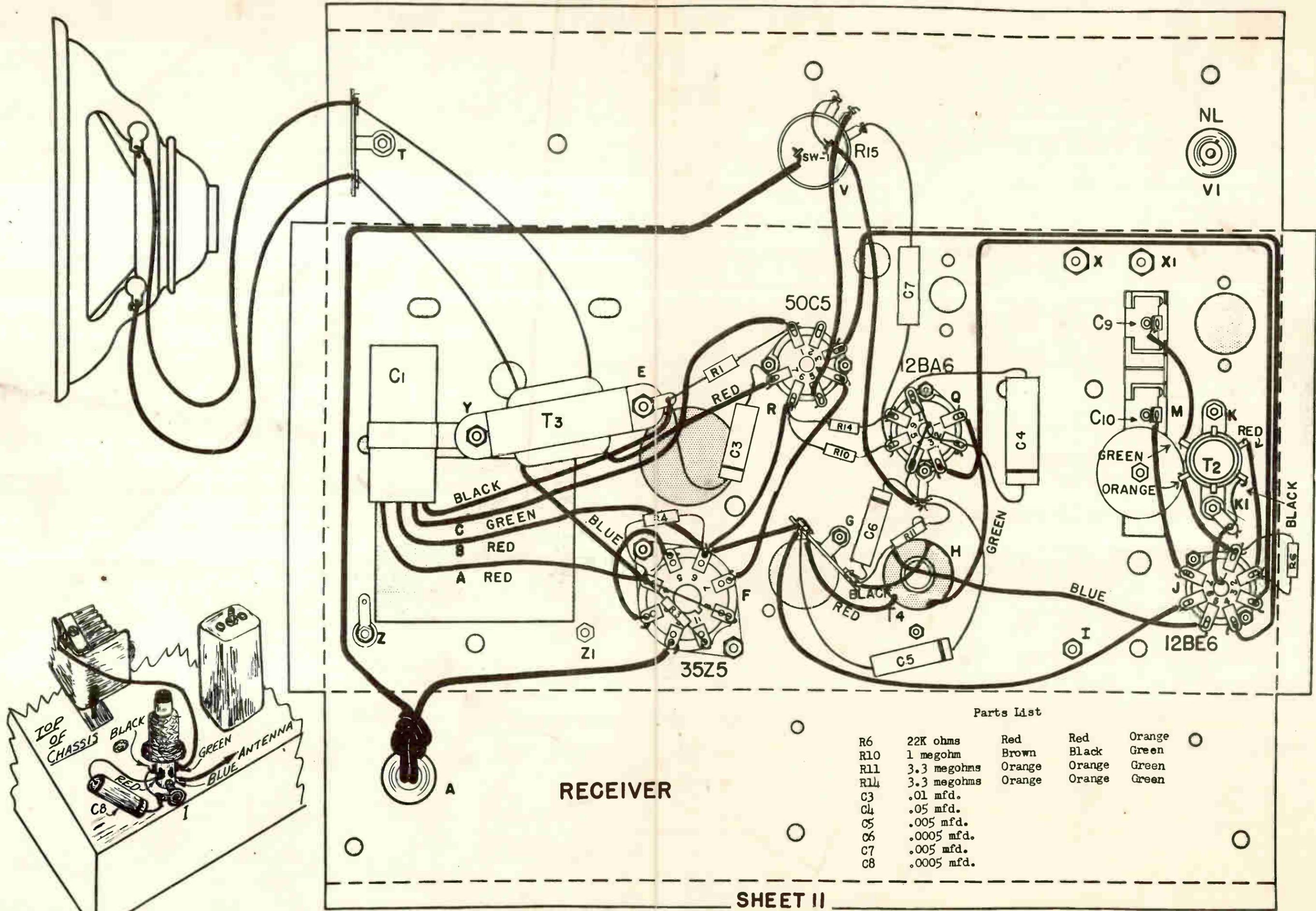
Parts List

R6	22K ohms	Red	Red	Orange
R10	1 megohm	Brown	Black	Green
R11	3.3 megohms	Orange	Orange	Green
R14	3.3 megohms	Orange	Orange	Green
C3	.01 mfd.			
C4	.05 mfd.			
C5	.005 mfd.			
C6	.0005 mfd.			
C7	.005 mfd.			
C8	.0005 mfd.			

SHEET II

Left Panel
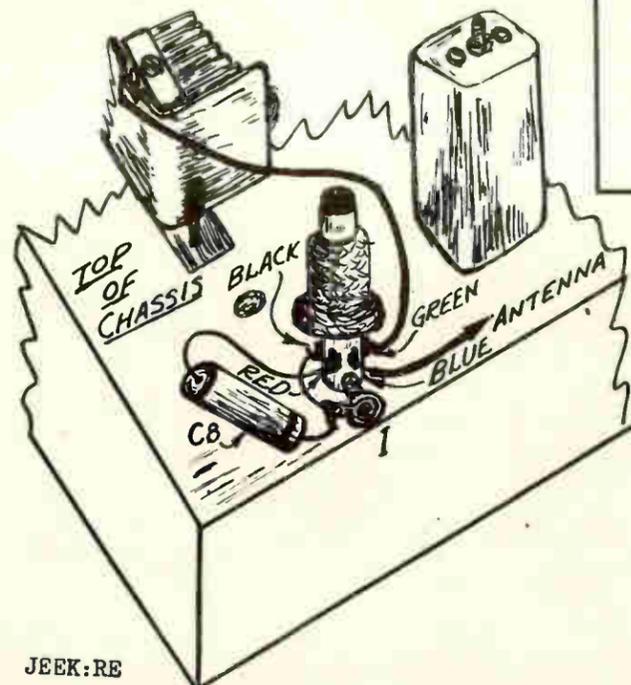
ILLUSTRATIVE DRAWING	PART	SCHEMATIC SYMBOL
	BEAM POWER PENTODE 50C5 — PIN 3&4 HEATER, PIN 1 CATHODE AND SUPPRESSOR GRID, PIN 2 or 5 CONTROL GRID, PIN 6 SCREEN GRID, PIN 7 PLATE	
	12BE6 PENTAGRID CONVERTER — PINS 3&4 HEATER, PIN 2 CATHODE AND SUPPRESSOR GRID, PIN 7 CONTROL GRID, PIN 5 PLATE, PIN 1 OSC. CONT. GRID, PIN 6 SCREEN	
	12BA6 REMOTE CUT OFF PENTODE — PIN 3&4 HEATER, PIN 2 SUPPRESSOR GRID, PIN 6 SCREEN GRID, PIN 1 CONTROL GRID, PIN 7 CATHODE, PIN 5 PLATE	
	35Z5 RECTIFIER — PINS 2&7 HEATER, PIN 3 HEATER TAP, PIN 5 PLATE, PIN 8 CATHODE	
	TUNING CONDENSER GANG — TWO GANG CONDENSER WITH SPECIALLY SHAPED OSCILLATOR SECTION TO PRODUCE 456 KILOCYCLE INTERMEDIATE FREQUENCY. TRIMMERS ON EACH SECTION OF GANG. C9 C10 TRIMMERS	
	KEY	
	NEON LAMP NL	
	LINE CORD & PLUG	
	CROCODILE CLIP (2)	
	CHASSIS, TOP VIEW	

Middle Panel

ILLUSTRATIVE DRAWING	PART
	18 FT. OF TINNED PUSH BACK HOOK UP WIRE
	10 FT. OF ROSIN CORE SOLDER
	18" PIECE OF COPPER WIRE LOOP FOR THEREMIN
	CONTROL KNOB (2)
	PAPER DIAL FOR RECEIVER — FOLD BACK
	7 PIN MINIATURE TUBE SOCKET (3)
	8 PIN OCTAL TUBE SOCKET
	TERMINAL STRIP (2)
	WASHER FOR MOUNTING VARIABLE TUNING CONDENSER
	RUBBER GROMMET
	6/32 SCREW
	4/40 SCREW (16)
	6/32 NUT (6)
	4/40 NUT (16)
	FIBER WASHER
	FIBER BUSHING
	SOLDER LUGS (5)

Right Panel

ILLUSTRATIVE DRAWING	PART	VALUE	COLOR CODE	SCHEMATIC SYMBOL
	C1 ELECT. COND. 3 SECTIONS — C1A	20 mfd at 150V	A RED	
A RED, B RED, C GREEN, BLACK	C1B	20 mfd at 150V	B RED	
	C1C	10 mfd at 25V	C GREEN	
		COMMON	BLACK	
	CONDENSERS — C2	.001	GROUND PRINTED OR BAND MEANS OUTSIDE FOIL CONNECTION	
	C3	.01		
	C4	.05		
	C5 & C7	.005		
	C6 & C8	.0005		
	RESISTORS		A B C	
	R1	150 ω ½ WATT	BROWN GREEN BROWN	
	R2	470 ω	YELLOW VIOLET BROWN	
	R3	2.2 kω	RED RED RED	
	R4	2.2 kω	RED RED RED	
ABC	R5	10 kω	BROWN BLACK ORANGE	ω = OHMS
	R6	22 kω	RED RED ORANGE	K = 1000
	R7	33 kω	ORANGE ORANGE ORANGE	meg = 1,000,000
	R8	47 kω	YELLOW VIOLET ORANGE	
	R9	100 kω	BROWN BLACK YELLOW	
	R10, R16, R17	1 meg ω	BROWN BLACK GREEN	
	R11, R14	33 meg ω	ORANGE ORANGE GREEN	
	R12	4.7 meg ω	YELLOW VIOLET GREEN	
	R13	15 meg ω	BROWN GREEN BLUE	
	POTENTIOMETER & SWITCH — R15, SW	1 meg		POTENTIOMETER / SWITCH
	ANTENNA TRANSFORMER T1		CONNECTION LUGS — RED, GREEN, BLUE, BLACK	BLUE GREEN, PRI. SEC., RED BLACK
	OSCILLATOR TRANSFORMER T2		CONNECTION LUGS — BLACK, GREEN, RED, ORANGE, GREY, YELLOW	GREY, YELLOW — ORANGE, GREEN, RED, BLACK
	OUTPUT TRANSFORMER T3 — RED, BLUE		BLUE PLATE, RED B+, TWO ENAMEL-COVERED SECONDARY	BLUE ENAMEL, PRI. SEC., RED ENAMEL
	INTERMEDIATE FREQUENCY TRANSFORMER — PRETUNED TO 456 KILOCYCLES T4		CONNECTION WIRES — RED, GREEN, BLACK, BLUE	BLUE GREEN, PRI. SEC., RED BLACK
	SPEAKER — 3-4 OHM VOICE COIL SP		CONNECTION LUGS NO COLORS	SPK.

AUDIO OSCILLATOR

HOW THE AUDIO OSCILLATOR WORKS

You will note that the power supply delivers a voltage to the neon bulb through R15 and R11. Condenser C6 is connected across the bulb, and gradually charges. The voltage across it increases until it reaches the point where the gas in the neon tube ionizes.

The tube then conducts heavily, draining the current stored in condenser C6. When the voltage across C6 falls to a very low value the bulb stops conducting until C6 is again charged up by current flow through R15 and R11. The length of time it takes to charge up the condenser depends upon the capacity of C6 and the value of the resistance consisting of R15 and R11 in series. By varying any of these components the amount of time it takes to charge the condenser can be changed. In this particular case, we vary the charging time by changing the value of the series resistance. This is done when the

setting of R15 is changed. As mentioned above, you can also obtain a variation in the charging time by varying the capacity of C6 by adding other condensers in parallel or in series. A parallel connection will increase the capacity and increase the charging time, while a series connection will reduce the capacity and the time it takes to charge the condenser. Since there is a variation in some neon bulbs, a different voltage may be required to cause them to ionize and discharge. If your bulb does not glow change the connection from the terminal strip to terminal 6 of the 35Z5 socket so that it goes to terminal 8. This will apply more voltage through the resistors to the bulb and parallel condenser. Of course, if the voltage is too high the bulb will not be able to discharge the condenser fast enough. No sound will be heard from the speaker, and the bulb will remain constantly lit. In such a case, you need more capacity across the condenser or a larger value of series resistor.

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THE CONDUCTIVITY TESTER

Assemble on your working space the parts listed with the pictorial diagram for this project. Be sure to check the color codes of the resistors against those given in the parts list. Study the pictorial diagram so you will know how the parts are to be placed in the circuit.

Build the project carefully. Make the test leads X and Y about 12" long. Compare the finished work with the pictorial diagram, and install the tubes in their proper sockets. Insert the power line plug in a wall socket and turn on the equipment. When the tubes have heated, adjust the setting of potentiometer R15 until the neon bulb starts firing, and a clicking or buzz is heard from the loudspeaker. Turn off the equipment. Next, push back about an inch of insulation from leads X and Y. Insert the bare ends of these wires in a glass or porcelain container. An ash-tray, cup, or water tumbler, will be entirely satisfactory. Turn the equipment back on, and adjust the setting of potentiometer R15 until the point is just reached where no signals are heard from the speaker.

Next fill the container with tap water so that the bare ends of leads X and Y are in the water. You should notice that a clicking noise is again heard from the speaker, showing that the water has some impurities and is conductive. Next, readjust potentiometer R15 until the clicking just ceases. Now sprinkle a little table salt in the water. Clicking should again be heard, showing that the salt has increased the conductivity of the water. Turn the potentiometer setting back again until the clicking ceases. With a stick or a pencil stir up the solution so that more salt is dissolved in it. The clicking should again be heard. You can continue readjusting the potentiometer and adding salt until the solution has taken up as much salt as it can. We say that the solution is then saturated.

To exhibit photoelectric effects adjust the volume control until the clicking is still present, but is at a minimum. A little practice is necessary to get best results. Find a small cardboard carton and tear the flaps off of one end. It should be large enough to cover the neon bulb. While the bulb is flashing very slowly, shield it from all light by putting the open end of the carton over the bulb. If the volume control was properly adjusted this will stop the clicking sound from the speaker. On removing the carton, so that light again strikes the bulb, the clicking sound will start up. This shows that the bulb is definitely affected by light. Either sunlight or strong artificial light will do.

Wire the circuit carefully as it is shown in the pictorial diagram. On top of the chassis, connect one lead of coupling condenser C8 to the solder lug on top of the rf (rear) section of the tuning condenser gang. To the other lead of C8, connect 5 or 6 feet of hook-up wire. This wire acts as the antenna. It should *not* be grounded but should be allowed to lie on your workbench top.

Compare your finished work with the schematic and pictorial diagrams. MAKE CERTAIN THAT THE TUBES ARE PLACED IN THEIR PROPER SOCKETS, checking the tube positions as shown from the bottom view of the chassis on the pictorial.

Insert the power plug in the line and turn on the switch.

Turn on your house receiver, which should be fairly near the oscillator, and tune it to a point near the high frequency end of its dial where no signal is received from a broadcast station. Next, depress the code key on the practice oscillator. This will cause the neon bulb to glow. While holding the code key closed, rotate the tuning condenser gang of the code practice oscillator until you hear a squeal in the receiver loudspeaker. You can then send dots and dashes with the key by following the code which appears with the pictorial and schematic diagram. A dash should be three times as long as a dot and should sound like "dah" while a dot should sound like "dit."

HOW THE CODE PRACTICE OSCILLATOR WORKS

The 50C5 is used as an oscillator in the broadcast band. Rf signals are radiated from the antenna and are picked up by your receiver which is tuned to the same frequency as the 50C5 oscillator. Any audio signals applied to the screen of the 50C5 will modulate the rf signals so that the rf signal carries these audio tones.

A neon type relaxation oscillator is used to produce the code tones. Condenser C6, across the neon bulb, is charged up through resistors R11 and R15 until the ionization voltage of the bulb is reached. At that point the gas in the bulb breaks down and conducts heavily, discharging condenser C6. This, of course, only occurs when the code key is closed. The resulting voltage pulse across condenser C6 is applied across the screen-supply resistor (R13) of the 50C5 through coupling condenser C2. The variations in voltage across this resistor serve to modulate the 50C5 oscillator.

The oscillator itself is of the plate feedback type. Variations in current flowing through the yellow-gray coded coil induce a voltage into the tank coil. The frequency to which the tank is tuned is governed by the coil inductance and the value of variable condenser C10. The voltage across the tank is transferred through the orange-coded pickup coil to the grid of the tube with further resulting changes in plate current. Thus, the voltage across the oscillator tank circuit is constantly reinforced and oscillation continues. By varying the setting of potentiometer R15, the frequency at which the neon bulb charges and discharges may be changed to produce the most pleasing code note. The spacing and length of the dots and dashes, however, is dependent wholly upon the length of time the code key is held down.

THE "THEREMIN"

You will need all of the components shown in the parts list on the pictorial diagram. When they are assembled, carefully study the schematic and pictorial diagrams. Wire the instrument exactly as shown in the pictorial. The only wiring above the chassis (this should be done only AFTER all under chassis wiring is completed) consists of the 18-inch piece of solid copper wire. Bend this in the form of an oval, bringing the two ends together. Insert one of these ends through the solder lug connection on the antenna (rear) section of the tuning condenser gang. Solder this connection, and solder the other end of the wire to it. You will now have a loop sticking up in the air.

Insert the tubes in the sockets as shown on the pictorial, plug the equipment into the power line and turn it on. When the equipment has heated up, rotate the tuning condenser until you hear a loud squeal. Adjust the condenser until the squeal is low in frequency and barely noticeable. Then bring your hand close to the loop and notice the change in pitch. Next, tune the equipment to the high frequency end of the squeal and again bring your hand near the loop noting a change in frequency. Since the frequency can be changed, it is possible, if you have

musical talent, to learn how to play rough tunes on the equipment. Of course, this is a very simple instrument and does not have the refinements found in professional instruments, but it illustrates the possibilities of electronic musical instruments. The Theremin is a specially designed, complicated, piece of equipment which is used in many orchestras.

You can carefully adjust the tuning condenser on the "Theremin" to the low frequency end of the squeal so that any approach towards the instrument, even to a distance of two or three feet, will cause a squeal to be heard, but if you are farther from the instrument the speaker will be silent. This shows how you can make an intrusion detector. Remove the loop, and connect C3 from the tuning condenser terminal to the green terminal of the antenna transformer. Connect a long wire to this terminal, and string it around the room. You can now adjust the tuning condenser so the "Theremin" will squeal when anyone approaches the wire.

Try placing the "Theremin" under or behind a chair. In place of the original loop put a long wire in the seat of the chair. When someone starts to sit in the chair, the Theremin will emit a loud squeal!
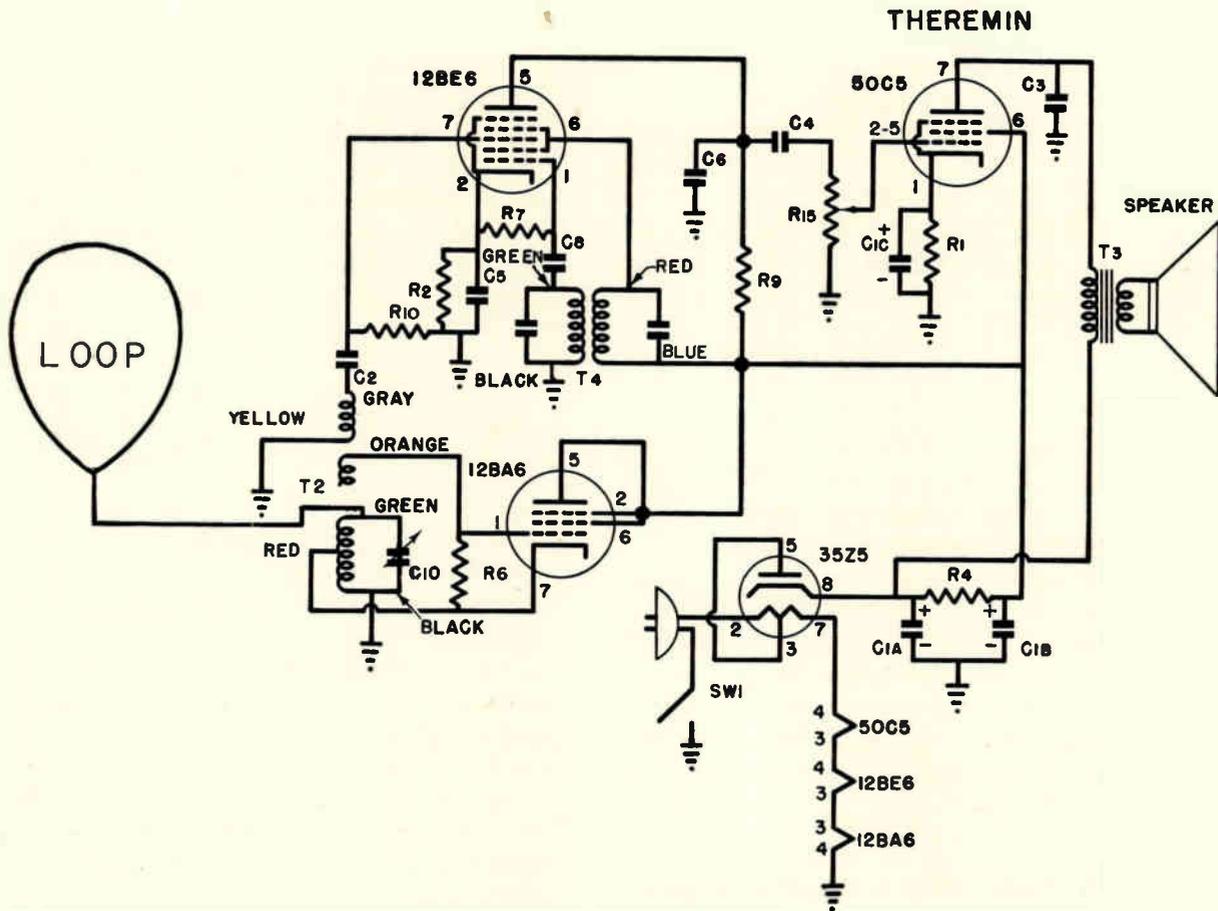
HOW THE THEREMIN WORKS

The Theremin consists of two oscillators, which operate at almost the same frequency, and an audio amplifier. Their signals are fed into the mixer section of the 12BE6 tube, and the sum and difference frequencies as well as the two original frequencies appear in the plate circuit. However, the plate by-pass condenser (C6) eliminates all but the lower frequencies from the load. These appear across the load and are fed through the coupling condenser and output filter condenser to the volume control. At this point they are impressed on the output tube which feeds the loudspeaker.

The 12BA6 is used as the control oscillator while the oscillator section of the 12BE6 is employed as the fixed oscillator. The i-f transformer is used as an oscillator transformer for the 12BE6. This oscillator is of the plate feedback type. The current flowing from the screen (terminal 6) of the 12BE6 induces a voltage into the other coil winding which is in the grid circuit of the tube. In this manner oscillation is set up.

In the 12BA6 tube we are using the same type of oscillator as is employed in the superheterodyne receiver. This type is known as a Hartley oscillator. The frequency of this oscillator may be varied over wide limits by the adjustment of tuning condenser C10. Small variations are produced by "hand capacity" effects when your hand is brought near the loop. The energy picked off the oscillator coil by the winding connected to the gray and yellow terminals is fed through coupling condenser C2 to the control grid of the 12BE6. The two signals are then mixed together in the tube, as previously described. The volume from the Theremin is varied by means of the volume control, which determines the amount of signal reaching the input of the audio amplifier (50C5) tube.

THE BROADCAST STATION

All of the parts shown in the list below the schematic will be required. Place these on your workbench. Double check on the values of the resistors, comparing their colors to the code shown in the parts list. After studying carefully the schematic and pictorial diagrams, build this project as it is shown in the pictorial diagram.

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BROADCAST STATION OR PHONO OSCILLATOR

Be sure to make the following changes in the basic wiring: remove the connection between terminals 8 and 4 of the 35Z5 and connect terminals 8 and 1, disconnect the red lead of T3 from terminal 7 of the 12BE6 and connect it to C5, disconnect the blue lead of T3 from terminal 4 of the 35Z5 and connect it to the ground lug at hole E, take R1 out and connect R10 in its place, and replace R4 with R5. On top of the chassis connect one lead of a .0005 mfd. condenser (C6) to the terminal on top of the rear section of the tuning condenser. To the other lead of this condenser connect 5 or 6 feet of hook-up wire. This wire will be your transmitter antenna. Carefully dress all leads.

Be sure that the bare wire lead which connects C3 to to terminal 2 of the 35Z5 does not touch the chassis or any other ground. If this lead is shorted you may blow a house fuse. The connection between C5 and the red lead of T3 must also be carefully dressed to prevent shorts. Compare your finished work with the pictorial and schematic diagrams. BE SURE THAT ALL TUBES ARE IN THE PROPER SOCKETS.

The power plug may now be placed in the wall outlet and the equipment turned on. A nearby receiver should also be turned on and tuned to a point near the high frequency

end of its dial where no station is received. Turn on the broadcast station, and after the tubes have heated up, slowly tune it over the range of its variable condenser while lightly drumming on the speaker cone with your fingertips. When the broadcast station is tuned to the same frequency as your receiver, the tapping noise caused by your fingertips hitting the speaker will be heard from the receiver loudspeaker.

Feedback will occur if you turn the volume up too high on either the broadcast station or the receiver. If howling occurs even with the volume turned down you can move the broadcast station or the receiver to another room. The equipment should operate over a distance of 15 or 20 feet with ease.

When both the receiver and broadcast station are tuned to the same frequency you can talk or sing into the broadcast station loudspeaker which, in this case, acts as a microphone. Your voice will be heard coming from the receiver loudspeaker. If distortion occurs turn down the volume control on the broadcast station or move further away from the loudspeaker.

The Broadcast Station may be used as a wireless baby watcher. Place the Broadcast Station near the crib. If the baby cries, the sound will be picked up and trans-

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mitted to your receiver. This may work from your house to your neighbor's.

A phono pickup can be used to modulate the broadcast station instead of the loudspeaker type microphone. To connect a phono pickup remove the output transformer lead from coupling condenser C5. Then connect the hot lead of the phono pickup to coupling condenser C5 and the shielded lead to the broadcast station chassis. When records are played they will then be reproduced by your receiver loudspeaker.

HOW THE BROADCAST STATION WORKS

The 50C5 tube is used as a modulated oscillator just as in the code practice oscillator project. In this case we modulate the screen grid of the 50C5 with voice or music rather than with a constant tone from the neon discharge lamp.

When you speak into the loudspeaker the cone and its attached voice coil move back and forth. This causes a voltage to be induced into the other winding of the output transformer, and this voltage is applied through coupling condenser C5 to terminals 1 and 2, the control grid and cathode, of the 12BE6 tube. Because the screen and plate of this tube are tied together it operates as a triode. The tube amplifies the applied signal which appears across the plate load resistor (R9). The amplified audio signal across plate load resistor R9 is applied through coupling condenser C7 and output filter condenser C1B to the volume control.

By varying the position of the slider of the volume control, any amount of the available signal voltage may be fed to the control grid and cathode (terminals 1 and 7) of the 12BA6 tube. This tube is wired as a high gain pentode amplifier and a much larger signal appears across its plate load resistor, R16. This signal is applied through coupling condenser C2 and output filter condenser C1B to the 15-megohm screen supply resistor (R13) of the 50C5 tube. While this tube oscillates the variations in screen supply voltage change the strength of the oscillation in time with the voice or music, produc-

ing what we call *amplitude* modulation. It is these variations in oscillator strength that are detected in the receiver, and reproduced by its loudspeaker.

The oscillator is of the ordinary plate feedback type. Variations in signal voltage through the coil connected to the yellow and gray leads induce a voltage into the tuned circuit consisting of the coil with the green and black leads connected to the rf section of the tuning condenser gang. This voltage sets up oscillation in the tuned circuit. The frequency will depend upon the setting of the tuning condenser. The rf voltage set up in this tuned circuit is coupled to the grid of the 50C5 by means of the pickup coil with the yellow coded lug. Thus we have a further change in the plate current at the frequency determined by the tuning condenser. Before the energy in the tuned circuit dies out it is reinforced by the energy from the plate circuit, and in this manner oscillation is maintained. You will note that the antenna, which consists of five or six feet of wire, is connected to the tuned circuit through coupling condenser C6. Therefore, there is a constant variation in voltage between this antenna and ground. As a result radiation occurs and radio waves go out from the antenna. However, the waves are weak and will not carry any great distance.

The "broadcast station" which you have built *is* actually a miniature broadcasting station. The FCC has very strict rules governing radio transmissions which forbid unlicensed operations. However, very low power oscillators, such as the one which you have just constructed and the popular phono-oscillators, are permitted by the FCC provided that the signal radiated does not exceed a certain maximum strength and is confined within the boundaries of the owner's property. The miniature transmitters that you have constructed in this kit all comply with the FCC's rules for low power oscillators, and a license is not required. However, beware of attaching too large an antenna to the output of your transmitter, because a very efficient or high antenna could cause your signal to be transmitted over a much greater distance than the FCC permits and cause interference with authorized stations.

THE SIGNAL TRACER

Build the signal tracer carefully, making certain that you read the color code values correctly and that the resistors are placed in the proper circuits. Note that both of the 2.2k resistors (R3, R4) are used in the power supply, and that the jumper is connected between terminals 8 and 1 instead of 8 and 4 of the 35Z5 socket.

The "Ground" and "Hot" test leads should be about 18 inches long, and the crocodile clips should be attached to the free ends of the leads by skinning back some of the insulation and placing the wire under the mounting screws on the jaw clips. The screws should then be tightened and the lugs bent over, thus electrically and

mechanically holding the wires firmly in place and in contact with the clips.

Before you turn the signal tracer on check the wiring and tube placements with the pictorial diagram.

HOW TO OPERATE THE SIGNAL TRACER

The signal tracer is an audio amplifier, and the first stage will also act as a detector. If RF or audio signals are fed into the special jaw clip leads RF signals will be detected, their audio component amplified, and sound will come out of the loudspeaker.

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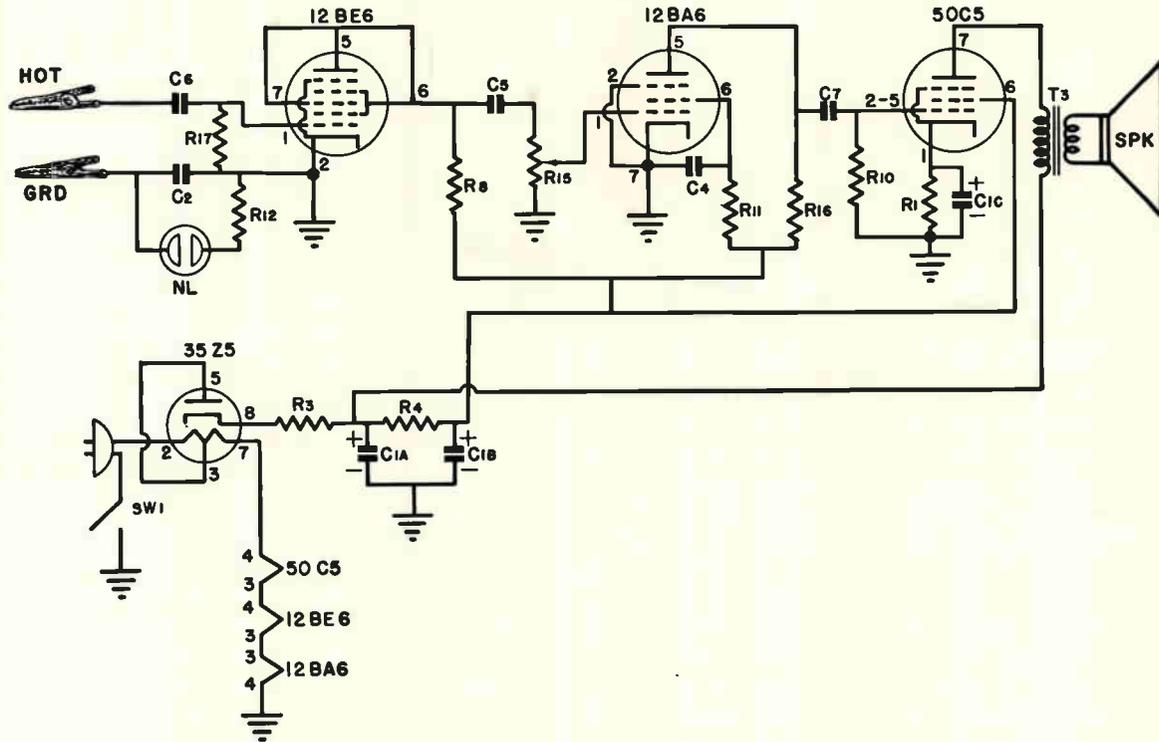
SIGNAL TRACER

Before attempting to use the signal tracer to check a radio receiver you must be sure that there is no voltage difference between it and the receiver chassis. If you fail to do this when working on an ac/dc receiver you may get a shock or blow a house fuse.

First connect the ground clip of the signal tracer to the chassis of the receiver and turn on both the set and the signal tracer. If the neon lamp lights there is a difference in potential between the two chassis. Reverse either the set or tracer line plug at the wall outlet. When the lamp does not light the chassis are at the same potential, and you are ready to signal trace.

Since a radio receiver is a succession of stages which handle the signal, you can connect the ground lead to the chassis of a receiver and move the hot lead from one stage to another, picking the signals up at the plate or control grid of each tube. If the receiver is working properly signals will be picked up at each test point. If the radio is dead you will go from a signal to no signal when you pass through the defective stage. Equipment of this sort enables a serviceman to localize trouble in a defective receiver. It will not only show up dead stages, but will also indicate the point at which distortion occurs in the receiver. With practice you will become proficient in the use of this simplified piece of service equipment. If the signal sounds distorted from the tracer but all right from the receiver, the volume control of the signal tracer is set too high and the 12BA6 tube is being overloaded. In such a case turn the volume down until the distortion is no longer present.

In this signal tracer the sensitivity has been made extremely high. If your hand is on the hot clip a hum will be heard in the speaker. For this reason the hot lead should be clipped to the point in the set you wish to examine and your hand removed. Then you will hear only those signals present at that point. When changing clip positions, the receiver should be turned off to avoid the possibility of a shock.

HOW THE SIGNAL TRACER WORKS

When the ground and hot leads are connected to a source producing an audio signal voltage in a receiver, audio signals flow through coupling condenser C6, the 1 meg grid resistor (R17) and coupling condenser C2. A portion of the applied audio voltage then appears across resistor R17, directly in the grid-cathode circuit of the 12BE6 tube, which is connected as a triode amplifier. The amplified signal voltage appears across the 51,000-ohm plate load resistor (R8) and the volume control through coupling condenser C5, and the output filter condenser (C16). By varying the position of the volume control slider any of the available signal may be applied to the grid-cathode circuit of the 12BA6 tube. This tube is connected as a high gain pentode audio amplifier. The large signal developed across its plate load resistor R16 is applied, through coupling condenser C3 and output filter condenser C1B, to the grid-cathode circuit of the 50C5. The cathode connection is through cathode by-pass condenser C1C. The 50C5, in turn, amplifies the signal and allows large amounts of audio power to flow through the

primary of the output transformer. This induces a voltage into the secondary, and the current flow through the speaker voice coil causes its attached cone to move in and out, setting up sound waves.

When the hot and ground leads are connected to a source of rf, the rf voltage is applied between terminals 1 and 2 of the 12BE6 tube. When the rf signal voltage makes terminal 1 positive with respect to terminal 2, electrons flow from the cathode (terminal 2) to the grid (terminal 1). When the applied signal reverses in polarity terminal 1 is negative with respect to terminal 2, and there is no electron flow between these electrodes. Thus we have rectification or detection in the grid circuit of the tube, and the audio signal riding on the rf signal is removed and appears across grid resistor R17. The signal tracer then amplifies this audio signal and delivers it to the loudspeaker as previously described.

BABY WATCHER

From the parts list on the pictorial diagram gather the the components which will be used in constructing this project. Then, after carefully studying the schematic and pictorial diagrams, wire the circuit as shown. Do not overlook the slight change in the basic wiring. You must change the wire that connected terminals 4 and 8 on the 35Z5 so that it connects terminals 1 and 8. You must disconnect the red lead of T3 from terminal 7 of the 50C5 and connect it to the ground lug at hole E. The blue lead of T3 must also be disconnected and reconnected to a terminal on the strip at hole G. Check all of your wiring with the pictorial diagram. Be sure that all tubes are installed in their proper sockets.

Use lamp cord or 300 ohm TV-type lead-in to connect the baby watcher to a receiver. This lead-in may be secured from any radio parts supply house and from most hardware stores. The baby watcher must be in a separate room from the receiver with the doors closed.

Connect the lead-in to your home receiver as shown in the pictorial diagram. One terminal of the receiver volume control will probably be grounded. Connect one lead-in wire directly to this terminal. Do not make any connection to the center terminal. Connect one end of R9 to the third terminal and the remaining lead-in wire to the other end of R9. Do not remove any of the connections that were already on the volume control.

The lead-in wire connected to the ground terminal on the receiver volume control should go to C7 on the baby watcher. The wire from R9 should go to C5. If these connections are reversed the baby watcher will not work. If you use lead-in which has color coded wire it will be be easy to get these connections right, otherwise, if the baby watcher does not work, reverse the connections of the lead-in to C5 and C7. After making the connections turn on both the baby watcher and the receiver. If a loud hum is heard remove the plug of either the baby watcher or the receiver (not both) from the wall outlet, turn it over, and reinsert it. This will minimize the hum.

You may now tune in a program on the receiver and adjust the receiver volume control to a comfortable level. If you

BABY WATCHER

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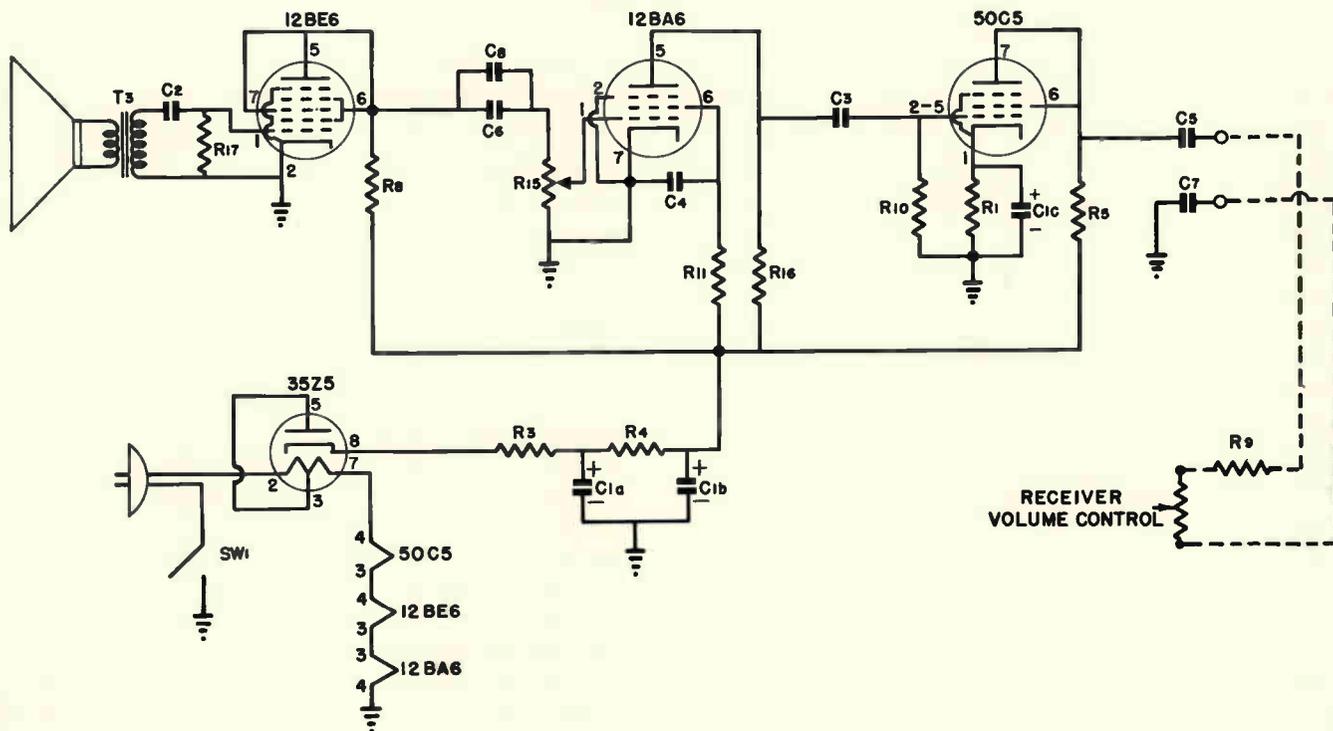
stand in front of the speaker used with the baby watcher and talk into it your voice will be amplified and will come out with the radio program. By adjusting the volume control of the baby watcher, you can vary the strength of the signal fed to the receiver.

If you attempt to use the baby watcher in the same room with the receiver, feedback between the receiver speaker and the speaker used as a microphone on the baby watcher may set up a howl.

The baby watcher may be placed by a baby's crib with the gain turned up high, or it may be used for making "spot" announcements on the radio. The setting of the volume control in the receiver will have little effect upon the volume of sound when you talk into the baby watcher microphone.

HOW THE BABY WATCHER WORKS

This instrument is a high gain audio amplifier. Any sounds reaching the diaphragm of the speaker cone will cause the voice coil to move back and forth. The voice coil acts as a generator and changes the sound waves into electrical signals of the same frequency. The signal currents flowing through the primary of the transformer induce a voltage into the secondary which is applied directly to the cathode, terminal 2, of the 12BE6 and through coupling condenser C2 to the control grid, terminal 1.

Because terminals 5, 6 and 7 are tied together the tube acts as a triode (a three element tube). The tube amplifies the signal, and the amplified signal appears across plate load resistor R9. This resistor is in parallel with

the volume control since it is connected to it through coupling condensers C6 and C8 and to its grounded end through output filter C1B. Therefore, the voltage across the plate load also appears across the volume control, and by changing the position of the slider, any amount of the available voltage can be fed to the control grid and cathode (terminals 1 and 7) of the 12BA6 tube. This tube is used as a high gain audio amplifier. It again amplifies the audio signal which appears across plate load resistor R16.

Plate load resistor R16 and its signal voltage are coupled by way of condenser C3 and C1B directly across grid resistor R10 of the 50C5 tube. The condensers allow the signal voltage to pass, but block the flow of dc, therefore, across R10 we have only the ac signal voltage. This signal is applied to the control grid (terminals 2-5) and to the cathode through cathode by-pass condenser C1C. Notice that the 50C5 tube is connected as a triode. The screen and plate (terminals 6 and 7) are connected together. The 50C5 contributes considerable amplification, and a large signal voltage appears across plate load resistor R5. This is fed through coupling condensers C5 and C7 and the connecting wires to the radio receiver. The volume control of the radio receiver is in the grid circuit of its first amplifier tube. By feeding the signal across the 100,000 ohm resistor which you have installed and the volume control, the signal is applied to the grid of the receiver first audio tube along with the radio programs picked up by the set. The amplification process is repeated in the receiver, and its loudspeaker changes the electrical signals from the baby watcher and the receiver into sound.

THE SUPERHETERODYNE RECEIVER

Wire this circuit carefully from the pictorial diagram, using the components given in the parts list. Keep all insulated wires connected to the tuning condenser, T2, and the 12BE6 reasonably short, and dress them so that they are close to the chassis. The above chassis wiring is shown at the bottom of the pictorial. It consists of a .0005 mfd. condenser (C8) connected from the red terminal of the antenna transformer (T1) to the solder lug at hole I, and a connection from the green lug of the antenna coil to the solder terminal of the antenna section of the tuning condenser gang (C10). This is the section farthest from the front of the chassis and tuning knob. There is also a connection from the black lug of the antenna transformer to the grounded solder lug. Last, you should connect five or six feet of insulated hookup wire to the blue terminal of the antenna transformer (T1).

The wire which you connected to the antenna transformer will serve as the antenna. Note that the primary of this transformer connects to the chassis through the .0005 mfd. condenser (C8). Because of this, the free end of the wire can be connected to a cold water pipe, or other good

ground. This often gives more pickup than if the antenna lead is lengthened by adding 10 or 15 feet of wire stretched out on the floor.

If you have an outside antenna you may try connecting the antenna lead to it, rather than to a grounded object. However, you may find that this will overload the receiver, and squealing (birdies) may be heard at various dial settings. This cannot be avoided with small receivers.

BEFORE YOU PUT THE SET IN OPERATION MAKE SURE THAT ALL TUBES ARE IN THE CORRECT SOCKETS. DO NOT PLACE THE SET ON A GROUNDED OBJECT SUCH AS A RADIATOR, ETC. Then turn the set on and tune to a setting near the high frequency end (1500) of the dial where you know a local station should be received. When the station comes in, adjust the antenna trimmer (mounted on top of the rear section of the gang) with a screwdriver, for maximum signal strength. Remove the tape from the top of the i-f transformer and adjust the trimmers slightly (a fraction
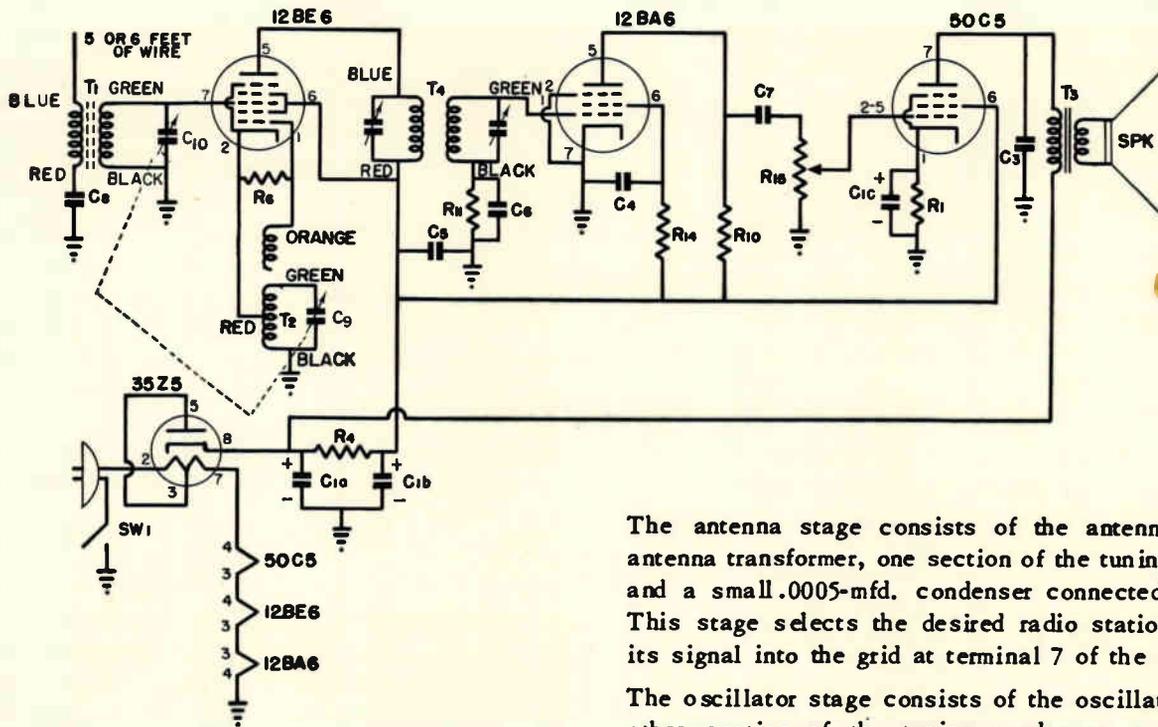
of a turn in either direction) to see if an increase in the strength of this station will result. The alignment is now complete.

If, however, a station is picked up that does not come in at the correct dial setting, turn the dial in the direction of the correct setting until the station can barely be heard. Then adjust both the antenna and oscillator (on top of the front section of the gang) trimmers for maximum signal strength from that station. Repeat the retuning and adjustment process until the station is received at the correct dial setting. A *slight* readjustment of the two i-f trimmers may now be made with a screwdriver for maximum volume on the station.

The volume, in some cases, may be improved by reversing the line cord plug position at the wall outlet. Simply pull out the plug, turn it over, and reinsert it in the wall outlet. Use the position which gives you best results.

HOW THE SUPERHETERODYNE RECEIVER WORKS

In the superheterodyne receiver there are five fundamental stages, or circuits. Each stage has a specific effect on the signal received by the receiver. We shall attempt to explain briefly the operation of each stage without going into detailed explanation of the function of each part in that stage. While reading this description look at the schematic, pick out the circuit elements of each stage, and follow the signal from the antenna through to the speaker. The five stages are as follows: the antenna stage, the oscillator, the mixer, the i-f stage, and the audio stage.

The antenna stage consists of the antenna wire, the antenna transformer, one section of the tuning condenser, and a small .0005-mfd. condenser connected to ground. This stage selects the desired radio station and feeds its signal into the grid at terminal 7 of the 12BE6 tube.

The oscillator stage consists of the oscillator coil, the other section of the tuning condenser, a 22,000 ohm resistor (R6), and elements 1, 2, and 6 of the 12BE6 tube. This circuit is a small transmitter which generates an r-f signal in the 12BE6 tube where it is mixed with the incoming signal from the antenna circuit. By mixing the antenna signal and the oscillator signal together, we get from the plate of the 12BE6 tube a signal which we call the i-f signal.

This i-f signal is fed into the primary of the i-f transformer (T4) and, through transformer action, is impressed on the secondary of the transformer. The secondary of the transformer feeds the signal to the grid (terminal 1) and the cathode (terminal 7) of the 12BA6 vacuum tube. The arrangement of components in this circuit is such that these two elements of the 12BA6 act as a detector or a rectifier. This picks off the audio portion of the i-f signal and eliminates the radio frequency portion. The audio portion of the signal is now amplified by the 12BA6 tube and fed to the next audio stage through the .005-mfd. condenser (C7). The volume control here selects the amount of the audio signal which we wish to feed into the grid of the 50C5 tube. In this manner it controls the volume of the audio that will be amplified by the 50C5 tube. The 50C5 tube and its associated components further amplify the signal and deliver it to the output transformer. The output transformer delivers a high current signal to the speaker voice coil. The signal current in the speaker voice coil forces the coil to move in and out. When the coil moves in and out it moves the cone with it, thereby creating movements of air which we know as sound waves.

We can now see that the incoming signal to a receiver is selected by the antenna section, mixed with the signal

from the oscillator section, converted into an i-f signal in the mixer section, changed into an audio signal at the output of the i-f section, and amplified by the audio section and converted into sound by the loudspeaker.

—————— n r i ——————

This completes the series of experiments in your Junior Experimenter's Electronic Kit. We hope that you have enjoyed performing these experiments and have at the same time, learned something about the fascinating subject of Radio and Television Electronics. The ten radio circuits which you constructed are only a minute fraction of all the fascinating things that can be done in the field of Radio and Television, but they illustrate the fundamentals which apply to all Radio and Television Circuits. Even though you knew nothing at all about radio when you embarked on these experiments, you can probably now do simple servicing jobs on your friends' radios!

If you have enjoyed building and operating these projects, we recommend that you seriously consider a career in Radio and Television Electronics. This is a young expanding industry that needs and welcomes young men who wish to grow with it.

—————— n r i ——————

NRI TRAINING GETS RESULTS

At this time you may not be in a position to consider enrolling for an NRI course. Ordinarily, we believe a student gets best results from NRI training if he is at least 16 years old and has finished high school. But the letters below are published to show you how well NRI training prepares men for success in Radio—Television. So when you are ready to think about preparing for your future career, be sure to consider the opportunities in Radio—Television. And remember that NRI training gets results.

Sees Future in Radio and TV
"I repair Radios, recorders and record changers for Sears Roebuck. I have a good salary and commission arrangement. I see a great future in Radio and Television, thanks to NRI training. I started doing Radio work after completing about 18 lessons of my course. I gained valuable experience from NRI kits."
L. J. HOWARD
2208½ Rossville Blvd., Chattanooga 8, Tenn.

Has Own Shop Built on Spare Time Earnings
"I have made Radio and TV my full time occupation. I built a shop and acquired a partner who stays in the shop. I handle outside business. While doing spare time work my test equipment, supplies, a Jeep station wagon, and my NRI course, were all paid for out of proceeds of my business. When I enrolled with the National Radio Institute I had practically no knowledge of Radio and absolutely none of Television."
WILLIAM A. NOAH, JR., 19 Arcadia Court, Albany 5, N. Y.

Television Technician

"I am in complete charge of the Instrument Repair Dept. of the Cleveland Television Clinic, Inc. The work is very interesting and I receive a nice salary. I gained much good information for this job by reviewing NRI lessons. Many thanks to you for starting me off in high gear."
BERNARD SIERS
1440 E. 66th St., Cleveland, Ohio

Finished While Senior in High School

"I completed my NRI course while a senior in high school. My parents were afraid it might interfere with my school work. But now neither my parents nor I regret my taking it. I work on Radios part time and have many satisfied customers."
EARLWOOD SMITH
RFD 4, Box 36, Hartsville 3, S. C.
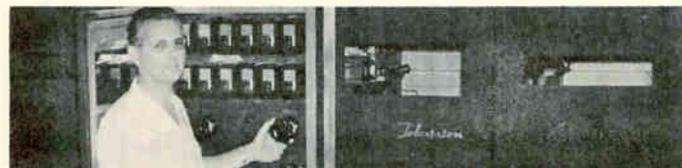
Audio Engineer at Station WDSU—TV
"After graduating from NRI I went into a Broadcasting Station as Engineer. Then I went to sea as Chief Operator aboard cargo passenger ships until I accepted my present position. Worked at the AM transmitter until a vacancy opened at the Television transmitter. I now serve as Audio Engineer on the microwave unit of WDSU—TV and also as an Engineer at the TV transmitter. I recommend NRI training very highly for any phase of Radio."
W. P. SEARCY, JR., 1916 Fern St., New Orleans 18, La.

Former Teacher Says Lessons

Are Clear and Complete

"I do not see how the presentation of subject matter in the NRI course can be improved. Each lesson is a clear, complete coverage of the assigned topic. Practical experiments are excellently correlated with lesson theory. As an NRI student, you are treated as an individual. I always received additional help cheerfully and quickly."
SMITH HARRIS, 19 Keep Street, Madison, New Jersey

I hope you have enjoyed building the projects with your Junior Experimenter's Electronic Kit and that you also have gained much profitable knowledge.

J. E. Smith

President

HOME OF THE NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

Established in 1914 by J. E. Smith, the National Radio Institute is the world's oldest and largest school teaching only Radio and Television by the home study method.

PRACTICAL TRAINING IN
TV SERVICING

2 TX

HOW TO RECOGNIZE AND LOCATE DEFECTS IN TV RECEIVERS

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

NRI

PIONEER HOME STUDY RADIO SCHOOL

STUDY SCHEDULE

This text is not intended as a regular study Lesson—it outlines a Practical Training Plan for getting practical experience in television servicing. We recommend that you follow this plan if you expect to do TV service work.

HOW TO RECOGNIZE AND LOCATE DEFECTS IN TV RECEIVERS

HERE IS THE second text in the series outlining a practical training plan in TV servicing. This plan is an extension of the NRI Practical Training Plan that was originally developed for Radio receivers.

The first book of this series, (1TX), which you have already received, outlines the complete plan; in it you were advised to get a commercial TV receiver. The receivers recommended were the RCA Model 630, the Stromberg-Carlson Model TV12, and the Hallicrafters Model T54 or 505, but a list of several equivalent receivers of other makes was given.

Also, in 1TX you were given a brief technical description of each receiver. You were also given instructions on how to operate their controls, and how to get them in and out of their cabinets. If you have not yet obtained your receiver, we strongly advise you to do so. Although this is not a requirement of the NRI Course, we are certain that you will benefit greatly from the experience this will give you.

If you have a receiver of the recommended type, and have carried out all of the steps outlined for it in the previous text, 1TX, you are now ready to go on with the remaining steps of the Practical Training Plan. (Be sure to carry out the steps in 1TX first, before attempting to go on.) This book is planned to show you how to:

1. Introduce defects into your receiver.
2. Observe the effects of each of these defects on the operation of the set.
3. Localize the defect by carrying out professional servicing techniques.

EQUIPMENT NEEDED

In addition to the TV receiver and its diagrams and other service information (given in 1TX), you will need a multimeter. This multimeter may be any standard service instrument with the usual voltage and ohmmeter ranges. A vacuum-tube voltmeter (if you have one) will serve the purpose well.

You will not need any test equipment other than a multimeter for the experiments in this text, although we shall suggest methods of localization using other equipment that will speed up your service work.

We are interested now in getting across the basic service procedures and in particular, effect-to-cause reasoning. For these purposes, a multimeter is sufficient.

In one experiment it would be desirable to be able to measure the high voltage. To do this you will need a special high-voltage test probe that has a built-in multiplying resistor. Such test probes are available for most standard high-sensitivity multimeters; if you have such a multimeter it would be advisable for you to obtain such a high-voltage probe. You will need it anyway for your future television service work.

Before we get to these experiments, however, let us review professional servicing techniques to refresh them in your mind.
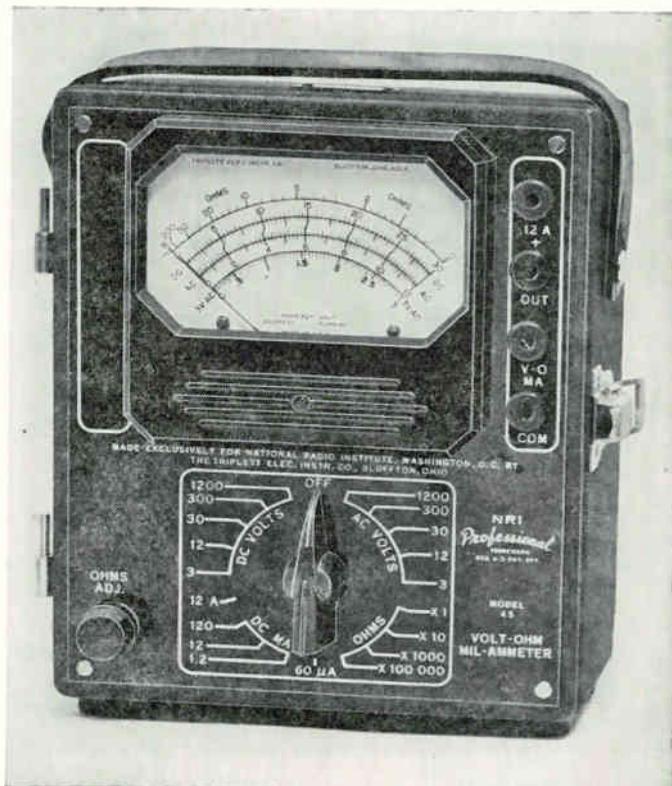
NRI TV Lab Photo

A typical service volt-ohm-milliammeter that is as suitable for TV work as for radio sets.

Review of Professional Servicing Techniques

When you are called to repair a TV set other than a brand-new one, you can assume that the set was operating properly at one time, that some part became defective, and that this, in turn, caused (either directly or indirectly) the complaint. It is your job as a serviceman to determine the defect from the complaint. Either by reasoning or by making tests, or both, you locate the defect and correct it so that the set is restored to normal operating condition. In doing this job, it is necessary for you to use your knowledge of television and radio circuits, your mechanical skills, and effect-to-cause reasoning—the most powerful tool of the professional serviceman. Proper reasoning leads to the choice of the quickest service procedure and may lead one almost directly to the source of trouble.

Briefly, the service procedure is a plan of about 7 steps, which may be shortened by use of effect-to-cause reasoning. Let's quickly run through the steps.

1. The first step is to find out exactly what the customer believes is wrong with the set. Since the customer does not have a technical understanding of the differences between degrees of poor set performance, you must be careful to be sure you understand exactly what is wrong. Most customers will call any condition that keeps them from getting a clear, steady picture "no picture." The serviceman, on the other hand must classify the complaint more specifically. This is most easily done by checking the operation
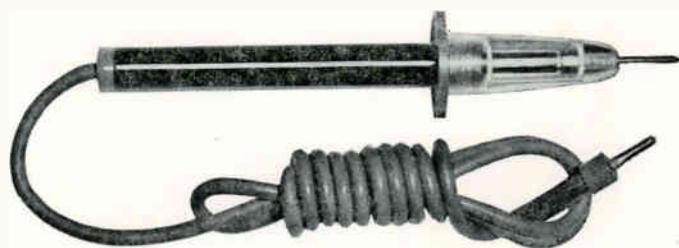
A typical high-voltage multiplier probe.

of the set in the presence of the customer, to be certain that he agrees that what you see is the trouble.

2. The next step is to determine whether the complaint is external or internal. When the set does not play at all, you must be very certain that a station is on the air at that time before blaming the set. Usually, a quick check by tuning to other stations (if available), or by referring to a monitor set that you should have set up in your workshop will show you whether stations are on the air, and whether their signal at that time is normal. If the operation of the set is in any way contrary to that of the monitor set, then you can suspect a difficulty with the set itself.

Similarly, when the trouble appears to be some

form of interference pattern, by referring to a monitor set in the same location you can determine whether the difficulty is being picked up or might arise in this set. Be careful about this, however, because sets differ in their ability to reject interference.

As far as the experiments in this book are concerned, we will consider primarily those defects that occur within the set itself. We will assume you have a good transmission line and antenna, and that the signal pickup is adequate in your particular locality. We will also assume that you do not have extremely bad local interference. In practical servicing, of course, you cannot always make this kind of assumption.

3. Once you have determined the complaint, you should make a preliminary examination of the set if the complaint is one that might be caused by any obvious defect such as a disconnected transmission line, plug out of the wall socket, etc.

4. The next step in the service procedure is the application of effect-to-cause reasoning. The use of this reasoning is the ability that distinguishes a good service technician from the "screw-driver mechanic." In order to use effect-to-cause reasoning, you must be familiar with basic radio and TV theory, and with the service techniques that have been described in your study Lessons. With this knowledge of how the circuits should work, it is very frequently possible to reason from the observed effect back to the most probable cause. In many cases it is possible to apply this reasoning only enough to tell you what section of the receiver contains the defect. In other instances, however, you may be able to reason to the defective stage or even to the circuit or part that must be causing the trouble.

If effect-to-cause reasoning does not lead directly to the defective part, the service procedure is to use a series of tests to locate the defective section, then the defective stage, the circuit, and finally the part.

We have already shown, on radio receivers, that there are three major methods of checking electronic equipment. One method is simply to make either voltage checks or ohmmeter readings to see if any operating condition is different from the normal given by the manufacturer. Another basic testing procedure is signal injection (which also includes circuit disturbance) in which a signal is introduced in the set and the signal source is moved to include more and more stages until the defect is encountered. The third basic method is that of signal tracing (and stage blocking). Here, a testing device is used to follow a known signal through the set to find out exactly what happens to it.

Let's review the procedures of signal injection and of signal tracing and see how they apply to television.

SIGNAL INJECTION

The technique of signal injection consists of exciting different stages in a receiver and observing the response. If the set is dead or weak, a signal of an appropriate type is introduced at a logical point and the response noted. If the response is normal, then the signal is introduced at points further back toward the input of the set until one crosses the stage containing the defect.

For dead or weak receivers, almost any signal generator can be used as a source, providing it generates a frequency that will pass through that and succeeding sections of the set. For these complaints, another simple form of signal injection is the circuit disturbance test. In a TV receiver using a power transformer, a disturbance test could be carried out simply by removing and replacing tubes. In the audio portion of the set, this should cause a click or thump to travel through the receiver; and in the video portion, it should cause a flash of light on the screen of the picture tube.

In sets having filament strings, this method is not so easy to apply, because removing any tube will break the filament string and may cause a disturbance in some remote stage, thus giving a false indication. Generally on such receivers a different form of circuit disturbance must be used. Touching a tube grid terminal, or the injection of a signal may be necessary.

The circuit disturbance test can normally be applied only to the circuits that carry the signal; it does not work in checking the sweep or sync circuits or power-supply circuits. Also, it won't work very well on many TV receivers because of interaction between circuits; the signal may travel around a defective stage, thus giving a false indication. In other instances, particularly when you are working in the video circuits, you may get almost as much of a flash or change in brilliancy on the raster when disturbing a defective stage as when disturbing a good one. You will have to learn by experience just how far you can go in depending upon tests of this kind.

To summarize: signal injection works well on sets that are weak or dead, but circuit disturbance is not as reliable as in radio servicing. Signal injection is not so helpful for signal distortion unless a special signal source is used.

SIGNAL TRACING

In the process we have just described—that of circuit disturbance or signal injection — the usual method is to inject a signal at a point near the output, and then to move back toward the input. In signal tracing, the opposite is done. A signal is applied to the input, then it is traced through the receiver. This input signal can be from a signal generator, or it can be a signal from a TV transmitter.

The signal tracers that are used in servicing sound radios are basically special receivers that can be used to follow the signal stage by stage. To date, however, no similar equipment has been developed for TV servicing. The problems of building a comparable device to tune to the TV frequencies have not permitted a suitable design. Undoubtedly, however, some day there will be developed an instrument of this type, which will simplify signal tracing.

Until the development of a true signal tracer, the best test instrument to use today is either a vacuum-tube voltmeter or an oscilloscope designed for TV service work, plus an rf probe. An rf probe consists of a rectifier right at the end of a test cable, arranged so that it offers very little loading and only small amounts of shunting capacity to the circuits across which it is connected. This probe delivers an equivalent dc voltage that can then be measured by a vacuum-tube voltmeter, or a signal equivalent to the modulation that can be viewed on an oscilloscope.

By the use of the rf probe, it is possible to follow the signal through at least most of the i-f stages, although the signal level may be too low to trace in some stages. When one gets to the video stages, an ordinary ac voltmeter or a cathode-ray oscilloscope can be used to follow the signal right up to the grid of the picture tube.

These same devices may be used to trace the sync pulses through the sync amplifier and clipper stages, as well as to trace the sweep voltages through the sweep chain. However, one must be careful about the sweep output where the voltage levels may be very high. The blocking condenser used with your measuring device may not be capable of withstanding such high voltages, and it can be damaged. Therefore, it is not advisable to check sweep voltages in or beyond the plate circuits of the sweep output amplifiers.

In the sound channel, the same devices can be used for signal tracing—a vtvm with an rf probe can be used to follow the signal through the sound i-f stages, and an ac voltmeter or an oscilloscope or even a signal tracer may be used to follow the audio signal through the audio stages.

USING ONE CHANNEL TO CHECK ANOTHER

TV receivers are of two basic types. One type, such as the Hallicrafters receiver, uses an intercarrier or intermodulation sound system. In these receivers, the sound and video signals travel through the video i-f amplifier, and a 4.5-megacycle beat is produced at the video detector. Somewhere in the video amplifier, this beat is removed for passage through an audio i-f chain.

In the other type of receiver, as for example the RCA and the Stromberg-Carlson, there are two

separate channels for the sound and picture i-f carriers. The division is made somewhere near the beginning of the video i-f amplifier, and from this point on, the two signals travel in entirely separate channels.

In either of these receiver types, it is possible to use the sound channel as a signal tracer through the video amplifier and through the sync and sweep chains. Furthermore, in the separate-channel type like the RCA and the Stromberg-Carlson, it is possible to use the sound channel as a signal source for
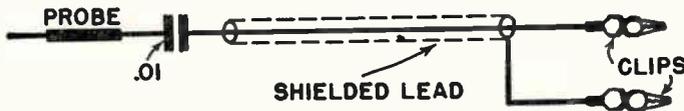
FIG. 1. A simple test cable.

signal injection. (this latter is not possible with an intercarrier set.)

For either use, all you need is a test cable like that shown in Fig. 1. This consists of a blocking condenser and a shielded lead about 2 or 3 feet long. The shielded lead preferably should have an insulating rubber sleeve or cloth loom around the outside of the shielding so that it cannot short anything.

As shown in Fig. 1, you attach a pair of clips to one end of the shielded lead, then fasten the condenser to the hot or center lead at the other end. Although a test probe is indicated, this can be just one lead of the condenser itself. If you prefer, you can purchase a large test probe and mount the condenser inside it. This gives a somewhat more rigid device.

The condenser size is not at all critical—you can use any value up to .05 mfd, and a working voltage of 600 volts or more. Don't use any rated at less than 600 volts, however.

Case I. The first case is using the sound channel as a signal tracer through the video amplifier. To do this, connect your test cable across the volume control as shown in Fig. 2. Then, if you have a set that does not have the tube filaments in a string, fix the sound i-f amplifier channel so that it won't work, by pulling out the first sound i-f amplifier tube. In a set such as the Hallicrafters, open the B supply lead to the first audio i-f tube. Be sure that you remove screen-grid voltage as well as the plate voltage so the tube won't be damaged.

With the sound i-f amplifier rendered inoperative, the audio amplifier can be used to trace the video signal from the video second detector right to the grid of the picture tube. A characteristic buzz can be heard from the loudspeaker if the signal is present.

Since the signal should increase as you go along, this device will roughly indicate whether you are getting gain or not, and will certainly indicate when the stage is dead. It is even possible to check inter-

stage coupling condensers by listening on either side of the suspected one. If the signal is normal on one side but is not present on the other, then the coupling device is defective.

This same setup can be used as a signal tracing device to follow the sync pulses from the point where they are separated from the video signal right through the sync amplifier to where they are applied to the sweep circuits. Here, however, you must remember that sync signals are not necessarily amplified; in the clipper they may even be reduced in amplitude.

Similarly, the cable can be used to follow the sweep signal through the sweep circuits. Here, however, you must remember that the response of the audio amplifier may produce weaker than normal responses, considering the actual levels of the sweep signals. After all, the horizontal sweep is at 15,750 cycles, which is somewhat above the response range of the average audio amplifier, and the 60-cycle vertical sweep may be below the low frequency cut-off in some cases. However, there will usually be harmonics of the 60-cycle sweep within the audio range, so tracing through the vertical sweep is more definite than is tracing through the horizontal sweep circuits. (Don't try this at the output of either of the sweep amplifiers—the voltage levels are higher than the rating of your blocking condenser.)

Notice that this use of the audio amplifier does not permit you to check through the video i-f stages.
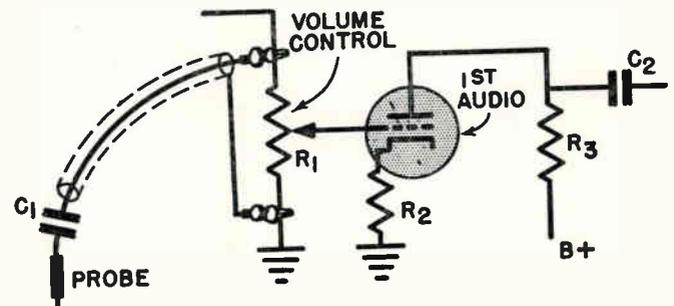
FIG. 2. Test cable connections to volume control.

However, this method can be used in those instances in which the audio system works but the video does not, or in cases where something is wrong with the sync or sweep chains.

As this suggests, any audio amplifier, even one from another set, could be used as a signal tracer in a television receiver, and, of course, a standard signal tracer can be used in these same stages providing you use a test lead with a blocking condenser to prevent shorting any dc voltage supply. Be careful when using a signal tracer to be certain that the blocking condenser has a sufficiently high voltage rating, and do not use it in the output stages of the sweep chains.

Case II. When the audio channel works, but the video signal is not coming through, the same test cable

4

can be used to provide a signal injection test in those sets using separate channels. (If the receiver is an intercarrier type, then the trouble in this case has to be in the output video stage or in the picture tube, so there is no point in signal injection.) You can couple your cable to the output of the audio amplifier, as shown in Fig. 3, and then can use the probe to inject a signal into the video amplifier. Starting at the output stage, you can move back toward the video detector. The audio signal should produce a pattern on the screen of the picture tube if everything between the point of signal injection and the picture tube is working normally.

In any of these cases, we are limited in that we can apply this test only between audio stages and video amplifier stages—it does not work satisfactorily in either the video i-f or the sound i-f stages.

STAGE BLOCKING

If the complaint is noise, oscillation, or a similar internal condition developing an interference pattern, blocking is sometimes an effective test. In a way, this is a form of signal tracing. The interfering signal is present, and you block stages to find out where it originates.

As an example, suppose that noise is being produced in one of the sound i-f stages. If you block or cut out any stages between the origin of the noise and the loudspeaker, the sound will disappear, but it will not disappear, if you block stages on the other side of the noise source. Thus, if you block or cut out the first sound i-f stage, and the noise is still present, you know that it is produced in one of the later stages. By blocking the next stage, you can determine whether the noise is introduced in that stage or not. If it disappears, you know that it is being introduced in that stage, but if not, that it is in one of the later stages, etc.

There are several methods that might be used for blocking a stage. On receivers that operate with the filaments in parallel from a power transformer, the simplest method is to pull out a tube for the stage to be blocked. However, this test cannot be done on a set in which the tube filaments are in a series or series-parallel string. In such a case, the simplest way is to shunt a large by-pass condenser between the grid of the stage to be blocked and ground. This works very satisfactorily in the rf and i-f stages, but in the audio stages themselves, the noise may only be reduced by this technique, as it may not prove a complete block with any practical by-pass condenser. A condenser of about .1 to .25 mfd is usually satisfactory for this test.

ISOLATION OF DEFECTIVE PART

Most of the preceding tests will localize at least the defective stage and perhaps the circuit. However,

they do not always indicate the defective part. An examination of the defective circuit may disclose the defect because you may be able to see that a particular part is burned or that a connection is loose. However, generally it is necessary to resort to a voltage or resistance check to localize the defect exactly.

Of course, you can use operational tests to localize the defective stage and circuit as well as the part. For example, you could check the operating voltages in each stage, and compare these voltages with the
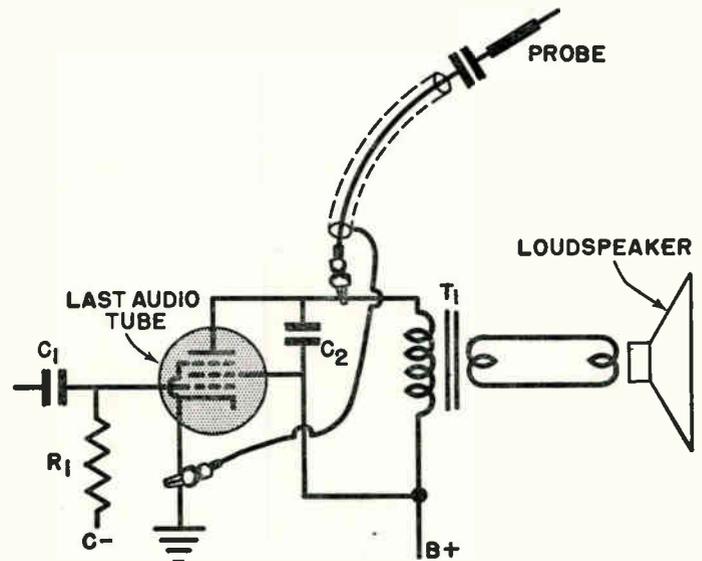

FIG. 3. Connections to audio amplifier output.

voltage values given by the manufacturer. By concentrating these measurements in the section that is suspected of being defective, you can frequently locate the defective stage and the circuit by noting differences between your measured voltages and those that should be present. Such voltage measurements may even indicate the nature of the trouble. For example, if you find no plate voltage on a tube, there may be an open load resistor or a shorted by-pass condenser associated with that circuit. On the other hand if the plate voltage is higher than normal, in all probability the tube is not drawing normal plate current so the drop across the plate load is lower than normal and one would suspect the tube or its bias.

When using a voltmeter, it is important that the meter have high sensitivity. Many TV circuits have very high resistances, so any additional current drawn by the voltmeter may upset the readings considerably. Be sure to determine what type of meter was used by the set manufacturer in making up his voltage tables. Unless you use a meter of somewhat similar sensitivity in high-resistance circuits, your readings are going to be higher or lower than those of the manufacturer.

In addition, an ohmmeter can be used to check the resistance of a complete circuit, a portion of a circuit, or an individual part. In using an ohmmeter on a TV

receiver, observe the same precautions as in a radio set—you must never use an ohmmeter in a hot circuit, and it is desirable to discharge filter condensers even after the set is turned off. Also, be cautious in checking parts not to jump to wrong conclusions. Examine the circuit or the diagram; there may be a number of parts in parallel, in which case it may be necessary to disconnect one lead of the part being checked in order to get an accurate indication of its resistance.

SUMMARY

The service procedure to use will depend upon the exact complaint and the kind of receiver you have for servicing. None of these tests are infallible, so you may have to use a combination of them to track down the trouble. Even in the application of reasoning, we must be careful to realize that because of interaction between circuits, and poor regulation in the power supply, one defect may cause several different complaints.

As an example, you would normally expect a burned-out audio output tube to cause only the sound

to be lost. In some TV receivers, however, such a defect may also greatly affect the picture. You may find that a very high setting of the contrast control is necessary to bring the picture back, and even then the picture may be blurred.

An interaction of this kind comes about because of poor power-supply regulation. When the power output tube in the audio section burns out, the operating voltages change considerably and the operation of several circuits may be affected. At the same time, the reduced current through the focus coil (which is usually in the B supply circuit) will cause improper focusing so that a blurred picture results.

In a case of this kind, we would have to service for the complaint indicating the greatest trouble—since the picture can be brought back with the contrast control, the picture channel is not completely dead, but the sound channel is. For this reason, it would be logical to clear up the lack of sound first, and then see if the other trouble has disappeared. If so, then the one difficulty caused both effects. We shall point out similar examples in some of the experiments which we shall conduct.

Preparing for the Experiments

Now that you have had a review of the servicing methods, it is time to prepare for the experiments we are about to conduct.

Once more, if you have not carried out the procedures outlined in 1TX, then you should do so before proceeding with the experiments that are to follow. In other words, you must have the required TV receiver, and must have learned how to operate its controls before you can go on.

Once you have completed all of the steps of the first book, proceed once more to remove the set from its

cabinet. In addition, carry out the following steps to connect the set together for carrying out the experiments. The following instructions also tell you what to do in order to give additional support to the picture tube, so you can move the chassis about.

Find the section applying to your particular set and follow these detailed instructions.

HALLICRAFTERS SERIES

The loudspeaker must be connected to the receiver for you to hear the sound when carrying out the
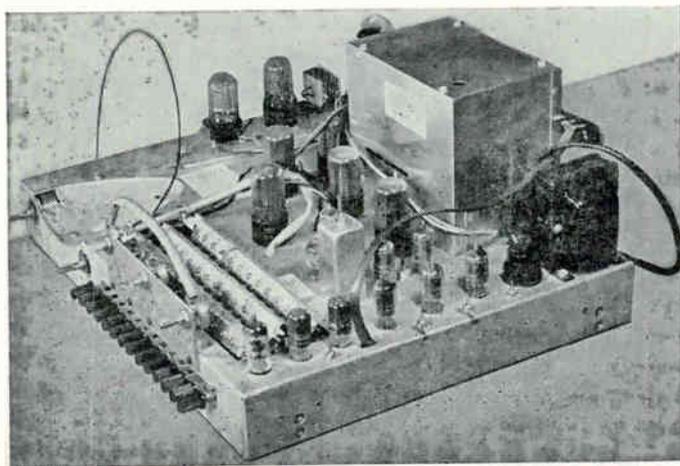
NRI TV Lab Photos

FIG. 4. The left-hand picture shows the wire fastening; the right-hand one shows the wire around the picture tube.
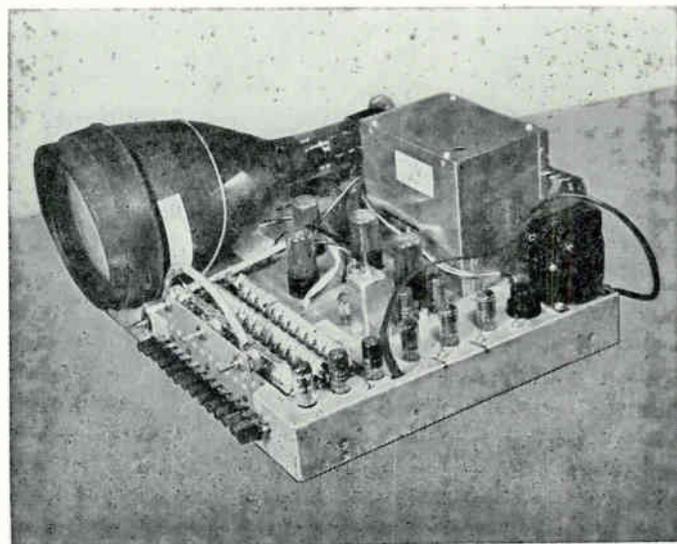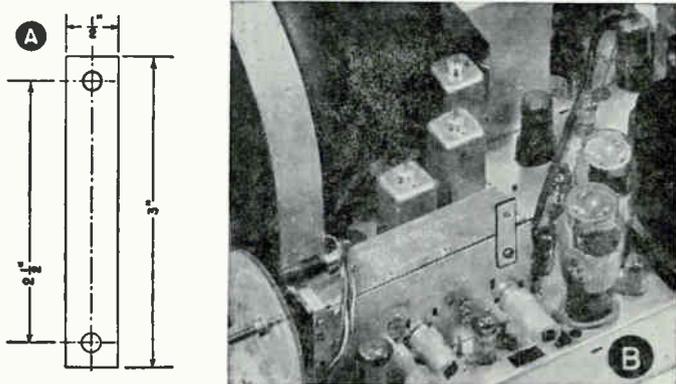
FIG. 5. The metal bracket at A is fastened to the side of the Inductuner as at B.

NRI TV Lab Photo

experiments. In this receiver, the loudspeaker is mounted on the front panel and either comes off with that panel (in the metal cabinet models) or is left in the cabinet when the chassis is taken out (in the wooden cabinet models). Therefore, you must remove the loudspeaker from the cabinet or from the front panel after you take the chassis out. Then reconnect the loudspeaker to the lead from the set chassis.

It is advisable to turn the speaker upside down on your workbench to protect the cone, or else use screen wire over the cone to minimize the danger of puncturing or tearing it.

Leave the rubber mask in place on the picture tube, as it serves to protect its lower edge. You may find, when removing the chassis from the cabinet, that the mask tends to stay in the front panel. A slight pressure on the front of the mask will loosen it from the panel so it will stay on the tube.

When the set is out of the cabinet, there is no anchor for the front end of the picture tube. Therefore, you should provide some sort of a strap around the tube so that the set can be tilted on its back or on one side without shifting the tube or without appreciable strain on the base of the tube. You can make a strap out of ordinary insulated wire, and use two machine screws and nuts to hold it in place on either side of the tube as shown in Fig. 4. There are holes already in many of these chassis that can be used for this purpose. If you find it necessary to drill holes, be sure to remove all tubes and be careful not to drill into any of the parts.

The wire strap should be tightened snugly in place. A little cement may be applied along the top of the wire where it goes over the tube to keep it from shifting in position—ordinary speaker cement or Duco cement is satisfactory for this.

STROMBERG-CARLSON SERIES

After the Stromberg-Carlson chassis is removed from the cabinet, it is necessary to remove the loud-

speaker from the cabinet so that it can be reconnected to the set chassis. Remove the screws holding the speaker in place and reconnect it to the cable from the receiver. Leave the speaker upside-down on your workbench to protect the cone, or else use screen wire over the cone to minimize the danger of puncturing or tearing the cone.

On this receiver, the picture tube is held in place by a metal strap that goes around the front of it so no mounting strap needs to be made.

However, the tuning eye tube is loose on the end of its cable, and may fall underneath the chassis or dangle loose and be broken. To avoid this, you can make a small metal bracket as shown in Fig. 5A. This bracket can be used to hold the tuning eye tube to the front-end tuner as shown below.

THE RCA SERIES

Remove the receiver from the cabinet according to the instructions given in 1TX. You must first open the cabinet and remove the picture tube.

The picture tube is supported by both the cabinet and the chassis when in the cabinet. Therefore, when the chassis is out of the cabinet, there is no support for the front of the picture tube. This makes this chassis rather difficult to work on unless a bracket is made to hold the picture tube in position. Such a bracket must hold the picture tube in place even when the chassis is moved or turned on its side.

The major parts necessary for building such a bracket are shown in Fig. 6. Two parts are used—a large metal bracket at A and a wooden block at B. The dimensions for the metal bracket are approximate only, and you should check the dimensions against your receiver before building the bracket or having it made. We recommend one-eighth-inch sheet aluminum because it is easy to work. However, any material of similar strength can be used. This metal
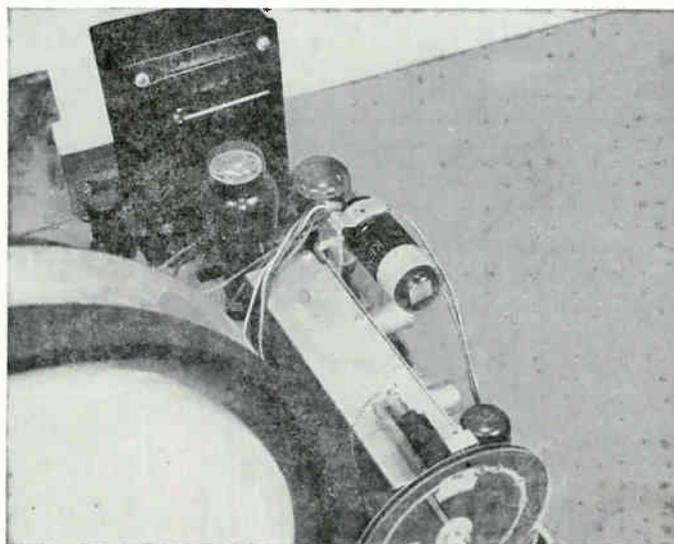
NRI TV Lab Photo

The tuning eye bracket in use on the Stromberg-Carlson.

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bracket is used to hold the wooden block under the tube, and is in turn held to the chassis by the three front-panel controls. The large holes in the aluminum strip should clear the control bushings—3/8" to 1/2" in diameter. The small holes should clear either No. 8 or No. 10 wood screws. (No. 18 or No. 10 drill, respectively.)

The thickness of the stock from which the wooden block is cut is not critical—we suggest material about 1½ inches thick to give a reasonably broad supporting edge for the front of the tube.

After the block is cut to the shape and dimensions shown in Fig. 6B, line the semi-circular cut-out of the wooden block with a strip of felt about one-quarter inch thick and as wide as the block of wood. Felting can be obtained from hardware stores, or from a stationery supply house—a felt typewriter pad is suitable. A piece of felt the correct length and size can be cut out of this with a razor blade. If the pad it too thick, you can split it to approximately one-quarter inch thickness, again using the razor blade. The felt padding should not be much more than one-quarter to three-eighths inch thick when compressed, or the tube will not line up with the deflection yoke and focus coil. The felt may be glued in place.

Fasten the block to the metal bracket with ordinary wood screws—at least three.

To install the metal bracket on the set, remove the nuts that hold the three front panel controls to the chassis. Then place the bracket over the control shafts and replace the nuts. When they are screwed on tightly, the bracket is held in the position shown in Fig. 7.
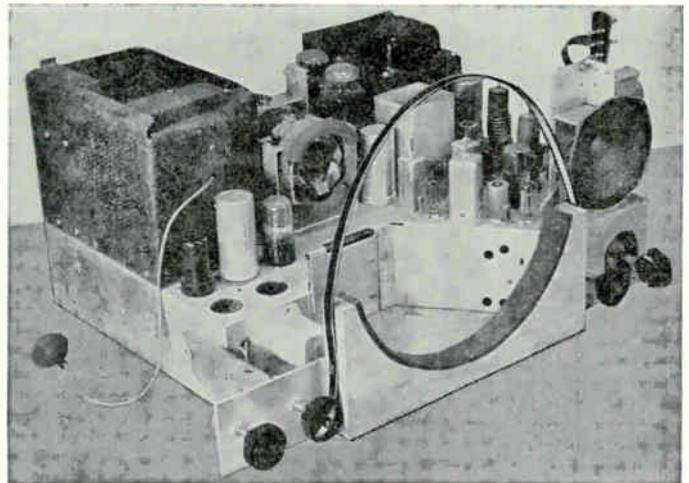
NRI TV Lab Photo
FIG. 7. How the tube support goes on the RCA.

With the bracket in position, replace the tube on the chassis by inserting its neck into the deflection and focus coils, replace the ion trap, and plug the tube into its socket.

The front edge of the tube should now be resting on the felt on the wooden block.

To hold the tube in place, a strip of canvas webbing or similar material is connected from one side of the wooden block over and around the picture tube to the other side of the block. Many servicemen use 300-ohm twin-lead transmission line for this purpose. To hold the strap in place, use wood screws and wide washers. The washers are placed under the screw heads so that a large area of the material is clamped in place. With the 300-ohm twin-lead as a strap, as shown in Fig. 7, washers should be chosen that are wide enough to clamp the wires. To put the strap in place, one side is fastened, the strap is stretched tightly around the tube, and then the other side is fastened into place.

Generally this material will stretch slightly, but will remain tight enough to support the tube.

GETTING INITIAL READINGS

Once you have prepared your set so that the loudspeaker is connected, and the picture tube is in place, it would be well for you to read again the precautions given in 1TX. Pay particular attention to the precautions about the voltages, and the care of the picture tube.

Connect the set to ac power, and run through the procedures of adjusting the operating and semi-adjustable controls as necessary to get a good picture. If you have disturbed the position of the focus coil or deflection yoke on either the RCA or the Stromberg-Carlson receiver, be sure to re-set it properly.

Using Your Multitester. Before getting readings, you should be reasonably familiar with the use of your multitester. If you are unfamiliar with your instrument, it would be well to review its instruction book and to measure some known voltages, preferably
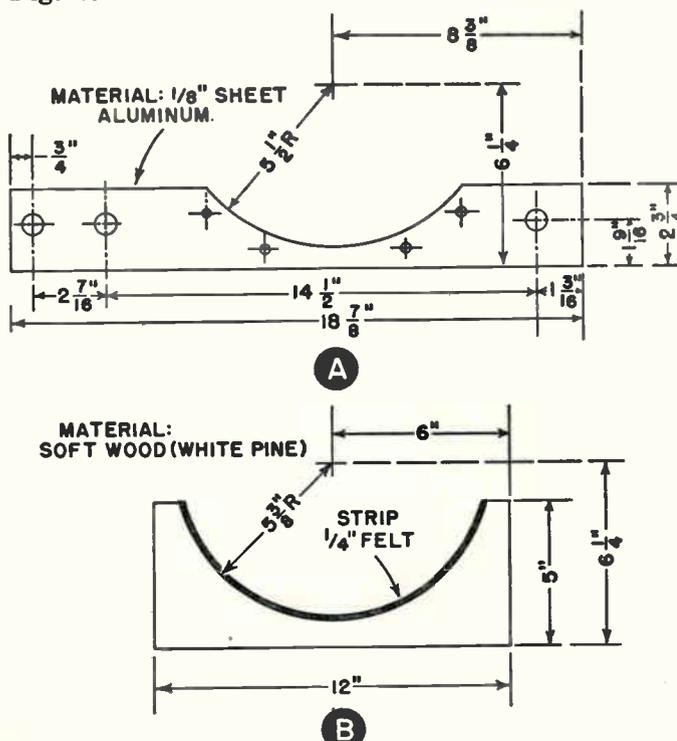

FIG. 6. Dimensions for the tube support for the RCA.

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in a radio receiver. Also become familiar with the ohmmeter by checking the values of known resistors until you can properly read the ohmmeter scales.

When using a multitester, remember that the service technician will seldom, if ever, make a current measurement. In almost all instances he will check either voltages or resistances. Of course, voltage checks are always made with the power on, but ohmmeter checks, on the other hand, should be made with the power off.

When making voltage tests, always use a range sufficiently high so there is no danger of over-loading the meter. When in doubt as to which range to use, start with the highest range.

Using a High-Voltage Probe. If you have a high-voltage probe for your multitester, set the multitester to the proper range, or plug into the proper jacks, as instructed by the probe manufacturer. Then, connect

As a warning, don't use a multimeter alone to measure voltages at the points indicated by the manufacturers where very high voltages may exist. For example, don't try to measure at the plate of the horizontal sweep amplifier tube or anywhere in the high-voltage supply of either the RCA or Stromberg series. In the Hallicrafters set, avoid the high-voltage supply and the outputs of either sweep amplifier.

Of course, if you have a high-voltage multiplier test probe for your multimeter, then you can make the measurements by observing the precautions we gave earlier.

As another important point, most voltage measurements are made between the various elements and the chassis or B— return circuit. This is not necessarily the operating voltage, as you will see by carefully studying some of the voltage readings. In other words, the actual plate voltage is the difference in
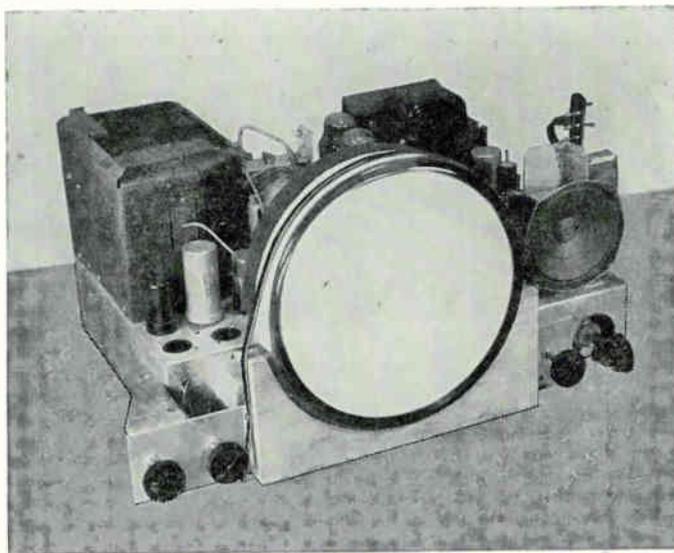
NRI TV Lab Photo
The RCA series showing the tube supported.

the ground lead from the tester to the chassis. The high-voltage probe can now be held to the proper point, with the set turned on. This probe is so insulated that it is safe to hold it.

Voltage Tests. To find out just what voltages are present in your receiver, it would be well for you to make a series of tests. The standard voltage readings for the recommended receivers are given in Figs. 8, 9, and 10. Locate the figure that applies to your particular receiver.

Your readings will depend on the parts tolerances in your set, and on the accuracy of your meter and the type of meter. Most TV voltage measurements are made with multimeters rated at 20,000 ohms-per-volt, or else with vacuum-tube voltmeters. Therefore, don't worry if some of your readings do not exactly duplicate those given by the manufacturer. However, you should make notes of any of your readings that are appreciably different, for future reference.

potential between the plate and the cathode of the particular tube. If the cathode goes to a negative supply, and the plate to a positive supply, the two voltages will add together and may give a much higher plate voltage than that found by reading between the plate and chassis alone.

Since all voltage readings are made with the set turned on, you must be careful to avoid shocks, and to avoid short circuiting anything with your test probes. You may have to use considerable ingenuity at times to reach a particular tube element because of other parts that are in the way. However, these are problems such as you would meet in servicing such a set, so this is good practice.

Ohmmeter Readings. After you have completed your voltmeter tests, it would be wise for you to experiment with your ohmmeter. To do so, unplug the receiver and allow plenty of time for filter and bypass condensers to discharge completely. Then,

Measurements made with receiver operating on 117 volts 60 cycles a-c and with no signal input except where otherwise indicated. Voltages shown are as read with Jr. VoltOhmyst between indicated terminal and chassis ground except where otherwise noted. Symbol < means "less than."

Tube No.	Tube Type	Function	Operating Condition **	E. Plate Pin No.	Volts	E. Screen Pin No.	Volts	E. Cathode Pin No.	Volts	E. Grid Pin No.	Volts	I Plate (ma.)	I Screen (ma.)	Notes on Measurements
V1	6J6	R-F Amplifier	Pictr. Min.	1 & 2	130	—	—	7	0	5 & 6	-9.2	<.1*	—	*Per Plate
			Pictr. Max.	1 & 2	55	—	—	7	0	5 & 6	+.05	7.0*	—	*Per Plate
V2	6J6	Converter	Pictr. Min.	1 & 2	125	—	—	7	0	5 & 6	-3 to -6.	.5 to 4*	—	*Per Plate
			Pictr. Max.	1 & 2	100	—	—	7	0	5 & 6	-2 to -5.	.2 to 3*	—	*Per Plate
V3	6J6	R-F Oscillator	Pictr. Min.	1 & 2	108	—	—	7	.25	5 & 6	-4.5 to -6.5	2.5	—	
			Pictr. Max.	1 & 2	90	—	—	7	.15	5 & 6	-3.5 to -5.	1.7	—	
V104	6BA6	1st Sound I-F Amplifier	Pictr. Min.	5	120	6	120	7	1.9	1	0	12.0	5.0	
			Pictr. Max.	5	110	6	110	7	1.6	1	0	10.5	4.5	
V105	6BA6	2d Sound I-F Amplifier	Pictr. Min.	5	122	6	118	7	1.9	1	0	12.5	4.9	
			Pictr. Max.	5	113	6	108	7	1.6	1	0	10.5	4.2	
V106	6AU6	3d Sound I-F Amplifier	Pictr. Min.	5	48	6	48	7	0	1	-.5	3.3	1.4	
			Pictr. Max.	5	41	6	41	7	0	1	-.5	2.8	1.2	
V107	6AL5	Sound Discrim.	Pictr. Min.	2 & 7	-.35	—	—	4 & 5	—	—	—	—	—	
			Pictr. Max.	2 & 7	-.45	—	—	4 & 5	—	—	—	—	—	
V108	6AT6	1st Audio Amplifier	Pictr. Min.	7	80	—	—	2	0	1	-.75	.5	—	
V109	6K6-GT	Audio Output	Pictr. Min.	3	253	4	265	8	0	5	-18	27.5	4.0	
V110	6AG5	1st Pix. I-F Amplifier	Pictr. Min.	5	135	6	135	2 & 7	0	1	-5.0	<.1	<.1	
			Pictr. Max.	5	109	6	109	2 & 7	.26	1	-1.0	5.5	.9	
V111	6AG5	2d Pix. I-F Amplifier	Pictr. Min.	5	135	6	135	2 & 7	0	1	-5.0	<.1	<.1	
			Pictr. Max.	5	113	6	113	2 & 7	.26	1	-1.0	5.6	.9	
V112	6AG5	3d Pix. I-F Amplifier	Pictr. Min.	5	135	6	135	2 & 7	0	1	-5.0	<.1	<.1	
			Pictr. Max.	5	98	6	117	2 & 7	.26	1	-1.0	5.7	.9	
V113	6AG5	4th Pix. I-F Amplifier	Pictr. Min.	5	99	6	127	2 & 7	1.2	1	0	6.8	1.7	
			Pictr. Max.	5	89	6	117	2 & 7	1.1	1	0	6.8	1.7	
V114-A	6AL5	Picture 2d Det.	Pictr. Min.	7	-.1	—	—	1	0	—	—	—	—	
V114-B	6AL5	DC Restorer	Brightness Min.	2	-100	—	—	5	-90	—	—	—	—	
			Brightness Max.	2	-1	—	—	5	-.9	—	—	—	—	
V115	6AU6	1st Video Amplifier	Pictr. Min.	5	240	6	135	7	0	1	-2.15	4.0	1.55	
			Pictr. Max.	5	255	6	125	7	0	1	-2.2	2.8	1.05	
V116	6K6-GT	2d Video* Amplifier	Pictr. Min.	3	105	4	135	8	3.7	5	-7.5	9.6	1.6	
			Pictr. Max.	3	95	4	125	8	2.9	5	-7.5	7.5	1.3	

** Where separate readings are not listed for max. and min. gain settings of the picture control, the effect of the control is slight and readings are given for "Picture Min."

Tube No.	Tube Type	Function	Operating Condition **	E. Plate Pin No.	Volts	E. Screen Pin No.	Volts	E. Cathode Pin No.	Volts	E. Grid Pin No.	Volts	I Plate (ma.)	I Screen (ma.)	Notes on Measurements
V117	10-BP4	Kinescope	Brightness Min.	Cap	9200*	10	275	11	0	2	-100	0	0	*Measured with VoltOhmyst and high voltage multiplier probe
			Brightness Max.	Cap	6000*	10	275	11	0	2	0	.7	—	
			Brightness Average	Cap	9000*	10	275	—	—	—	—	.05	—	
V118	6SK7	1st Sync. Amplifier	Pictr. Min.	8	163	6	129	5	0	4	-4.3	11.5	3.8	
			Pictr. Max.	8	185	6	115	5	0	4	-4.4	9.2	2.9	
V119	6SH7	Sync. Separator	Pictr. Min.	8	134	6	135	5	0	4	-5.2	.1	.05	
			Pictr. Max.	8	123	6	125	5	0	4	-9*	.3	.1	*Depends on noise
V120-A	6SN7-GT	2d Sync. Amplifier	Pictr. Min.	2	88	—	—	3	0	1	-.5	9.0	—	
			Pictr. Max.	2	80	—	—	3	0	1	-9*	7.9	—	*Depends on noise
V120-B	6SN7-GT	Horizontal Discharge	Pictr. Min.	5	-37	—	—	6	-100	4	-140	.5	—	
V121	6J5	Vertical Oscillator	Pictr. Min.	3	70*	—	—	8	-100	5	-150	.15	—	*Height, linearity and hold affect readings 2 to 1
V122	6K6-GT	Vertical Output	Pictr. Min.	3	180	4	180*	8	-70	5	-100	9.0	*	*Screen connected to plate
V123	6AL5	Horizontal Sync. Discr.	Pictr. Min.	2 & 7	-6.5	—	—	1 & 5	-2.1	—	—	—	—	
V124	6AC7	Horizontal Osc. Control	Pictr. Min.	8	194	6	105	5	.05	4	-2.0	3.8	1.1	
V125	6K6-GT	Horizontal Oscillator	Hold Max. Resistance	3	190	4	208	8	0	5	-30	17.0	6.7	
			Hold Min. Resistance	3	180	4	194	8	0	5	-23.5	19.5	8.2	
V126-G	6BG6-G	Horizontal Output	Pictr. Min.	Cap	Do not Meas.*	8	134	3	-91	5	-113	77.0	11.5	*6000 volt pulse present
V127	8016	H.V. Rectifier	Brightness Min.	Cap	*	—	—	2 & 7	9200	—	—	0	—	*9200 volt pulse present
			Brightness Max.	Cap	*	—	—	2 & 7	6700	—	—	.7	—	*9200 volt pulse present
V128	5V4G	Reaction Scanning	Pictr. Min.	4 & 6	Do not Meas.*	—	—	8	350	—	—	90	—	*1200 volt pulse present
V129	5U4G	Rectifier	Pictr. Min.	4 & 6	390*	—	—	2 & 8	300	—	—	146	—	*A-C measured from plate to trans center tap
V130	5U4G	Rectifier	Pictr. Min.	4 & 6	390*	—	—	2 & 8	300	—	—	146	—	

** Where separate readings are not listed for max. and min. gain settings of the picture control, the effect is slight and readings are given for "Picture Min."

Following readings taken with video signal applied through video amplifiers to produce 25 volts peaks to peak on Kinescope grid.

Tube No.	Tube Type	Function	Operating Condition	E. Plate Pin No.	Volts	E. Screen Pin No.	Volts	E. Cathode Pin No.	Volts	E. Grid Pin No.	Volts	I Plate (ma.)	I Screen (ma.)	Notes
V114-B	6AL5	DC Restorer	Pictr. Min.	2	-41	—	—	5	-27	—	—	—	—	
V119	6SH7	Sync. Separator	Pictr. Min.	8	136	6	142	5	0	4	-21.5	.9	.8	
V120-A	6SN-7GT	2d Sync. Amplifier	Pictr. Min.	2	88	—	—	3	0	1	-5.4	9.0	—	
V123	6AL5	Horizontal Sync. Discr.	Pictr. Min.	2 & 7	-20	—	—	1 & 5	K.* K.-2.1	—	—	—	—	*See grid voltage of V124
V124	6AC7	Horizontal Osc. Control	Pull-in*	8	200(a)	6	100(b)	5	<.1	4	-1.5 to -3	<.8	<2.5	*Varying Hor. Osc. tuning
			Hold*	8	200(c)	6	100(d)	5	<.1	4	(e)	<.8	<2.5	

(a) Pull-in range varies with tubes from 110-210 to 195-270.
(b) Pull-in range varies with tubes from 80-100 to 100-115.
(c) Hold range varies with tubes from 110-270 to 140-270.
(d) Hold range varies with tubes from 80-115 to 90-115.
(e) Hold range varies with tubes from 1.5-7.0 to 1.-4.5.

Courtesy RCA

FIG. 8. Here is the voltage chart for the RCA series. Note carefully the conditions for measuring; they must be duplicated for proper results.

ALIGNMENT AND VOLTAGE CHART

Courtesy Stromberg-Carlson

FIG. 9. Voltage chart for the Stromberg-Carlson series. These readings were taken at a line voltage of 117 volts. The "audio output" readings above are for the TV-12P model using a plug to feed a separate amplifier. For the model TV-12L, the audio output socket voltages should be: (1) 0; (2) 6.3 ac; (3) 205; (4) 235; (5) —7.2; (6) —10; (7) 0; (8) 0.
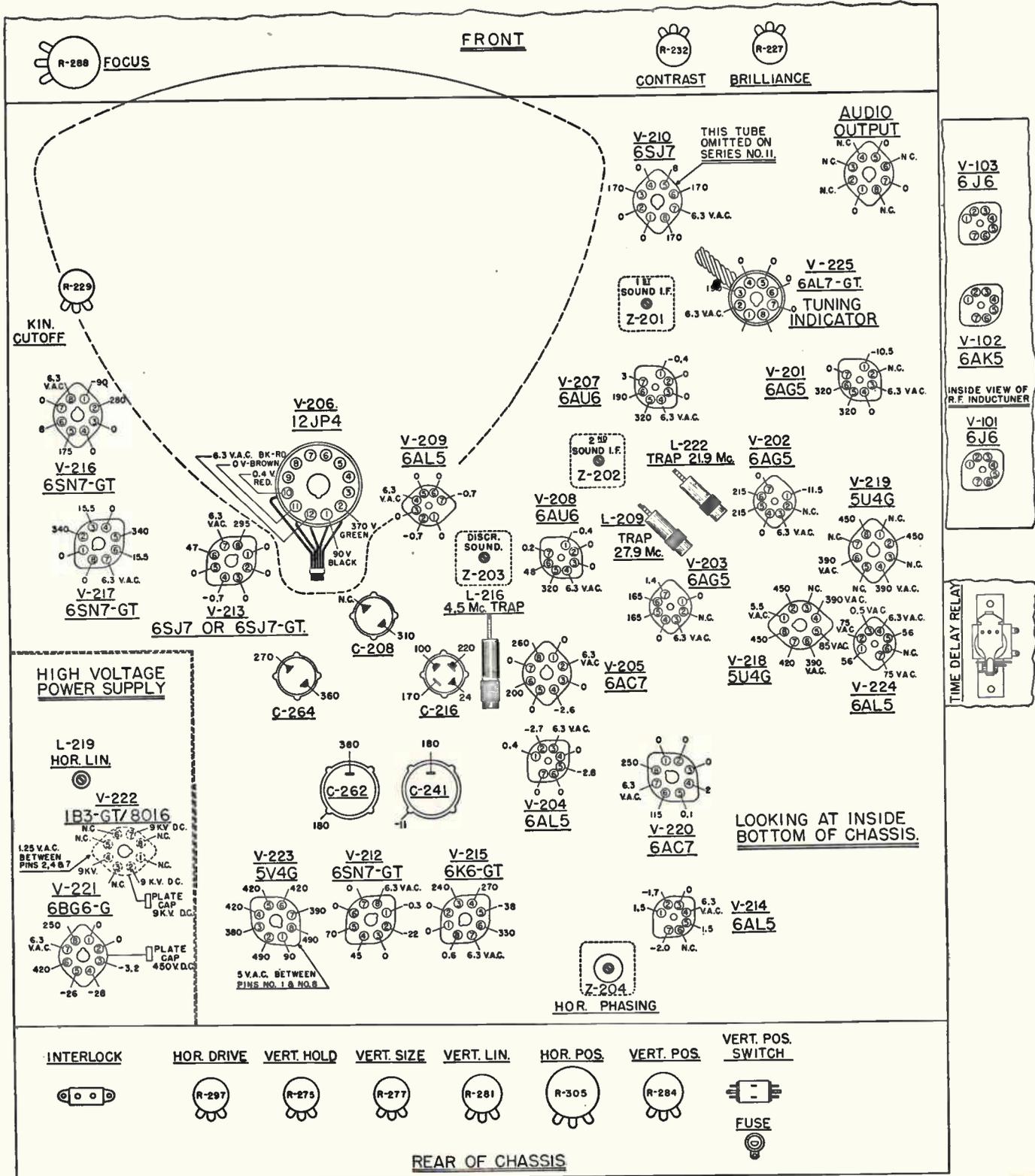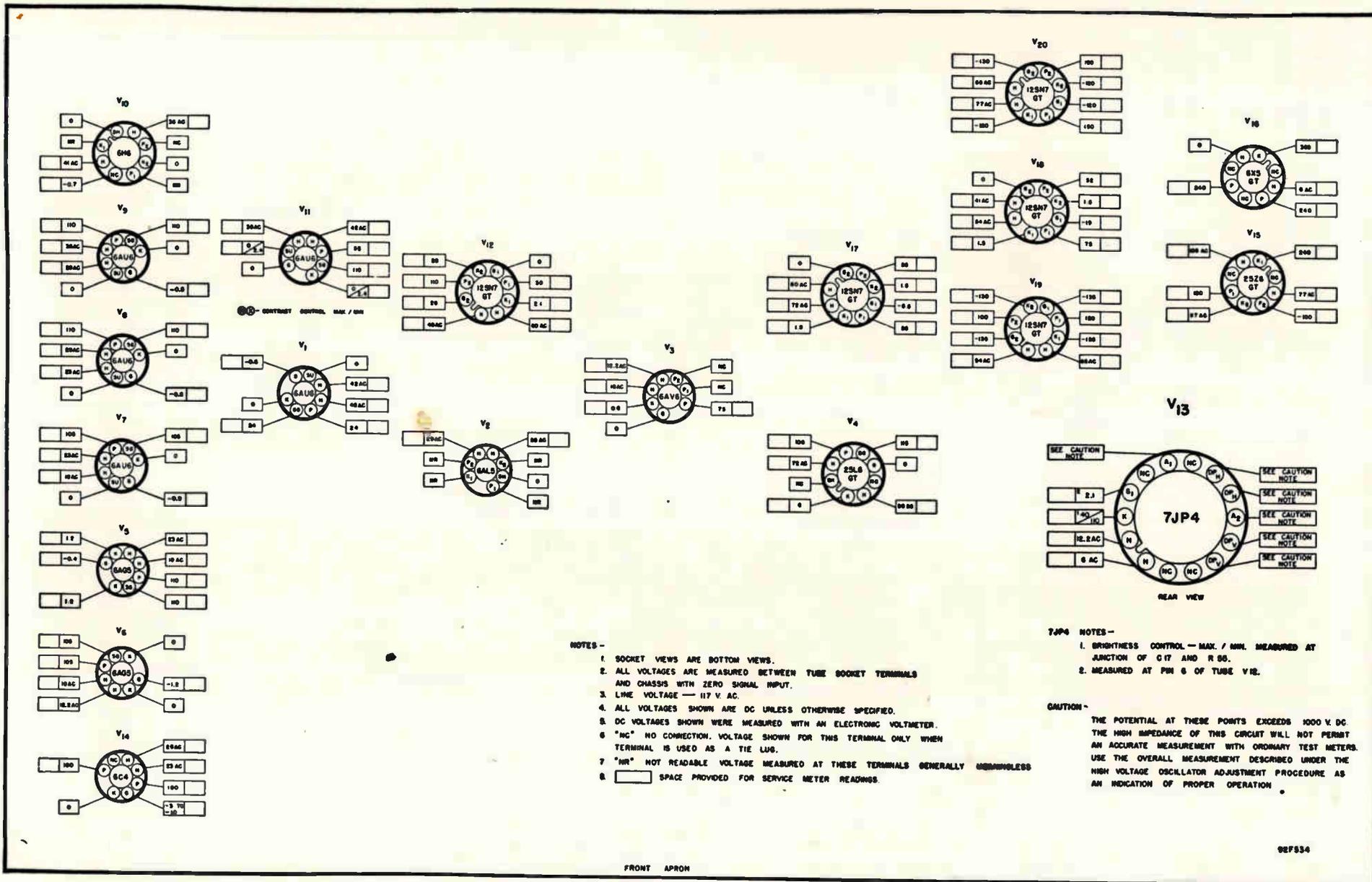
FIG. 10. Voltage chart for the Hallicrafters series. Read all notes to see how values were obtained.

switch your multitester for use as an ohmmeter. Take readings, then examine the schematic diagram to compare your readings with the values you might expect in each case. Notice particularly the readings between B+ and the chassis, as well as readings between tube plates and B+. In each instance, try to determine why you have a particular reading by tracing the circuit to see just what resistances are between the points at which you are measuring.

Now that you have your set out of the cabinet, and have arranged for any necessary tube support, you are ready to go on with the experiments. First, however, let's learn just what complaints we may expect to find in TV receivers.

Complaint Groups

Since a television set is basically just a radio, the same kinds of general complaints will be found in them as in radio receivers.

Broadly, any defect can be classed as dead set or improper operation. Either of these broad classifications can be broken down into a number of sub-divisions, however, each with its own clues as to the source of difficulty. Let's briefly classify these sub-divisions in the groups that the service technician would recognize or as he would describe them. It is important to remember, however, that the service technician will often use entirely different language when describing a particular complaint from that which the layman uses.

DEAD SET

With a sound receiver, we say the set is dead when there is no sound from it. As you will recall, however, the alert service technician will listen carefully to the set to see if he can detect any hum or noise. A completely dead set—one without hum, noise, or signal, usually means trouble in the output stage or in the power supply. On the other hand, a small amount of hum or noise would indicate that part of the set was working and that the defect is probably earlier in the set. Similarly, in a TV receiver, we must be careful to classify all of the conditions that might be called "dead."

Broadly speaking, the condition of no sound *and* no picture occurring simultaneously, corresponds most directly with that of a dead sound radio. Of course, we still should listen for hum or noise from the sound channel.

However, in addition to having both no sound and no picture, we can have a case of either no sound or no picture. Thus, a so-called "dead" TV set may have:

1. **No sound AND no picture.**
2. **No sound but picture okay.**
3. **Sound okay, but no picture.**

Also, "no-picture" in cases 1 or 3 could be all the way from a truly blank screen through conditions wherein a dot, line, raster, or merely an unsynchronized picture may be present. Therefore, by examination the serviceman must classify the "no picture" complaint into one of the following classes:

A. *A blank screen on which absolutely nothing can be seen. (This is a true case of no picture.)*

B. *A dot of light on the screen when the brilliancy control is advanced.*

C. *A line, either vertical or horizontal, on the screen when the brilliancy control is advanced.*

D. *A complete raster when the brilliancy control is advanced, but no evidence of a picture signal.*

E. *Evidence of a picture signal being present on the raster, but because of lack of synchronization, the picture is completely jumbled so that the set owner considered the complaint to be "no picture."*

Each of these five conditions (A, B, C, D, and E) must be considered carefully in either case 1 or 3 in which there is no picture, because they give important clues as to the trouble.

When the screen is completely blank no matter what the setting of the brilliancy control (condition A), either the picture tube itself is defective or it is receiving improper operating voltages. Most likely, either the low voltage or the high voltage is missing altogether.

If it is possible to see a dot of light in the center of the screen when the brilliancy control is advanced (condition B), turn the control down quickly because otherwise the screen will be damaged. This condition indicates that neither sweep circuit is working. However, the fact that a dot can be produced indicates that the picture tube is all right and that it is receiving normal low- and high-voltage supplies. For both sweep circuits to be defective, there would have to be some trouble with a power supply common to the two, or else a trouble in some stage that is connected to this supply is killing it. It is important to realize that the fact that we get a high-voltage supply on the picture tube may be an important clue. If the high-voltage supply is a fly-back type which operates from the horizontal sweep circuit, it will be impossible for the high voltage supply to work unless the horizontal sweep chain works up to the point of high-voltage take-off. In this case, the only possible difficulty would be a defective yoke on the picture tube. On the other hand, if the high-voltage supply comes from an rf oscillator and is entirely separate from the sweep circuits, then the sweep circuits can both

be defective without affecting the high voltage.

If you observe just a line on the face of the picture tube (condition C), one of the sweep circuits is functioning. A vertical line indicates that the vertical sweep is working but the horizontal sweep is defective. (Once again, if the high-voltage supply is the fly-back type, the trouble has to be in the yoke; otherwise it can be anywhere in the horizontal sweep chain.) If only a horizontal line is seen, then the vertical sweep chain contains the defect.

If you are able to see a normal raster on the face of the tube (condition D) but get no evidence of the picture, you know that the tube is working and that both power supplies are normal. The presence of the raster indicates that both sweep circuits are performing normally. Therefore, since the sweep circuits are working and the picture tube is working, we know that at least a portion of the low-voltage supply is normal and that the high-voltage supply is all right. Hence, the lack of a picture must be caused by a difficulty somewhere in the stages carrying the picture signal between the input and the picture tube.

The fifth case, in which the picture is present but is so torn up that the set owner may not realize it is present (condition E) will be treated elsewhere because such a case of lack of synchronization is not actually a case of a dead set.

Now, with the above evidence that is given by an examination of the picture tube, let's go back to consider the three "dead" set cases. To reason about these conditions properly, we must know whether the set uses an intercarrier sound system wherein the sound signal travels through practically all the video stages, or whether it is one of the "standard" types that uses i-f channels for the sound and picture signals.

Case 1. If we have a case of no picture and no sound, and a blank picture-tube screen indicates the probability of a low-voltage power-supply difficulty, we should first look there because a low-voltage power-supply difficulty would naturally kill the sound stages as well as the picture stages and picture tube. On the other hand, if there is a dot, line, or raster on the picture tube, we have reason to believe that the low-voltage supply is working at least partially, so the absence of a sound signal as well as a picture signal indicates that the difficulty probably is somewhere between the antenna input and the point where the sound signal is taken off. In the standard set, this localizes the trouble to the input tuner and to the one or two video i-f stages that may also carry the sound signal. In the case of an intercarrier set, however, we have to consider not only these stages but also all the video i-f stages, the video detector, and the video stages themselves, since a sound signal passes through all of them.

Case 2. In any case in which we have a normal picture but no sound, the trouble is definitely localized to those stages that handle the sound signal alone. The fact that you get a picture signal indicates that the power supply is probably normal.

Case 3. When the sound is normal but the picture is not present, we know that the low-voltage power supply must be all right or the sound system would not work. Also, all stages from the input of the set to the point of the sound take-off must be in good condition. In the standard set, this clears the front end, but leaves the video i-f, video detector, and video stages as possible points at which the signal may be wiped out. On the other hand, with the intercarrier set, only such stages as are between the sound take-off point and the picture tube could possibly be at fault.

From the foregoing, it is possible to apply effect-to-cause reasoning with great force in cases of a dead TV set. It is necessary to inspect the picture tube carefully to determine just what sort of pattern is on it, but then this clue, plus the presence or absence of sound, will generally lead you right to the section that is defective. Once you have your attention concentrated on the section, then there may well be some particular characteristic of the set that will lead you at once to the stage, and perhaps to the circuit and part. We will give more of this reasoning as we carry out some of the experiments.

IMPROPER OPERATION

Any condition that cannot be exactly classified as a dead set is a case of improper operation. With a sound radio receiver, it is rather easy to break down improper operation into rather definite classes such as weak reception, noisy operation, etc.

In a TV set, there are two broad classifications—weak operation, and picture distortion, and the latter can be sub-divided into about four major classifications.

Weak Operation. Weak operation is the condition in which the set is not completely dead. As a matter of fact, it may be that one stage is completely dead and that the signal is getting around this stage by stray coupling, but since the set plays after a fashion, we determine that the signal is weaker than normal, and service the set accordingly. Such a condition of weak reception may occur only on the sound, only on the picture, or on both, depending entirely on where the defect is located. Obviously, if the sound only is affected, the defect must be in one of the stages that carry the sound signal alone. If the picture alone is affected, the defect must be primarily in a picture-carrying circuit. You will have to be careful here, however, because a defect could be more or less common to both channels but may affect the picture more than the sound is apparently affected. Only long experience will lead you to suspect cases of this kind.

Picture Distortion. This broad classification can

usually be sub-divided as follows into more practical units by an inspection of the picture.

Class I. In this class, a picture is present, but is twisted or non-linear because of sweep non-linearity or because of overloading.

Class II. Here, the picture is present, whether or not the owner of the set realizes it, but the trouble is a lack of synchronization. In such a case, the vertical running or the horizontal tearing will lead you at once to the sync and sweep circuits.

Class III. Here is a case in which the quality of the picture is poor. A good example of a poor-quality picture is the case where the focus control is improperly set—a simple experiment of rotating the focus control will show exactly what is meant here. In addition to a lack of proper focusing, however, the picture quality will suffer if the high or low frequency response of the receiver is abnormal because of a defect, or improper alignment.

Case IV. Now we have interference overlays. These are patterns that lie over the actual picture. Although most of these patterns are caused by external interferences, which you will have to learn to recognize, a few may be caused by difficulties within the set itself. For example, oscillation will quite generally provide a pattern very similar to FM interference. Noise within the set will generate a characteristic noise pattern in the picture, etc.

From the foregoing, the low- and high-frequency response of the receiver generally would be normal in classes I, II, and IV. However, in the case of non-synchronization, it is important to realize that a severe loss of low-frequency response in the video i-f amplifier or in the video stages up to the point of the sync-signal takeoff may wipe out the vertical sync signal. In such a case, it may be possible to adjust the vertical hold control to get the picture to stand still, but it will then soon drift off, thus indicating that the sync signal is not reaching the vertical sweep circuit.

If the loss of low-frequency response extends far enough, it is even possible for it to affect the amplitude of the horizontal sync pulse. Also, overloading of one of the i-f stages may result in a form of clipping that may also reduce the value of the sync pulses. Ordinarily, these conditions would also affect the picture; once you got it to sync long enough to examine it, the additional clue of poor response (when observable) should lead you to the signal-carrying circuits rather than the sync chain.

In the remainder of this text, we are going to suggest a number of defects you can introduce in the receiver you have. For convenience, we have broken the text into sections on dead set, weak response, sync and sweep troubles, poor picture quality, interference overlays, and a group of miscellaneous complaints.

In introducing certain complaints we may have to use a different example for each receiver because the sets themselves differ. In other words, exactly the same trouble may not produce an identical reaction in the three set types we are using. In fact, in some instances, we cannot introduce certain troubles in one set or the other because of their electrical differences.

In every instance, we shall introduce a difficulty that will cause a particular complaint. As a practicing serviceman, you would follow the usual procedures of identifying the complaint, and then once you had localized the defective section, you would carry out the preliminary tests, such as checking tubes. Let's turn now to each complaint group and begin to introduce actual defects.

Dead Set Conditions

A considerable amount of effect-to-cause reasoning has been given in preceding sections of this text on the subject of dead receivers. Before getting into the actual complaints, let's rephrase some of these conclusions as follows:

1. If there is either sound or picture, but not both, we know that the front end is operating, as well as all stages handling whichever signal is coming through. Hence, the defect must be between the sound take-off and the output of the signal path that is not functioning.

2. If there is any sort of pattern on the screen of the picture tube, even if just a line or a dot, we can be reasonably sure the picture tube is in operating condition, and that the high-voltage supply is working. This would also indicate that the low-voltage power supply is working, because the high-voltage

NO SOUND—NO PICTURE

For our first example of this complaint, simulate a defective on-off switch by disconnecting one of the leads to it. Of course, the set should not be plugged in while you are doing this. Tape the lead so that it cannot short to anything, then set the receiver in a normal operating position.

Next, turn on the set and observe its operation. There will be no sound and no picture. Furthermore, an examination of the picture tube even with the brilliancy control advanced, will show that there is no raster, line, or dot. Hence we have a true case of a "dead" set.

The lack of a picture tube pattern of any kind indicates that either the low or the high voltages are missing or that the picture tube is defective. The lack
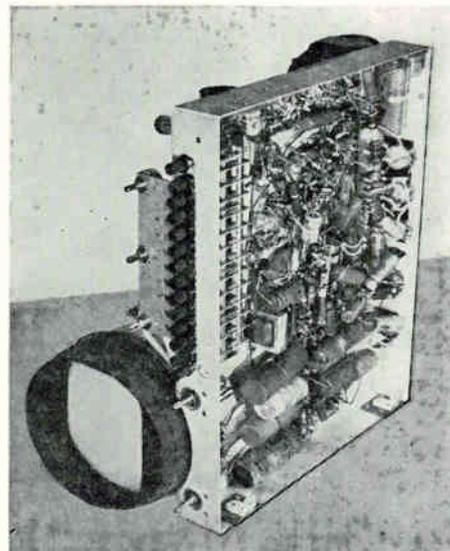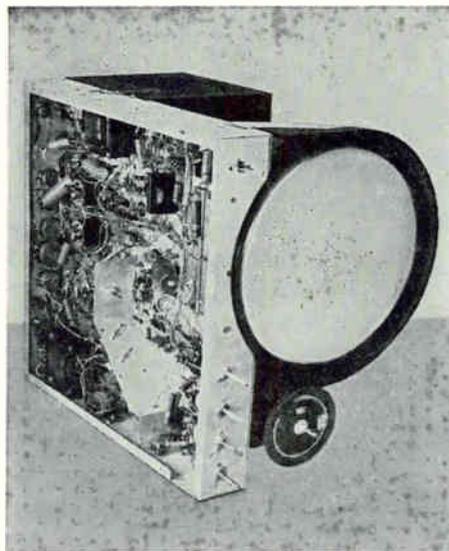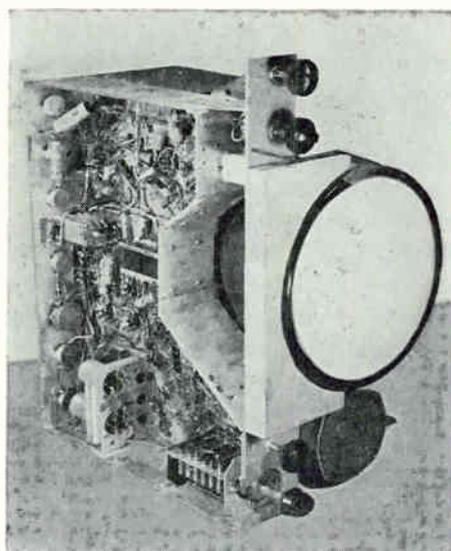
How to stand the chassis on end so that you can reach both top and bottom.

supply is dependent upon the operation of the low-voltage supply.

3. If there is a raster, we are sure that both sweeps are working, and that the high-voltage and low-voltage power supplies are both working.

From these conclusions, we can see that by applying effect-to-cause reasoning we can eliminate certain circuits and sections and can concentrate our tests on those circuits that are likely to cause the complaint encountered.

With these conclusions in mind, let's now turn to individual defects that will cause a dead set. Introduce each suggested defect, and carry out the tests that are discussed so that you can learn exactly what to expect. Incidentally, we will assume that you have restored the set to normal operating condition after completing each experiment, before you go on to the next one.

of sound at the same time further indicates the probability that the low-voltage supply is involved.

Upon examining the set, you will find an important visual clue. None of the tubes are lighted. This indicates at once that the set is getting no power. When faced with this difficulty, most servicemen would first check to be sure that there was power at the wall outlet either by plugging in a lamp or by measuring the voltage at this point with an ac voltmeter.

Finding power at the wall outlet, you can then either make a continuity check between the terminals of the ac cord, or make further voltage measurements in the set with an ac meter. If this were a service call, the set would still be in its cabinet, so you would make the simpler ohmmeter test. You would find that the ac cord showed no continuity; this would indicate that the cord itself, an interlock switch, the on-off switch, or the device receiving the power was open.

In a set using a power transformer, the interlock switch or the transformer primary would be suspected, but in a set such as the Hallicrafters, the tube filaments are in series-parallel across the power line and a tube with its filament common to all branches might be to blame. A check of such tubes (in the Hallicrafters, the 7JP4 and the 6X5) should be made. Also, the interlock switch should be checked.

As a precaution—many TV receivers have fuses; naturally, a burned-out fuse will open the circuit and prevent the application of all power.

If you cannot locate the trouble by a tube test or by an examination of devices on the surface of the set, you must remove the set from the cabinet. With the set out, you can use an ohmmeter to check for continuity through the supply circuit or you can use an ac voltmeter.

To sum up—in a receiver that has a power transformer, if the set is completely dead and none of the tubes light, the defect is usually an open fuse, a defective interlock, a defective switch, an open primary in the power transformer, or a defective line cord or plug when ac power is available at the wall outlet. In sets such as the Hallicrafters using a filament string, the most probable defect is an open tube filament, next, a defective interlock, an open fuse, an open series resistor in the filament string, a defective switch, or an open line cord.

Special Case. In the Hallicrafters receiver and other similar types, it is possible to have no sound and no raster, although some of the tubes are lighted. This is because a two-branch filament string is used, which has only two tubes common to both branches. If one of these two tubes should open, then both branches would go out. However, if a tube in any of the other branches should open, only the tubes in that branch would go out. The tubes in the other branch would remain lighted. This will usually take out so many tubes that the set exhibits no sound, no picture, and usually no raster.

In cases where certain tubes in a filament branch are shunted by small resistors, it may be possible for a tube to burn out and for the rest of the tubes in that branch to remain lighted. The resistor will be overloaded, however, and probably will eventually burn out, causing the tubes in that branch to go dark. Under such conditions, you may get a different complaint as long as the resistor is good. It may even be possible to get sound, or to get a raster until the resistor burns out and completely opens the particular branch circuit in which it is connected.

Before going on to the next experiment, reconnect the lead to the on-off switch that you disconnected earlier in this experiment. Be sure the set is unplugged while you make this connection. Try the set out to be sure that it is in good working condition, then go on to the next experiment.

NO SOUND—NO PICTURE

To simulate a second condition of no sound—no picture, let us open the B-supply circuit. A different technique must be used on each receiver.

On the RCA receiver, locate the two 5U4 rectifier tubes. From terminal 8 of one of these tubes is a lead that goes to the filter condensers and from there to the speaker field or to a choke coil, depending on the model. Disconnect this lead from the rectifier tube socket and tape it so that it cannot make contact with the socket again.

In the Stromberg-Carlson receiver, locate the time-delay relay tube (a 6AL5) and remove this tube from its socket. This will prevent the delay relay from closing and will thus remove plate voltage.

In the Hallicrafters receiver, locate the lead from socket terminal 8 of the 25Z6 rectifier tube and disconnect this lead from the tube socket. Although this does not remove all of the B-supply voltage in this set, it will take out most of it.

Turn on the set. An examination will show that the set is dead in that there is no sound, no picture, and no raster or other pattern on the picture tube. Upon making your first examination of the set, you will find that all of the tubes are lighted. Of course, on such a call, if any tube is obviously dark or burned out, it should be replaced before further tests are made—except if it is a rectifier tube. If you find that a rectifier tube is burned out, check between B+ and ground with an ohmmeter to make sure there is no short in the B circuit before installing a replacement rectifier tube.

Since in our example the tubes are lighted, we must fall back on reasoning. Since both the sound and picture circuits as well as the picture tube are affected, we realize that the defect must be in a circuit that is common to all of these.

The low-voltage power supply circuit is the only one. Therefore your next move would be to check for operating voltages. In each case we have simulated an open circuit near the rectifier tube that could be caused by a defective rectifier in the Hallicrafters set, or by an open field coil or choke in the other two.

A further clue for the Stromberg-Carlson receiver is the fact that the tuning-eye tube does not glow green even when the function switch is thrown to a position that should light it. Such a lack of illumination can only mean no B voltage if the tube is good. This coupled with the other symptoms certainly indicates no B voltage.

For this kind of defect, we should measure for B supply voltage; finding none, we must then assume either that there is a short circuit across the B supply or that it is open in some manner. Ordinarily, a defective rectifier tube would not be lighted, so if an examination shows that the rectifier is lighted,

our first check would probably be for a short circuit. In other words, the defect is more often shorted filter or by-pass condensers than an open in the B-supply choke.

If you find no short circuit, then a check of the B+ continuity should be made from the rectifier tubes to other tube plates. The B— continuity can be checked from an amplifier tube cathode back to the center tap on the high-voltage winding of a power transformer, or back to the power line and plug of a set such as the Hallicrafters. Naturally, when you are using an ohmmeter, the set is not plugged into a power outlet.

We have chosen an example that will wipe out the raster. It is possible for other defects to exist in the low-voltage power-supply circuit, such as a short in one of the decoupling networks, which will remove voltage from one or more of the tubes. When this happens, we may find no sound but a picture, we may find no picture but sound and a raster, or we may find no raster but sound. It is rare to have all three go out except for a major supply defect. Both sound and picture can be wiped out by a defect in one of the stages between the antenna and the sound take-off point, but this is exceedingly unlikely to remove the raster.

NO SOUND—NO PICTURE

As a third example of the condition of no sound and no picture, introduce a defect as follows:

To simulate a defective converter or mixer tube, merely remove this tube if your set is of the RCA or the Stromberg-Carlson series. In the RCA this is tube V2; in the Stromberg-Carlson the converter is tube V-102.

We cannot remove tubes from the Hallicrafters receiver. Therefore, to simulate a defective mixer tube in this set, locate the B supply for the mixer. The plate supply is furnished through coil L14 and by tracing from the end of this coil that connects to the screen-grid terminal of the mixer tube V6, you will find by-pass condenser C42 and a resistor R36. Disconnect the resistor R36 so that both the screen-grid voltage and the plate voltage will be removed from the mixer tube.

With this simulated defect, turn on the set and notice how it acts. You will see that you now have a raster (turn up the brilliancy enough to see this), but neither sound nor picture. This means that the low-voltage power supply must be working because the sweeps are working to produce the raster, and also that the high-voltage supply is working. Whatever defect exists must be in some stage between the antenna input and the point where the sound signal is taken off. Of course, one must be careful not to be fooled by the fact that the stations may not be on the air at the time of making such a trial, and one

must be certain that the antenna and lead-in systems are performing normally.

With no station on the air, you should be able to see the effects of noise in the form of snow on the raster. However, in our case of a defect between the antenna input and the sound take-off point, there may be no snow. In particular, since the mixer is the "defective" stage, most of the noise developed within the set will be removed also.

Since both the sound and the picture are gone, the trouble has to be ahead of the sound take-off point, as we have mentioned. Here, a knowledge of the circuit is important—you must know where the sound take-off is located. In the RCA receiver, the sound take-off is at the first i-f transformer, right at the output of the converter, so this means that the trouble must be between the antenna and this point in the set. This leaves only the front end of the set as a possibility. We can at once limit our tests to this particular section.

In the Stromberg-Carlson receiver, the sound take-off is at the output of the first video i-f stage. Here, we have the front end and this one stage as possible sources of trouble, and our tests are again concentrated.

In intercarrier sets like the Hallicrafters, however, the sound take-off is in the video section. In the Hallicrafters, it is at the output of the first video amplifier. Since both the sound and picture are missing, we know that the trouble in this set must be somewhere in the front end, the i-f, the video detector, or the first video amplifier, but we now have many more stages to check. The practical serviceman would first check the tubes in these sections. If this does not localize the trouble, further tests are more easily made with the set out of the cabinet. (When you take this set out of its cabinet, you must take off the interlock connector to supply power, as was described in text 1TX. A special cable is available that will void the interlock, but unless you service large quantities of this type of set, it doesn't pay to buy it.) With the set out, you might try a signal injection test of one form or another. An audio frequency introduced across the video-detector load would show up on the raster as a series of bars if the video amplifier is working. However, this test isn't extremely valuable as it tests only one tube circuit in the group we must check. Another test is to introduce a signal at an i-f frequency in the i-f section. You can connect to the hot signal-generator lead either several turns of wire or a tube shield. (Be sure the shield doesn't ground to the chassis.) Placing this coupler over a tube early in the i-f chain will introduce enough signal into the tube circuit to give a visible or audible indication. You can also couple directly into a grid circuit by using a blocking condenser in the signal generator lead.
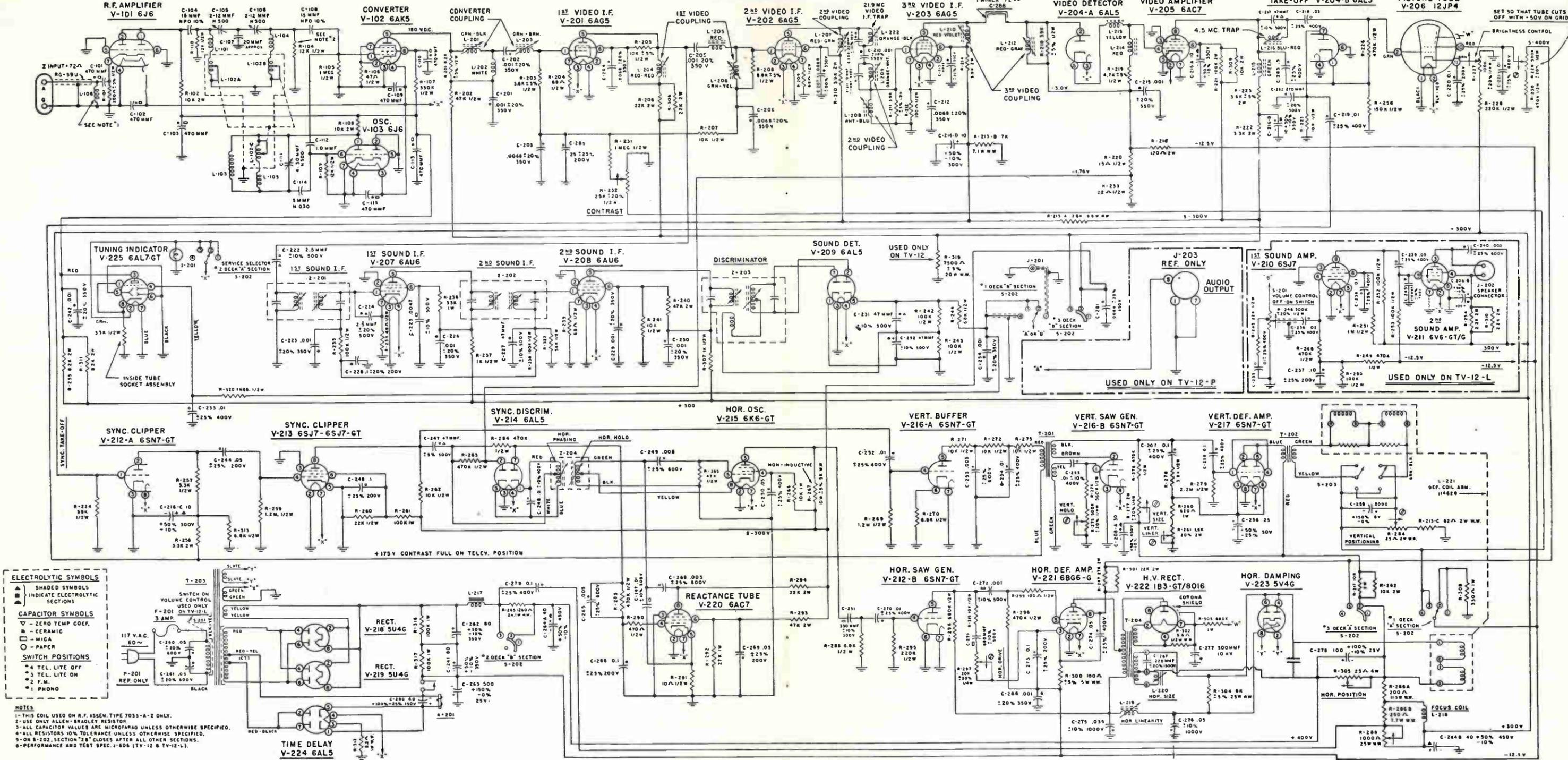
Note: 1. Terminal 5 of horizontal output transformer T204 returns to +400 volts.
2. R-258 is 33K instead of 3.3K.
3. R-309 is 100K instead of 10K.
4. On recent models the relay contacts of K-201 break the B+ lead instead of the B—. This is between the junction of R-316 and L-217, and the cathodes (pin 8) of V-218 and V-219.

FIG. B. STROMBERG-CARLSON SERIES.

CIRCUIT SCHEMATIC DIAGRAM


FIG. C. THE RCA 630TS.

FIG. A. HALLICRAFTERS SERIES.

After this test, the next most logical test method would be reading the operating voltages.

We have assumed in this discussion that there is only one defect. However, an important point to remember is that there is always the possibility of a dual defect. Thus, although in general we can reasonably assume that when we get no sound and no picture the trouble must be in the circuits common to both, it is possible that there is trouble in two circuits at the same time. There may well be some defect that would make both an audio and a video stage inoperative at the same time. This is particularly likely to occur when there is a common power supply connection for these stages. Also, half of a multi-purpose tube may be used in one channel and half in another, in which case a defect in the tube or in its supply would block more than one channel. Therefore, if you find your tests do not seem to indicate trouble in the stages common to both channels, you may have to check other sections as well.

After examining the conditions produced by the simulated defect, be sure you restore the set to normal. Replace the converter tube (or restore the screen-grid and B-supply in the Hallicrafters set). Check the set to be sure it is normal before going on to the next experiment.

PICTURE OK—NO SOUND

The second class of dead set defects are those in which the picture channel works normally but there is no sound. In this experiment you will simulate this condition.

Locate the first audio i-f amplifier tube and disconnect the B supply decoupling resistor that feeds both the screen-grid and the plate of this tube. Be sure that you disconnect this resistor so that both the screen and plate supplies are removed. (If you remove only the plate supply from a pentode tube, the screen-grid current will be excessive and the tube may be damaged.) In the Hallicrafters receiver, this tube is V_1, a 6AU6 tube; the resistor for you to disconnect is R_{14}. In the Stromberg-Carlson, the tube is V-207, and the resistor is R-237. In the RCA receiver, the tube is V-104 and the resistor is R-213. Locate this resistor and disconnect one end to interrupt the B supply in either case.

Turn on the set and try it out. If a station is on the air, you will find that you can get a picture, but there will be no sound.

Here is an important thing to remember—many TV stations remove the sound transmission for a period of time when sending the test pattern. This is usually done near the hour or half hour for about five minutes. In such cases, the sound will disappear entirely, but there is nothing wrong with the set.

When there is a picture but no sound, reasoning indicates that the difficulty must definitely be in a tube that handles only the audio signal. It cannot be in any stage that is common to the picture signal path without affecting the picture signal also. Furthermore, the sync circuits and sweeps must be normal or you would not get a picture.

Since the trouble could be anywhere in the sound path from the second take-off to the loudspeaker, it is desirable to make an isolation test. You can perform a circuit disturbance test on sets that do not have filament strings by withdrawing tubes and listening for a thump or click from the loudspeaker as the tube is withdrawn. (If one of the sound i-f stages is a limiter, you may find that the circuit disturbance test of pulling out and reinserting tubes ahead of that point does not produce as loud a click as you would imagine, because of normal limiting action.)

With filament strings, this may not work very well because pulling out a tube in a dead stage interrupts the filament supply for the output stage and all other audio stages as well, so it is possible for the disturbance to travel through the set. Therefore, the logical thing to do is to check the tubes in the audio section and then to measure supply voltages.

With the set out of its cabinet, you can make several other tests. For example, you can run the volume control up to a full "on" position, and then touch the hot terminal of the volume control with your finger. Ordinarily this will produce at least a click and more probably a hum if the audio stages are working. You can try a signal injection test by using a signal generator set at the sound i-f carrier frequency and feeding the signal in at various points through the sound i-f amplifier.

Restore the set to normal before going on to the next experiment.

SOUND OK—NO PICTURE

In the third class of complaint, we have a condition in which we can hear the sound signal, but the picture is not visible. Again you must be sure that the particular station is actually sending out a picture—there may have been some failure, which they will undoubtedly announce. It is desirable to know what is on the air, so in your shop, you can have a monitor receiver set up that will permit you to monitor the programs constantly. If you are out on a service call, it may be advisable for you to call the shop to ask just what is being picked up there at the moment.

To simulate the complaint, follow these instructions:

In the RCA or Stromberg-Carlson series, remove the horizontal sweep oscillator tube. In the RCA this is tube V125, and in the Stromberg-Carlson series it is tube V-215. It is a 6K6 tube in either case.

In the Hallicrafters receiver you cannot pull out tubes (except the high-voltage rectifier) without

breaking the filament string. Therefore, in this set, break the plate supply to the high-voltage oscillator tube V_{21}. Do this by disconnecting either end of the choke coil L_{26B}.

Turn on the set. In any of these cases, you will find that you can get sound, but that there is no picture—in fact there is no raster, line, or dot on the picture-tube face. The fact that there is no picture-tube pattern further indicates that the trouble is with either the picture tube or its voltage supplies. The fact that we get sound indicates that the low-voltage supply is working at least partly, so it is logical to suspect the high-voltage supply or the picture tube.

Picture tubes do go bad, but on the average their life is surprisingly long. However, their filaments may open or the cathode may lose emission. The latter condition can be found only by trying another tube, but an examination of the picture tube should disclose a lighted filament. Learn the angle at which you can see this glow—it is necessary to look at an angle from the front of the tube back into the gun.

If the picture tube appears normal, or if you try another one and get the same result, the high-voltage supply is left to be suspected.

In sets such as the Hallicrafters, the high-voltage supply operates from an oscillator which generates an rf voltage that is stepped up, rectified, and filtered.

In sets such as the RCA and Stromberg-Carlson, a fly-back supply is employed. Here, the horizontal sweep oscillator produces a driving signal to operate the horizontal output tube. The fly-back from the operation of the yoke, through the fly-back transformer, generates the high-voltage pulse that is rectified and filtered.

In either type of receiver, we can determine whether or not there is high voltage by measuring the voltage applied to the picture tube. With electromagnetic tubes, it is easiest to measure between the set chassis and the high voltage contactor on the side of the tube. With electrostatic tubes the high voltage is applied to the tube socket. Of course, in either instance, this measurement can be made only if you have a high-voltage multiplying probe for your multimeter.

It is possible to tell whether or not high voltage is applied to an electromagnetic picture tube by drawing an arc with a screwdriver. The screwdriver must be one with a well insulated handle. The shaft is held firmly against a bracket or shield that will ground it, then the blade is brought near the high-voltage contactor on the side of the picture tube. An arc indicates voltage is present, and with experience, you can tell fairly well from the size of the arc approximately how much voltage there is. However, because of the danger of possible shocks, you should use a high-voltage multiplier probe if available.

In the Hallicrafters receiver, since the high-voltage supply consists of only two tubes, there is not much point in trying to break it down into sections. However, in the other receivers, since the whole horizontal sweep circuit is involved, breaking into sections is desirable.

In many receivers, it is possible to see the filament of the high-voltage rectifier through the shield around the high-voltage supply, if you get down to look up into the tube. If you can observe this filament, note carefully whether or not it is illuminated. Filament current for this tube comes from the same source as the voltage being rectified; therefore, if this source is lacking, the high-voltage rectifier tube will not glow.

If you observe that the rectifier tube is lighted, but find no high voltage, then this shows that excitation is reaching the rectifier tube. Therefore, we undoubtedly have an open in the filter circuit between the rectifier tube and the picture tube, or else the rectifier tube itself has lost its emission. The latter condition could be caused by a short circuit in one of the filter condensers, so if you find the rectifier tube is defective, use an ohmmeter to check the filter circuit. Be very careful to allow plenty of time for these condensers to discharge, however, then short circuit them with a test lead.

If the rectifier tube is not lighted, it is burned out or is not being excited, but you have no real guarantee that this lack of excitation is due to trouble ahead of this tube—a short circuit in the filter circuit following the rectifier may load the source sufficiently to remove excitation.

In the case of the Hallicrafters type of rf supply, remove the high-voltage shield, and then be very careful not to get shocked. Measure the dc voltage developed across the oscillator grid resistor. If there is no voltage there, the oscillator is not functioning. In this case, remove the rectifier tube from its socket and again make a check. If the circuit now works, the trouble is a short in the filter circuit beyond the rectifier tube, which is so loading the oscillator that it cannot function. However, if the oscillator remains dead with the rectifier out of its socket, make voltage measurements or use your ohmmeter on the oscillator circuit, after checking the tube.

In the fly-back supply, you can make a check for excitation at the grid of the horizontal output tube. To do this, you can either measure the dc voltage across the grid resistor of this tube, or use an oscilloscope to check for a signal at its grid. In measuring the grid voltage, be sure you get right across the grid resistor, as frequently the grid return goes back to a highly negative supply. If you find a dc voltage across this resistor that makes the grid negative, then a signal is reaching this point. In using the

oscilloscope between the grid and the chassis, you should get a deflection corresponding to the input voltage if such voltage is reaching this point. This gives a visual check on the signal.

If you find that excitation is not reaching the horizontal output tube, then obviously the trouble must be in the horizontal sweep oscillator or in the sweep shaping stage.

On the other hand, if you find excitation at the grid of the horizontal output tube, you could have a defective output tube, a defective output transformer, a defective deflection yoke, or a defective rectifier or filter circuit.

WARNING: Don't try to measure the plate voltage on the horizontal output tube at the tube socket unless you have a voltage-multiplying probe. This voltage reaches very high peak values—often as much as several thousand volts. If you do measure at this point, however, and find that you have such a high voltage present, then the output tube, the fly-back transformer and the yoke are working. On the other hand, if this voltage is absent, one of these three devices is defective.

Restore your set to normal, then observe the filament in both the picture tube and the high-voltage rectifier. Be sure the set operates normally.

Special Case. In sets of the Hallicrafters type having electrostatic deflection, leakage in the coupling condensers between the sweep amplifier tubes and the deflecting plates of the picture tube may cause any of three complaints related to no picture.

In the first case, the leaky condenser may load the high-voltage supply and cause the high voltage to disappear, thus completely blanking the picture tube. A check of the high-voltage supply will show no voltage, and removing the rectifier will show that the oscillator performs if you measure across the oscillator grid resistor for a dc bias. In such a case, you should check the high-voltage filter condensers. Finding them all right and resistance values apparently nearly normal, you should disconnect these coupling condensers to find the offender. An ohmmeter check is practically useless because the leakage values are fairly high.

In the second case, the picture is off the screen because the sweep output stage is upset, but the high-voltage supply is still working. Turn off the set. If as you turn it off, the beam suddenly moves in from off the face of the tube to settle down near the center of the screen, it was being deflected too much in one direction. If it comes from the side, the horizontal condensers are leaky; if it comes from the top or the bottom, the vertical condensers are leaky.

In the third case, the picture will be centered normally but as the set warms up will gradually drift off. Readjusting the centering controls will move it back, but eventually it will be impossible to center it with the controls. In this case also, these condensers are leaky. These latter conditions should be described in the section on sweep and sync difficulties but must be mentioned here because of the interaction between these effects.

SOUND OKAY—NO PICTURE

To show another case of this complaint, introduce the following simulated defect:

On the Hallicrafters receiver, simulate an open coupling condenser in the video amplifier. The best one to work on is condenser C_{17}, which goes from the cathode terminal 3 of the video output V_{12} to the cathode terminal of the picture tube. Disconnect one terminal of this condenser but leave the rest of the circuit normal.

In the RCA and Stromberg-Carlson receivers, pull out the video second detector.

When you turn on the set, you will find normal sound. Looking at the picture tube, you will see that a raster appears on the screen of the tube when the brilliancy is turned up, but that either no picture at all, or at best an exceedingly faint indication of a picture will be seen.

Regardless of the type of set, if you get a raster on the screen of the picture tube, you know immediately that the sweep circuits, the high-voltage supply and most of the low-voltage power-supply circuits must be working. Since you get sound, all the audio stages and all the stages that are common to the picture and audio signal paths must be working. Therefore, we know that our difficulty must be between the point of sound take-off and the picture tube grid. In intercarrier sound systems, such as that in the Hallicrafters, the sound take-off is in the video amplifier, which leaves very little of the set for you to examine. As a matter of fact, the trouble in the Hallicrafters set has to be centered between the plate circuit of the first video amplifier and the picture tube grid, which leaves only one stage and its input and output couplings to be examined. You would normally check this tube and measure operating voltages. If these are both normal, an open coupling condenser is the most logical suspect. As you know, an ohmmeter will not show up an open coupling condenser, so the only logical test with the set out before you is to try other condensers in place of those in the set in the questioned stage.

In the case of the RCA and Stromberg-Carlson types, the sound take-off point is early in the video i-f section. There is much more of the set in which trouble could develop—we have the remainder of the video i-f, the picture detector, and the video amplifier to consider.

We could check tubes and possibly measure voltage. However, once the set is out where you can work on it, you could try signal injection to determine

whether the video amplifier is working. To do this, you can feed an audio signal into the picture second detector. This signal can be from an audio signal generator, or else you could use the test probe described earlier in this text to feed a signal from the output of the audio amplifier into this point.

If the video stages are working, this audio signal will travel through them and will produce a series of lines on the raster. If you fail to get these, the trouble must be in the video stages. On the other hand, if you do get them, you know the trouble must be between the sound take-off point and the place where you have introduced your signal. Since the signal is being fed into the input of the first video stage, you now have the trouble localized to three or four stages at the most.

Another possible check for you to make would be to measure for a dc voltage across the load of the picture second detector. Lack of voltage here when a signal is tuned in (indicated by a sound signal) means that the picture signal is not reaching this point. On the other hand if you find a dc voltage here that varies as you tune the set, then the trouble would have to be in the video stages.

With the trouble localized to either the video amplifier or to the i-f amplifier and picture detector, you would normally proceed to test tubes and check operating voltages.

However, if the set is out of its cabinet, you can try the signal injection test further. With a signal generator adjusted to the i-f of the set, the signal can be injected a stage at a time as you move back from the video detector toward the input until you pass through the stage that does not pass the signal satisfactorily. The only difficulty with this procedure is the fact that the signal generator has to have a fairly high output, and there is some trouble in coupling it to the stages. It is possible to couple by using several turns of wire or a tube shield connected to the hot lead of the signal generator. By placing the wire or shield over a tube, enough signal may be introduced into the plate circuit of this tube to give an indication on the picture tube. A better method is to connect to the control-grid terminals (through a blocking condenser) as you move along.

It is possible to signal-trace through the video i-f amplifier if you have a cathode-ray oscilloscope and an rf probe. This probe rectifies the incoming signal, allowing the oscilloscope to reproduce the modulation. In signal tracing, you start near the input of the set where a signal is known to be present because a sound signal passes, and then work back toward the output of the set. The rf probe can be connected directly to the grid circuits of the tube stages as you move along. If the signal is weak, you may find it difficult to get a reasonable indication when working in the first few i-f stages.

SUMMARY

In the foregoing section, we have given several examples of each of the classes of dead receiver, and have also shown how effect-to-cause reasoning can be applied to what you see on the picture tube screen to help you to localize the trouble. Tests are then suggested for localizing the difficulty further. If you have been following our plan of introducing a defect, these tests should lead you to the stage in which you have introduced it. Where we told you to withdraw a tube, you have simulated a defective tube, which would be found by a tube test in a practical service job.

Although methods of testing in a TV set are not as well developed as those used in radio servicing because of the lack of properly designed equipment, the TV set does have the advantage that the operation of the various sections is indicated by the picture tube and by the loudspeaker, so it is generally easier to localize the defective section than it is in a radio receiver. However, once again we must point out that it is important not to be fooled by defects in one section that may also affect another section. Also, we have assumed that there is only one difficulty in the set, whereas it is always possible that there are two at the same time, or that two or more circuits are affected by one common defect in a power supply or in a dual tube. Difficulties of this kind should always be suspected whenever you find that the most logical isolation procedure is giving you what is apparently an incorrect result.

After this test, the next most logical test method would be reading the operating voltages.

We have assumed in this discussion that there is only one defect. However, an important point to remember is that there is always the possibility of a dual defect. Thus, although in general we can reasonably assume that when we get no sound and no picture the trouble must be in the circuits common to both, it is possible that there is trouble in two circuits at the same time. There may well be some defect that would make both an audio and a video stage inoperative at the same time. This is particularly likely to occur when there is a common power supply connection for these stages. Also, half of a multi-purpose tube may be used in one channel and half in another, in which case a defect in the tube or in its supply would block more than one channel. Therefore, if you find your tests do not seem to indicate trouble in the stages common to both channels, you may have to check other sections as well.

After examining the conditions produced by the simulated defect, be sure you restore the set to normal. Replace the converter tube (or restore the screen-grid and B-supply in the Hallicrafters set). Check the set to be sure it is normal before going on to the next experiment.

PICTURE OK—NO SOUND

The second class of dead set defects are those in which the picture channel works normally but there is no sound. In this experiment you will simulate this condition.

Locate the first audio i-f amplifier tube and disconnect the B supply decoupling resistor that feeds both the screen-grid and the plate of this tube. Be sure that you disconnect this resistor so that both the screen and plate supplies are removed. (If you remove only the plate supply from a pentode tube, the screen-grid current will be excessive and the tube may be damaged.) In the Hallicrafters receiver, this tube is V_1, a 6AU6 tube; the resistor for you to disconnect is R_{14}. In the Stromberg-Carlson, the tube is V-207, and the resistor is R-237. In the RCA receiver, the tube is V-104 and the resistor is R-213. Locate this resistor and disconnect one end to interrupt the B supply in either case.

Turn on the set and try it out. If a station is on the air, you will find that you can get a picture, but there will be no sound.

Here is an important thing to remember—many TV stations remove the sound transmission for a period of time when sending the test pattern. This is usually done near the hour or half hour for about five minutes. In such cases, the sound will disappear entirely, but there is nothing wrong with the set.

When there is a picture but no sound, reasoning indicates that the difficulty must definitely be in a tube that handles only the audio signal. It cannot be in any stage that is common to the picture signal path without affecting the picture signal also. Furthermore, the sync circuits and sweeps must be normal or you would not get a picture.

Since the trouble could be anywhere in the sound path from the second take-off to the loudspeaker, it is desirable to make an isolation test. You can perform a circuit disturbance test on sets that do not have filament strings by withdrawing tubes and listening for a thump or click from the loudspeaker as the tube is withdrawn. (If one of the sound i-f stages is a limiter, you may find that the circuit disturbance test of pulling out and reinserting tubes ahead of that point does not produce as loud a click as you would imagine, because of normal limiting action.)

With filament strings, this may not work very well because pulling out a tube in a dead stage interrupts the filament supply for the output stage and all other audio stages as well, so it is possible for the disturbance to travel through the set. Therefore, the logical thing to do is to check the tubes in the audio section and then to measure supply voltages.

With the set out of its cabinet, you can make several other tests. For example, you can run the volume control up to a full "on" position, and then touch the hot terminal of the volume control with your finger. Ordinarily this will produce at least a click and more probably a hum if the audio stages are working. You can try a signal injection test by using a signal generator set at the sound i-f carrier frequency and feeding the signal in at various points through the sound i-f amplifier.

Restore the set to normal before going on to the next experiment.

SOUND OK—NO PICTURE

In the third class of complaint, we have a condition in which we can hear the sound signal, but the picture is not visible. Again you must be sure that the particular station is actually sending out a picture—there may have been some failure, which they will undoubtedly announce. It is desirable to know what is on the air, so in your shop, you can have a monitor receiver set up that will permit you to monitor the programs constantly. If you are out on a service call, it may be advisable for you to call the shop to ask just what is being picked up there at the moment.

To simulate the complaint, follow these instructions:

In the RCA or Stromberg-Carlson series, remove the horizontal sweep oscillator tube. In the RCA this is tube V125, and in the Stromberg-Carlson series it is tube V-215. It is a 6K6 tube in either case.

In the Hallicrafters receiver you cannot pull out tubes (except the high-voltage rectifier) without

breaking the filament string. Therefore, in this set, break the plate supply to the high-voltage oscillator tube V_{21}. Do this by disconnecting either end of the choke coil L_{26B}.

Turn on the set. In any of these cases, you will find that you can get sound, but that there is no picture—in fact there is no raster, line, or dot on the picture-tube face. The fact that there is no picture-tube pattern further indicates that the trouble is with either the picture tube or its voltage supplies. The fact that we get sound indicates that the low-voltage supply is working at least partly, so it is logical to suspect the high-voltage supply or the picture tube.

Picture tubes do go bad, but on the average their life is surprisingly long. However, their filaments may open or the cathode may lose emission. The latter condition can be found only by trying another tube, but an examination of the picture tube should disclose a lighted filament. Learn the angle at which you can see this glow—it is necessary to look at an angle from the front of the tube back into the gun.

If the picture tube appears normal, or if you try another one and get the same result, the high-voltage supply is left to be suspected.

In sets such as the Hallicrafters, the high-voltage supply operates from an oscillator which generates an rf voltage that is stepped up, rectified, and filtered.

In sets such as the RCA and Stromberg-Carlson, a fly-back supply is employed. Here, the horizontal sweep oscillator produces a driving signal to operate the horizontal output tube. The fly-back from the operation of the yoke, through the fly-back transformer, generates the high-voltage pulse that is rectified and filtered.

In either type of receiver, we can determine whether or not there is high voltage by measuring the voltage applied to the picture tube. With electromagnetic tubes, it is easiest to measure between the set chassis and the high voltage contactor on the side of the tube. With electrostatic tubes the high voltage is applied to the tube socket. Of course, in either instance, this measurement can be made only if you have a high-voltage multiplying probe for your multimeter.

It is possible to tell whether or not high voltage is applied to an electromagnetic picture tube by drawing an arc with a screwdriver. The screwdriver must be one with a well insulated handle. The shaft is held firmly against a bracket or shield that will ground it, then the blade is brought near the high-voltage contactor on the side of the picture tube. An arc indicates voltage is present, and with experience, you can tell fairly well from the size of the arc approximately how much voltage there is. However, because of the danger of possible shocks, you should use a high-voltage multiplier probe if available.

In the Hallicrafters receiver, since the high-voltage supply consists of only two tubes, there is not much point in trying to break it down into sections. However, in the other receivers, since the whole horizontal sweep circuit is involved, breaking into sections is desirable.

In many receivers, it is possible to see the filament of the high-voltage rectifier through the shield around the high-voltage supply, if you get down to look up into the tube. If you can observe this filament, note carefully whether or not it is illuminated. Filament current for this tube comes from the same source as the voltage being rectified; therefore, if this source is lacking, the high-voltage rectifier tube will not glow.

If you observe that the rectifier tube is lighted, but find no high voltage, then this shows that excitation is reaching the rectifier tube. Therefore, we undoubtedly have an open in the filter circuit between the rectifier tube and the picture tube, or else the rectifier tube itself has lost its emission. The latter condition could be caused by a short circuit in one of the filter condensers, so if you find the rectifier tube is defective, use an ohmmeter to check the filter circuit. Be very careful to allow plenty of time for these condensers to discharge, however, then short circuit them with a test lead.

If the rectifier tube is not lighted, it is burned out or is not being excited, but you have no real guarantee that this lack of excitation is due to trouble ahead of this tube—a short circuit in the filter circuit following the rectifier may load the source sufficiently to remove excitation.

In the case of the Hallicrafters type of rf supply, remove the high-voltage shield, and then be very careful not to get shocked. Measure the dc voltage developed across the oscillator grid resistor. If there is no voltage there, the oscillator is not functioning. In this case, remove the rectifier tube from its socket and again make a check. If the circuit now works, the trouble is a short in the filter circuit beyond the rectifier tube, which is so loading the oscillator that it cannot function. However, if the oscillator remains dead with the rectifier out of its socket, make voltage measurements or use your ohmmeter on the oscillator circuit, after checking the tube.

In the fly-back supply, you can make a check for excitation at the grid of the horizontal output tube. To do this, you can either measure the dc voltage across the grid resistor of this tube, or use an oscilloscope to check for a signal at its grid. In measuring the grid voltage, be sure you get right across the grid resistor, as frequently the grid return goes back to a highly negative supply. If you find a dc voltage across this resistor that makes the grid negative, then a signal is reaching this point. In using the

oscilloscope between the grid and the chassis, you should get a deflection corresponding to the input voltage if such voltage is reaching this point. This gives a visual check on the signal.

If you find that excitation is not reaching the horizontal output tube, then obviously the trouble must be in the horizontal sweep oscillator or in the sweep shaping stage.

On the other hand, if you find excitation at the grid of the horizontal output tube, you could have a defective output tube, a defective output transformer, a defective deflection yoke, or a defective rectifier or filter circuit.

WARNING: Don't try to measure the plate voltage on the horizontal output tube at the tube socket unless you have a voltage-multiplying probe. This voltage reaches very high peak values—often as much as several thousand volts. If you do measure at this point, however, and find that you have such a high voltage present, then the output tube, the fly-back transformer and the yoke are working. On the other hand, if this voltage is absent, one of these three devices is defective.

Restore your set to normal, then observe the filament in both the picture tube and the high-voltage rectifier. Be sure the set operates normally.

Special Case. In sets of the Hallicrafters type having electrostatic deflection, leakage in the coupling condensers between the sweep amplifier tubes and the deflecting plates of the picture tube may cause any of three complaints related to no picture.

In the first case, the leaky condenser may load the high-voltage supply and cause the high voltage to disappear, thus completely blanking the picture tube. A check of the high-voltage supply will show no voltage, and removing the rectifier will show that the oscillator performs if you measure across the oscillator grid resistor for a dc bias. In such a case, you should check the high-voltage filter condensers. Finding them all right and resistance values apparently nearly normal, you should disconnect these coupling condensers to find the offender. An ohmmeter check is practically useless because the leakage values are fairly high.

In the second case, the picture is off the screen because the sweep output stage is upset, but the high-voltage supply is still working. Turn off the set. If as you turn it off, the beam suddenly moves in from off the face of the tube to settle down near the center of the screen, it was being deflected too much in one direction. If it comes from the side, the horizontal condensers are leaky; if it comes from the top or the bottom, the vertical condensers are leaky.

In the third case, the picture will be centered normally but as the set warms up will gradually drift off. Readjusting the centering controls will move it back, but eventually it will be impossible to center it with

the controls. In this case also, these condensers are leaky. These latter conditions should be described in the section on sweep and sync difficulties but must be mentioned here because of the interaction between these effects.

SOUND OKAY—NO PICTURE

To show another case of this complaint, introduce the following simulated defect:

On the Hallicrafters receiver, simulate an open coupling condenser in the video amplifier. The best one to work on is condenser C_{17}, which goes from the cathode terminal 3 of the video output V_{12} to the cathode terminal of the picture tube. Disconnect one terminal of this condenser but leave the rest of the circuit normal.

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When you turn on the set, you will find normal sound. Looking at the picture tube, you will see that a raster appears on the screen of the tube when the brilliancy is turned up, but that either no picture at all, or at best an exceedingly faint indication of a picture will be seen.

Regardless of the type of set, if you get a raster on the screen of the picture tube, you know immediately that the sweep circuits, the high-voltage supply and most of the low-voltage power-supply circuits must be working. Since you get sound, all the audio stages and all the stages that are common to the picture and audio signal paths must be working. Therefore, we know that our difficulty must be between the point of sound take-off and the picture tube grid. In intercarrier sound systems, such as that in the Hallicrafters, the sound take-off is in the video amplifier, which leaves very little of the set for you to examine. As a matter of fact, the trouble in the Hallicrafters set has to be centered between the plate circuit of the first video amplifier and the picture tube grid, which leaves only one stage and its input and output couplings to be examined. You would normally check this tube and measure operating voltages. If these are both normal, an open coupling condenser is the most logical suspect. As you know, an ohmmeter will not show up an open coupling condenser, so the only logical test with the set out before you is to try other condensers in place of those in the set in the questioned stage.

In the case of the RCA and Stromberg-Carlson types, the sound take-off point is early in the video i-f section. There is much more of the set in which trouble could develop—we have the remainder of the video i-f, the picture detector, and the video amplifier to consider.

We could check tubes and possibly measure voltage. However, once the set is out where you can work on it, you could try signal injection to determine

whether the video amplifier is working. To do this, you can feed an audio signal into the picture second detector. This signal can be from an audio signal generator, or else you could use the test probe described earlier in this text to feed a signal from the output of the audio amplifier into this point.

If the video stages are working, this audio signal will travel through them and will produce a series of lines on the raster. If you fail to get these, the trouble must be in the video stages. On the other hand, if you do get them, you know the trouble must be between the sound take-off point and the place where you have introduced your signal. Since the signal is being fed into the input of the first video stage, you now have the trouble localized to three or four stages at the most.

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With the trouble localized to either the video amplifier or to the i-f amplifier and picture detector, you would normally proceed to test tubes and check operating voltages.

However, if the set is out of its cabinet, you can try the signal injection test further. With a signal generator adjusted to the i-f of the set, the signal can be injected a stage at a time as you move back from the video detector toward the input until you pass through the stage that does not pass the signal satisfactorily. The only difficulty with this procedure is the fact that the signal generator has to have a fairly high output, and there is some trouble in coupling it to the stages. It is possible to couple by using several turns of wire or a tube shield connected to the hot lead of the signal generator. By placing the wire or shield over a tube, enough signal may be introduced into the plate circuit of this tube to give an indication on the picture tube. A better method is to connect to the control-grid terminals (through a blocking condenser) as you move along.

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SUMMARY

In the foregoing section, we have given several examples of each of the classes of dead receiver, and have also shown how effect-to-cause reasoning can be applied to what you see on the picture tube screen to help you to localize the trouble. Tests are then suggested for localizing the difficulty further. If you have been following our plan of introducing a defect, these tests should lead you to the stage in which you have introduced it. Where we told you to withdraw a tube, you have simulated a defective tube, which would be found by a tube test in a practical service job.

Although methods of testing in a TV set are not as well developed as those used in radio servicing because of the lack of properly designed equipment, the TV set does have the advantage that the operation of the various sections is indicated by the picture tube and by the loudspeaker, so it is generally easier to localize the defective section than it is in a radio receiver. However, once again we must point out that it is important not to be fooled by defects in one section that may also affect another section. Also, we have assumed that there is only one difficulty in the set, whereas it is always possible that there are two at the same time, or that two or more circuits are affected by one common defect in a power supply or in a dual tube. Difficulties of this kind should always be suspected whenever you find that the most logical isolation procedure is giving you what is apparently an incorrect result.

Conditions Causing Weak Reception

When the complaint is weak reception of the sound or the picture or both, some stage is not operating at maximum efficiency. As a matter of fact, it is possible for one stage to be completely dead, and for the signal from a strong station to get around this stage because of stray coupling to a sufficient degree to make the complaint that of weak reception rather than dead set.

As a general rule, when called to service a set with weak reception as the complaint, be sure to check the installation carefully. Watch particularly for cases in which one side of the transmission line from the antenna may be disconnected. In your shop, you can try the set in comparison with your monitor set on the same antenna system to determine whether the set is truly defective.

Notice carefully whether both the sound and picture are affected, or whether only one of them is. If both are affected, the trouble must be in some stage that handles both signals, or there are improper operating voltages on several stages. On the other hand, if the trouble is present only on the picture, or only on the sound, then obviously it must be in some stage that handles only that signal.

Where the set uses separate sound and picture channels, a defect producing weak reception on both sound and picture must be in a limited number of stages or in the power supply. On the other hand, with an intercarrier set, there are a lot more stages that could be involved.

An important clue is whether the weak reception has developed very gradually or came on suddenly.

Any sudden development of this complaint indicates more definitely a *breakdown*—look for a defective tube, shorted by-pass condensers, etc., and expect to find a single defect. A gradual development of trouble may be the result of a single defect, but may also be the result of conditions like emission loss in several tubes, over-all reduction in operating voltages due to loss of input filter capacity or weak rectifiers, or set going out of alignment. These may represent slight changes in individual stages but the over-all effect may be appreciable.

The most obvious way to localize weak reception would be by means of some form of signal tracer that was capable of indicating gain. Unfortunately, as we indicated earlier, no such signal tracer has yet been developed for TV service work. Furthermore, one has to be very careful about checking stage gain at any one particular frequency, particularly when dealing with the video i-f amplifier. Here, some stages have very little gain at one frequency but may have quite a reasonable gain at another. This is particularly true in a stagger-tuned system.

Since the most logical test—that of signal tracing in which one measures gain—is not readily available, about the only thing that can be done is to check operating potentials carefully in the section affected, or else to use an oscilloscope as a peak indicator and thus to obtain an idea of the relative gain. The oscilloscope can be used directly in the video and audio stages, but in the i-f amplifiers, one must use an rf probe to rectify the signal and deliver the modulation envelope to the oscilloscope. The normal small signal amplitudes in the early i-f stages make this method unreliable except in the later stages.

Let's consider several typical examples and see just what can be done to localize this difficulty.

PICTURE AND SOUND WEAK

This complaint may be rather difficult to simulate because it depends on your local signal strength.

In the Hallicrafters receiver, you can open a coupling condenser in an i-f stage. Disconnect one end of condenser C_{30} from pin 5 of the first i-f amplifier tube V_7. When you disconnect this condenser, leave the condenser lead very close to the tube pin—as close as you can get it without touching the socket lug. This simulates the small amount of distributed capacity that might exist in an "open" condenser, and should pass enough signal so that you can have a case of weak reception.

In the case of the Stromberg-Carlson or RCA receivers, pull out the rf amplifier tube. If you are in the primary service area of a television transmitter, this should cause weak reception. If it makes the set dead, try the following:

In the Stromberg-Carlson, simulate a leaky screen-grid by-pass condenser by connecting a 500-ohm, 1-watt resistor across condenser C-204, between the screen grid of the first video i-f amplifier and the set chassis.

In the RCA, since the sound take-off is right at the output of the tuner, you might try disconnecting the transmission line from the input of the set and then experimenting to see how far from the terminals you can leave its ends and still get a weak signal.

One of the foregoing should produce weak reception but this depends on the strength of the signal. We suggest you set the controls on the receiver to get a normal picture and sound before introducing the defect, then turn the set on again after introducing the defect and see just how you must change the control settings to get a signal.

By setting the contrast control much higher than normal, and turning up the volume control, you may be able to get the signal back, but the controls are definitely at a higher than normal setting. In most

instances, you will find it impossible to get the signal back as good as during normal operation.

You may or may not have trouble with synchronization, depending on the sync-voltage levels.

Since both the sound and picture are weak, we naturally suspect a trouble in a section common to both signal paths. The low-voltage power supply is a logical source. However, try turning up the brilliancy control. If the raster reaches a normal high level of brightness, and there is no evidence of an extreme out-of-focus condition, it is probable that the low-voltage supply is okay in a set with an electromagnetic picture tube. This test is inconclusive on an electrostatic-tube set, because the picture-tube operating voltages all may come from the high-voltage supply.

To make a quick check on the low-voltage supply, measure the voltages on some tube that does not have high resistance in its plate circuit—a video i-f stage or the audio output tube will do. Even if the main power supply is cleared, we still have the possibility of a breakdown in a decoupling filter affecting one or two stages.

The only stages that are common to both sound and signal paths in the RCA are the stages in the tuner. In the Stromberg-Carlson, we have as well as the tuner, one i-f stage that is common to both, but in an intercarrier set such as the Hallicrafters, there are quite a number of stages that handle both the sound and picture signals. Therefore, in sets such as the RCA and Stromberg-Carlson, you have already localized the trouble to a matter of three or four stages, and it would be logical just to check these stages quickly. In intercarrier sets, there are enough stages involved to make it worthwhile to attempt some means of localization. An oscilloscope with an rf probe can be used in the later i-f stages, but usually the signal level is so low at the input of the i-f section that such a device gives very little indication anyway.

Signal injection does not work out very well either, because rather high signal levels are needed when starting from the video detector and moving back toward the input. Furthermore, with a signal generator set at one frequency, you may find that some of the stagger-tuned i-f circuits give very little gain at one frequency, and others give very little gain at other frequencies. You must know what the normal gain of each stage is at the frequency you are using before you can determine whether or not the stage is defective.

With these limitations in mind, you might try signal tracing or signal injection. If you do not use these tests, then test each of the tubes in the common section, and take voltage readings in these stages.

Of course, with a defect such as an open coupling condenser, which you may have introduced, neither a voltage test nor a tube test will disclose the trouble. However, if the operating voltages are normal and the tubes are good, then the only thing left would be a defect in some signal-coupling device, or misalignment. With this kind of difficulty, the signal-injection or signal-tracing techniques may prove more valuable.

If you localize the defect to the front end of the set, you can, of course, test the tubes in the usual manner, and can measure the voltages by probing down through the top of the tube sockets in sets where the tubes can be removed. With the tubes in a filament string, it is usually necessary to open the front end to get at some points at which measurements can be made. This may or may not be practical, depending upon the construction of the particular front end, and its position on the set chassis. If the front-end operating potentials are normal, the tubes are good, and you are sure the rest of the set is normal and that the installation is satisfactory, then you should make a check of the alignment of the front end. If there is any real difficulty with the tuning elements at the front end, it is usually best to replace it or return the original to the factory for repair.

After you have experimented with various methods of making measurements for this complaint, restore your set to normal and check it to be sure everything is working properly. Then go on with the next complaint.

PICTURE OK—SOUND WEAK

To produce this condition, simulate an open coupling condenser at the volume control. In the RCA receiver, locate condenser C206, which connects to the center terminal of the volume control, and disconnect one end of it. In the Stromberg-Carlson, disconnect condenser C-236, which is connected the same way. In the Hallicrafters receiver, disconnect one end of C_{21}.

In each instance, you have simulated an open coupling condenser. The sound should be quite weak, even when the volume control is turned full on. However, the picture should not be affected by this, thus indicating that all of the stages having the picture signal are operating normally.

This important clue at once localizes the difficulty to the stages that handle the sound signal alone. This includes the sound i-f stages, the FM detector, and the two audio stages.

The sound system lends itself somewhat more readily to a form of circuit disturbance. Turn the volume control full on, then touch the hot terminal of the volume control. If everything is all right from this point through to the output, you should hear a loud hum or buzz when your finger touches it.

If you don't get this buzz, but hear clicks, reverse the line plug—sometimes this makes the indications

more definite. Now, a lack of buzz or hum indicates that the trouble is in the audio amplifier, but if you do hear the buzz, then the trouble must be in the audio i-f stages or in the FM detector. With the conditions we have introduced, you would hear the hum or buzz in the Hallicrafters receiver, since the condenser that is open is ahead of the volume control, but in the other two sets, you would not.

If you localize the trouble to the audio amplifier, you can follow any of the standard test procedures that you would use on a radio receiver. You can introduce an audio signal at the input and use signal injection stage by stage, or you can use a receiver-type signal tracer. You can take voltage readings, and in receivers that do not have filament strings, you can try a circuit disturbance test by pulling out the first audio-amplifier tube.

If the trouble is ahead of the audio amplifier—in the FM detector or in the audio i-f stages—once again you are faced with stages tuned to frequencies above the range of the average signal tracer. In an intercarrier set, the audio i-f operates at 4.5 megacycles, whereas in the standard receivers, the audio i-f operates at a frequency 4.5 megacycles below the video i-f carrier—somewhere between 21 and 41 megacycles.

You can use signal injection, but you must measure across the limiter grid resistor (or the ratio-detector filter condenser if the ratio circuit is used) to determine how much the signal changes as you move from stage to stage.

If you have a TV signal tuned in, and have no reason to suspect that the alignment of the set is at fault, you can follow the audio signal by using an oscilloscope and an rf probe.

Restore the set to normal and go on with the following section.

SOUND OK—PICTURE WEAK

To simulate this complaint, carry out the following procedure:

In the Hallicrafters receiver, locate R_{49}, which connects to one of the grids (terminal 1) of tube V_{12}, the video output tube. Disconnect one end of this resistor so that the tube grid is no longer connected to B+. This will remove the positive bucking bias that is inserted to overcome the high bias produced across R_{53}.

On the RCA, locate the end of the coil L183 that connects to the grid terminal 1 of the fourth picture i-f tube V113. Disconnect it, but leave the coupling condenser still connected.

In the Stromberg-Carlson, locate the coupling capacity formed by the piece of twin-lead, marked on the diagram C-288, that is used to couple the third video i-f and the video detector. Disconnect one terminal of this twin-lead from either the third video i-f plate circuit or the video detector circuit.

Turn on the set and notice the results. You will have to turn the contrast control to a much higher than normal setting to get a picture, but the sound output will be normal. You may find it impossible to get a very good picture even with the contrast control turned full on, depending on the strength of your local signal.

Since the sound is normal, the trouble must be between the sound take-off point and the picture tube.

In an intercarrier set such as the Hallicrafters, this localizes the trouble at once because the sound take-off is at the plate circuit of the first video stage. Therefore the only circuits that could affect the picture signal alone are those of the output video stage or the picture tube.

In the case of the RCA and Stromberg-Carlson receivers, we must look through many more stages, because the sound take-off point is nearer the input of the set. We can follow the same test procedure that we used for the case of picture and sound both weak, except for limiting ourselves to the stages that are carrying the picture signal alone.

When you are through checking for this complaint, restore your receiver to normal and check it.

SUMMARY

From what we have said, the best technique to use on a weak receiver would be to check individual stage gains so that a weak stage could be immediately spotted. When proper instruments for this are made available, servicing a set for this complaint will not be quite as complex as it is now.

At the present time, the best technique is to isolate the trouble to a section of the set. One way of doing this is to keep a record of the voltages you find across the video detector load in various receivers when they are working normally from a particular antenna, such as the one in your shop. With this record, you can soon see about what the average detector load voltage ought to be. Voltage far below normal indicates trouble ahead of this point.

Although it is possible to try signal injection and forms of signal tracing, your basic test will be that of making a voltage analysis and a tube test. Fortunately, these tests will locate the trouble in all but a few instances.

Distortions of the Raster

The rather broad classification that might be called distortion can be broken logically into three classes. It isn't likely that the customer will be able to distinguish between these too well.

Briefly stated, these three classes are:

1. A condition in which the picture would be normal except that there is a distortion in the raster. This can be non-linearity, lack of synchronization, improper centering, etc., which when cleared up will permit normal operation.

2. A condition in which the raster is normal but the picture quality is poor. A loss of low- or high-frequency response, smearing, blurring, and poor focus fall into this class.

3. A condition in which both the picture and the raster are normal, but an interference produces an overlay pattern, ruining the quality of the picture.

Re-read the above descriptions again, carefully.

In the following sections, we shall follow the plan of the previous sections; you are to introduce defects that will cause characteristic pictures to appear, and you should study these very carefully. This will help you in future attempts at identifying the difficulty.

In this section we shall discuss distortions of the raster, such as are caused by defects associated with the various control circuits and with the sync and sweep circuits. Before going on with this section, carefully check the adjustment of all of the controls on the receiver. Use the information given in Text 1TX. Be certain you have the set in the best possible adjustment.

PICTURE NOT CENTERED

This somewhat rare servicing complaint can be simulated by the following:

In the Hallicrafters receiver, disconnect one of the leads going to an outer terminal of the horizontal positioning or centering control.

In the RCA series, shift the position of the focus coil on the neck of the tube by loosening the mounting screws and twisting the coil.

In the Stromberg-Carlson series, you can short-circuit the horizontal centering or positioning control.

With the defect introduced, your first check would normally be to try to re-center the image by adjusting the horizontal or vertical centering control. If you find the control has no effect on the image, as will be the case in the Hallicrafters and Stromberg-Carlson, then obviously something is wrong with the control or its associated circuit.

In the RCA, the control will move the picture, but may not be able to get it back to exactly the right place. This definitely indicates that either improper current is passing through the control, or else the focus coil has shifted to the wrong position.

As a supplementary experiment on the Stromberg-Carlson, you can restore the set to normal and move the focus coil, just as in the RCA.

From the foregoing, improper centering normally is just an indication of the wrong adjustment of the centering control or of the wrong position of the focus coil. Hence, a readjustment of these items should recenter the picture in practically all cases. When you do have incorrect centering as a service complaint, however, and the control does not respond properly, an investigation of the control circuit and a check of the control with an ohmmeter should be made.

Don't try to open the controls on the Stromberg-Carlson or RCA receivers; they are in the B supply, so opening them would remove plate voltage. Furthermore, they are by-passed, and an open control would apply an excessive voltage to the by-pass condenser so that it might be damaged.

Because these controls carry a fairly heavy current, they are usually very husky, so there is very little likelihood of difficulty with them.

Restore your set to normal, then go on with the following experiments.

PICTURE TOO SMALL

When this defect is coupled with poor linearity, as it commonly is, you would service the set for the poor linearity. However, under certain conditions it is possible for the picture to be reduced in size without too much distortion. Simulate these conditions as follows:

In the Hallicrafters receiver, locate resistor R_{86}, which goes to pin 2 of tube V_{20}, which is a 12SN7 tube. Disconnect only this resistor from this plate terminal—leave the coupling condenser connected to the plate terminal of the tube.

In the Stromberg-Carlson, reduce the voltage on the vertical saw-tooth generator tube V-216B by shunting condenser C-208A with a 5000-ohm, 2-watt resistor. You can locate this condenser by tracing from the vertical size control to the condenser.

In the RCA receiver, locate condenser C220B and shunt it with a 10,000-ohm, 2-watt resistor. You can locate this condenser most easily by tracing from the center terminal on the height control.

After introducing these conditions in your set, turn it on. In each instance the picture should have lost vertical height. It may or may not be quite obviously non-linear depending upon the exact adjustments and the operating voltages in your set.

The thing to do is to try readjusting the vertical size control since it is the height of the picture that

is off. If adjusting the height control does not bring the picture back to completely normal height, or introduces severe non-linearity, then it is logical to suspect that the output from the vertical sweep circuit is below normal.

In such a case you would check for operating potentials and check the tubes in these circuits. Remember in checking the operating voltages that the plate voltage at the output amplifier may be fairly high in a set using an electrostatic sweep, such as the Hallicrafters.

In electromagnetic picture tube sets, the operating voltage of the vertical output stage is not unusually high, but be careful if you ever have to measure in the horizontal circuit. Remember that the horizontal output tube has high-voltage pulses on its plate as a result of the kick-back from the horizontal yoke.

The obvious extreme of this particular difficulty is a complete lack of sweep voltage, so that you get only a vertical or a horizontal line on the picture-tube face. This we have treated as a no-picture condition.

Be sure to restore the set to normal before going on. Check the operation of the receiver after each of these experiments to be sure it is normal.

POOR VERTICAL LINEARITY

To simulate this condition, proceed as follows:

In the Hallicrafters, simulate cathode-to-heater leakage in the vertical amplifier tube V_{20} by connecting a resistor of about 50,000 ohms from one of the filament pins to the cathode of this tube. After observing the condition produced, you might try a 10,-000-ohm resistor to simulate increased leakage, and again observe the effect on the picture.

In the Stromberg-Carlson, try shunting a 1-megohm resistor across condenser C-258, which is the coupling condenser going to the grid of the vertical deflection amplifier.

In the RCA receiver, shunt condenser C157 with a 1-megohm, 1-watt resistor. Condenser C157 can be located from its connection to the grid of the 6K6 vertical output tube.

In each instance you should notice that the picture is no longer linear vertically. Any such lack of linearity might first lead you to try adjusting the vertical height and linearity controls. However, if the controls prove ineffective, then you must check the tubes for leakage, and also check the operating voltages.

It is possible for the leakage in coupling and by-pass condensers to be so small that it does not greatly upset the operating voltages, but does interfere definitely with the wave shape of the signal. Sometimes it is necessary to disconnect these condensers and check them individually on an R-C tester to determine their condition.

You can use an oscilloscope if you have one to follow the signal through the vertical sweep chain, and by observing the wave shape, you may get an indication as to the source of the difficulty. However, since there are rarely more than two stages involved in this chain, it is usually simpler to make a direct check of each stage.

Changing the size of any of the resistors associated with the wave-shaping network or upsetting the operating voltages on either of the tubes in the vertical circuit is quite likely to destroy linearity. It takes a surprisingly small change to produce this upset in many instances.

NOTE: Ordinarily, you are likely to have *either* vertical or horizontal non-linearity but not usually both. If the trouble is vertical non-linearity, you need to look only at the vertical sweep; if it is horizontal non-linearity, you need to look only at the horizontal sweep. However, in the case of the Hallicrafters receiver, you will have to be careful about this. Excessive cathode-to-heater leakage in the amplifier in one sweep chain may affect the other chain because their cathodes both go back to the same B— point in such a way that any defect altering the cathode voltage in one tube will also change the cathode voltage in the other. Hence, you may find a twin non-linearity caused by a defect in only one chain.

When you have finished, restore the set to normal.

POOR HORIZONTAL LINEARITY

You can simulate this condition in practically the same way that you did poor vertical linearity. In all three sets, try a resistance of about 1 megohm across the coupling condenser between the oscillator or wave-shaping tube and the output amplifier.

Methods of localization are almost identical, too. However, in the case of electromagnetic tube sets, there are now at least three tubes involved, and an oscilloscope is somewhat more helpful in running down the source of difficulty.

Although it is not as common, it is possible for any of the transformers involved in the sweep circuits to cause non-linearity because of leakages. If the tubes and operating voltages are normal, and you can find no leakage in the coupling, by-pass, and filter condensers, then don't fail to check these transformers, also.

In the horizontal sweep circuits of electromagnetic sets, non-linearity may be caused by partial defects in the damping tube and its associated circuit. For example, in the RCA receiver, an open in condenser C186, or in the linearity resistor R209 can cause non-linearity.

HUM RIPPLE IN RASTER

This particular defect can be demonstrated on the Hallicrafters receiver but apparently does not occur as a single defect in the Stromberg-Carlson and RCA

series; on these it is accompanied by hum or hum patterns on the picture. Therefore, on them, we will discuss it when we discuss hum.

In the Hallicrafters receiver, locate condenser C_{57B}, connected to cathode terminal 8 of the 6X5 rectifier tube, and disconnect the condenser from the rectifier tube cathode. Connect a 1000-ohm, 1-watt resistor between this disconnected condenser lead and the rectifier cathode to simulate a high power factor in this condenser.

Turn on the set. You should not be able to hear any hum, but there will be a ripple in the raster. If hum bars show up across the picture, remove the picture signal by tuning away from the station and rotate the centering control so that you can see the edge of the raster. If the raster itself has a ripple in it, then the hum is being introduced in the sweep circuits. Logic tells us that such a hum ripple must be the result of a hum voltage in the supply of the sweep circuits, or of cathode-to-heater leakage. In the Hallicrafters receiver, we can introduce hum in the plate supply of the sweep circuits because it is a separate supply from that of the other tubes. However, in the other sets, the low-voltage supply furnishes power not only to the sweep circuits but also to the other sections of the set. Therefore, a low-voltage supply defect that causes hum will cause bars across the picture in addition to the ripple in the raster.

IMPROPER HORIZONTAL SYNC

To simulate this complaint, it is necessary to remove the horizontal sync pulses. Proceed as follows for your set:

In the Hallicrafters locate coil L_{22} which is connected to terminal 1 of tube V_{17}—the 12SN7 horizontal oscillator. Connect a short piece of wire from terminal 1 to ground to short-circuit the coil and thus remove the horizontal sync pulses.

In the Stromberg-Carlson or the RCA, short-circuit the control grid of the horizontal-oscillator control tube. In the Stromberg-Carlson, this is terminal 4 of tube V-220, and in the RCA, it is terminal 4 of tube V124. In both instances it is a 6AC7 tube. Connect a short piece of wire from the grid terminal to ground in either case.

Turn on the set. You will probably notice that the picture is torn up because of a lack of synchronization. Try adjusting the horizontal hold control. You may be able to get the signal to sync momentarily, but there will still be a tendency for it to tear, and it will not stay in sync very long.

Since the vertical sweep remains in sync, the defect must be in a section that handles the horizontal sync signal only. This rules out the clipper and sync-amplifier chain.

Another important clue is the fact that the horizontal oscillator can be brought to nearly the right frequency with the hold control. This ordinarily indicates that the horizontal oscillator is not defective.

From this reasoning, you can limit your testing to the parts immediately associated with feeding the horizontal sync signal to the horizontal oscillator. In sets such as the RCA and Stromberg-Carlson, this includes the sync discriminator and control circuits.

Restore the set to normal and readjust the horizontal hold if necessary, then go on with the following.

IMPROPER VERTICAL SYNC

To simulate a defect in the vertical sync coupling networks, proceed as follows:

In the Hallicrafters receiver, locate the condenser C_{66}, which couples the vertical sync signal into the network feeding the grid of tube V_{18}—the vertical oscillator. Disconnect one lead of this condenser.

In the Stromberg-Carlson, locate the condenser C-252, which feeds the grid of tube V-216A, and disconnect one lead.

In the RCA, locate the coupling condenser C149, which couples the second sync amplifier into the vertical integrating network, and disconnect one lead.

Turn on the set. Because of the stability of the vertical oscillator, it may be some time before the set goes out of vertical synchronization. When it does, adjust the vertical hold control. In all probability you can bring the set back for periods of time this way but it will drift out again.

The presence of a raster when the contrast control is turned all the way down and the brilliancy is turned up indicates that the sweep oscillators are working but is, of course, no guarantee that they are anywhere near their correct frequencies. However, when we turn up the contrast controls so that the picture signal is applied to the tube, the fact that we can sync once in a while, even if only momentarily, does indicate that the sweep oscillator is operating near its correct frequency and that the trouble is lack of sync pulse.

Because of the low frequency of the vertical sync pulse, we have to be careful in our assumptions about where it is disappearing. The best check to use is an oscilloscope set up to view the vertical sync pulse, so that you can follow it through the sync chain to determine where it disappears. In each instance we have introduced a defect that should affect only the vertical sync pulses. Actually, it is possible for defects in circuits handling both the vertical and horizontal syncs to affect only the vertical pulse because of its low frequency. For example, an open coupling condenser earlier in the sync chain will wipe out the vertical sync pulse, but will not remove all

of the horizontal sync pulse if there is enough stray capacity to pass on the higher-frequency horizontal pulses.

Furthermore, misalignment of the video i-f amplifier that reduces the low-frequency response of the system (having the carrier too low on the response slope) will tend to suppress the vertical sync pulse more than the horizontal.

If the vertical sync signal is wiped out in the video i-f or in the video amplifier, you may be able to observe this when you get the picture to stand still on the picture tube. Look for the retrace lines. Ordinarily, the retrace lines will be visible up to the very moment of synchronization. At that time, the sync pulses should suppress the retrace lines. If you can get the picture to stand still, and the retrace lines are still quite visible, as they are when the picture is not in sync, then the vertical sync pulses apparently are not coming through to the grid of the picture tube and probably not going on to the sync clipper circuit. On the other hand, if proper blanking occurs, the vertical pulses are probably being wiped out in the sync chain.

In general, therefore, although it is logical first to check in the small section of the sync chain that handles only the vertical pulses, if this does not show up the difficulty, you may have to go back further in the set. Signal tracing with the oscilloscope is the best means of localizing the difficulty.

In each instance, we have simulated an open condenser, which of course would not be shown by voltage readings. In a case of this sort, after you have checked tubes and taken voltage readings, it is necessary to check the components individually, unless you have an oscilloscope, as mentioned above. Notice that an oscilloscope will show up the defect because the vertical sync signal will appear on one side of an open condenser, but not on the other side.

Restore your set to normal, and re-set the vertical hold.

IMPROPER VERTICAL AND HORIZONTAL SYNC

On the Hallicrafters, locate pin 4 of tube V_{12}, the 12SN7 sync clipper. Run a short wire from this terminal to ground to simulate a shorted condenser C_{55}.

On the Stromberg-Carlson, locate the sync-clipper tube V-213 and disconnect condenser C-244 from its grid terminal 4.

On the RCA, locate sync-clipper tube V119 and disconnect condenser C147 from its terminal 4.

This simulated defect should wipe out both the vertical and the horizontal sync in each set. Study the effects on the picture carefully, and compare it with the lack of horizontal sync you had before. Notice that it is rather difficult to tell the two conditions apart because the picture is very jumbled even with only improper horizontal sync. However, a

careful and slow adjustment of the two hold controls may make one or both of the circuits come momentarily into sync, so that you can notice the difference.

Since both are now out of sync, you would look for trouble in the circuits common to both, which includes the sync chain of each set. Once again, using an oscilloscope as a signal tracer is probably the fastest means of running down the trouble. If you must depend on a multitester, the best you can do is to check tubes and operating voltages, and if these are all right, proceed to check component parts. If the operating voltages are normal, an open condenser is far more likely than a shorted one.

Restore the set to normal after you have made your tests.

MORE THAN ONE COMPLETE PICTURE

To get this condition, we will simulate a partially open vertical hold, or a hold control that has increased greatly in value.

On the Hallicrafters receiver, disconnect resistor R_{83} from the center terminal on the vertical hold control and connect a 1-watt, 500,000-ohm resistor between the two.

On the Stromberg-Carlson receiver, it is somewhat easier to disconnect the vertical hold control from its ground terminal and to insert the 500,000-ohm resistor between the control and ground. On the RCA receiver, locate the center terminal of the vertical hold control and disconnect R171 from it. Connect a 1-megohm resistor between the free lead of R171 and the hold control.

When you turn on the set, you should notice that it is out of vertical sync. However, when you turn the vertical hold control until you get a stationary pattern, you may find that there are two pictures, one above the other. Actually, you may have to reduce the height of the picture slightly so that the entire raster can be seen to get this effect. This would be particularly true if the set were in its cabinet and therefore had the face of the picture tube masked. Since the pictures are stacked vertically, you can tell that the vertical sweep is operating at half normal frequency. Since this frequency is determined by the R-C time constant in the grid circuit of the vertical oscillator, something must be the matter either with the resistors in this circuit or with the grid blocking condenser. You can check the resistors with an ohmmeter, and if they are normal, the condenser is probably defective and a new one should be tried in its place.

On the Hallicrafters receiver, you can demonstrate the same defect in the horizontal circuit by introducing a resistor in the horizontal hold-control circuit. You will get two or three pictures side by side. However, the extremely stable horizontal oscillator circuits used in the Stromberg-Carlson and RCA re-

ceivers will prevent you from making a similar observation on these sets. If you try to run the horizontal oscillator circuits at half-normal frequency on these sets, they will lose sync.

As an additional test, try to make the vertical oscillators of each of these receivers run faster than normal. To do this, you need to decrease the resistance in each grid circuit. Take out the resistor you have introduced, and restore the original connections.

Then connect the resistor you used from grid to ground in each instance so as to make it act as a shunt across the resistances now in the circuit, you will find that different parts of the picture are superimposed upon one another. This test can be done on all three sets. The same reasoning applies to this as for half-normal frequency—the trouble must be in the resistors or the condenser associated with the grid circuit of the sweep oscillator.

Poor Picture Quality

In this section, we shall study conditions in which the raster is of normal shape and remains in synchronization, but the picture quality is not good in that the picture is blurred or smeared in some way.

There are three major defects that will cause a blurred picture: (1) high-frequency loss may cause the finer details of the picture to disappear; (2) the picture may be out of focus; or (3) low-frequency loss may result in smear.

Only close examination even on a test pattern will disclose exactly which of these possibilities exists, and sometimes on regular pictures it is practically impossible to tell them apart. You should study all three of these conditions and compare them, preferably on a test pattern. Then, you might try each of these conditions while looking at a regular program, to see just how well it is possible to distinguish between them. If you can determine which of the three conditions exists, it simplifies the servicing considerably.

Of course, whenever you are called upon to service a set with this complaint, you must be certain that the trouble is in the set and not in the station. Try another station, or find out from a monitor set whether the station at that time is transmitting a poor picture.

If it is a set defect, almost always, the trouble is in the picture tube, the video amplifier, or the video i-f section.

We shall assume that normal sound is received, which in general eliminates the possibility of a misalignment of the front end, although this still must be considered if everything else is normal.

LOSS OF HIGH FREQUENCIES

To simulate this difficulty, adjust the set to get a test pattern as nearly perfect as possible.

Then, reduce the high-frequency response by shorting peaking coils in the video section. In the RCA, locate the first video tube V115, and short-circuit coil L189 and also coil L190.

In the Stromberg-Carlson, locate the video detector V-204A and short-circuit coils L-213 and L-214.

In the Hallicrafters, locate the video detector V_{10} and short-circuit coils L_{18} and L_{19}.

In each instance, the high-frequency response will be greatly reduced. The effect on the test pattern should be somewhat as shown in Fig. 11. Observe that in the test pattern, the high-frequency loss is indicated mostly by the vertical wedges. The lines in the vertical wedges do not go all the way to the center circles—they tend to blend together before reaching this point.
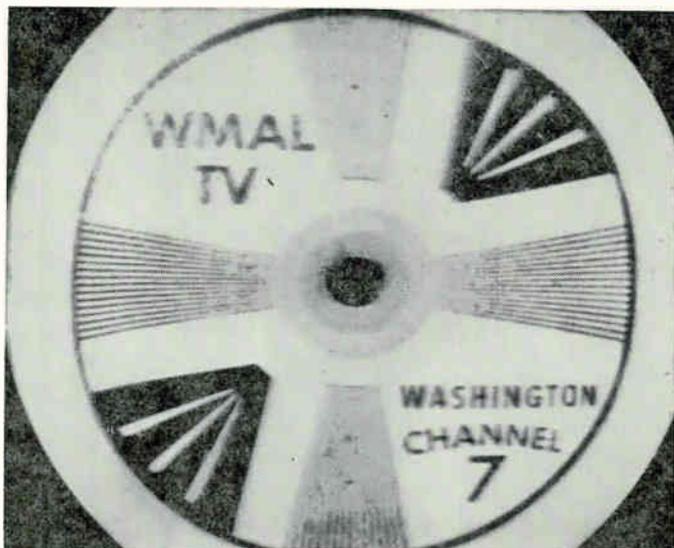
NRI TV Lab Photo
FIG. 11. Loss of high-frequency response smears the vertical wedges, but does not affect the horizontal wedges.

A short-circuited peaking coil is relatively rare. Ordinarily, loss of high-frequency response is caused by misalignment of the video i-f stages. As these circuits drift out of alignment, the high-frequency response suffers rather quickly, causing this loss of detail.

Another way of simulating this same difficulty is to mistune the receivers by using the fine tuning control (in the Stromberg-Carlson, turn the main tuning control). As you tune away from the right point, you will find that the high-frequency response suffers.

From the foregoing, if you find that the set has a definite loss of high-frequency response, your first effort should be made toward realigning the set. If this does not clear up the trouble, then you might suspect the possibility of a shorted peaking coil. It is necessary to check each coil carefully, because they are of relatively low resistance. If one shows a complete short, then that one should be replaced by an exact duplicate.

Incidentally, in the Hallicrafters receiver, the sound output will be affected by this reduction in the

Courtesy RCA

FIG. 12. Out of focus blurs all details.

high-frequency response. However, you may or may not notice this drop in sound volume. If coil L_{20} is the one shorted, the sound output might be even further reduced.

Restore the set to normal, then go on with the following two cases, comparing all three carefully.

POOR FOCUS

To simulate this condition proceed as follows:

In the Hallicrafters receiver, locate the voltage divider across the high-voltage supply that includes the focus control and the positioning controls. At the grounded end of this string, between the focus control and ground, are resistors R_{92} and R_{93}. Use a 1-megohm, 2-watt resistor shunted across R_{92} first, then after you have observed the effects of this, move this resistor so that it shunts both R_{92} and R_{93}.

For the Stromberg-Carlson, locate the filter condenser C-246B, which is electrically connected between one end of the focus coil and the chassis. Connect a 10,000-ohm, 10-watt resistor across this condenser.

For the RCA set, remove the 6K6 audio output tube from its socket.

In each case, you should notice that the focus has become poorer, as shown in Fig. 12. You may or may not be able to restore focus by adjusting the

focus control. If you find that the focus control approaches the proper setting near one end, then this definitely indicates that there is a defect that is changing the current through the focus coil, (or is changing the voltage division in a set using an electrostatic tube).

In the RCA receiver, removing the 6K6 audio tube changes the current through the focus coil by the amount that was being drawn by this tube, thereby affecting the focus.

After you have observed the conditions in each case, be sure to remove the resistors or replace the tube so that normal currents flow.

With the sets using electromagnetic focus, you might also try shifting the position of the focus coil, which is a fairly common cause of poor focus. If you shift the coil far enough, you will find that the focus control will no longer restore normal focusing. (As a matter of fact, in some receivers, the focusing adjustment consists of moving the focus coil.)

Of course, in the RCA, in which you pull out the audio tube, there will be no sound, so you would
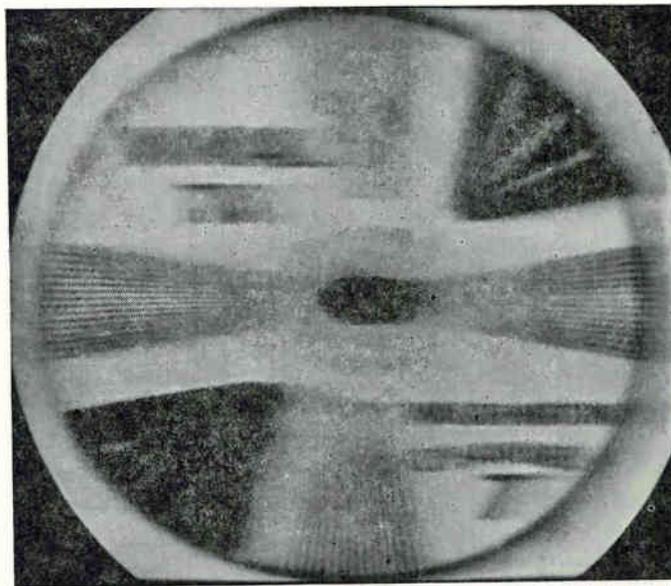

NRI TV Lab Photo

FIG. 13. Loss of low frequencies causes smear.

service the set for this rather than for lack of focusing in the picture. Replacing a defective tube in the audio system should automatically clear up the focus. However, as in other sets, if the current through the focus coil increases or decreases, because of leaky condensers beyond the focus coil, or a reduction in the total B supply as a result of defective input filters, the focusing will be affected.

POOR LOW-FREQUENCY RESPONSE

Smearing, which occurs when the low-frequency response of a set is affected, is shown in Fig. 13. To simulate this, proceed as follows:

In each set, you are to simulate an open coupling

condenser in the video section. However, since even an open condenser has a small amount of capacity, it is desirable to complete the circuit with a small condenser, somewhere between 3 and 10 mmf.

In the RCA, locate either condenser C130A or C140, which act as coupling condensers in the video amplifier. Disconnect one end of the condenser you choose, and connect the small condenser between the free lead and the point where it originally connected so that it is in series with the original coupling condenser.

In the Stromberg-Carlson, locate condenser C218, which connects to the grid of the picture tube. Disconnect one end of this condenser and connect the small condenser between the free lead and the point where it was originally connected.

In the Hallicrafters set, locate condenser C_{52}, which connects to the grid terminal 1 of tube V_{12}. Disconnect one end of this condenser and connect the small condenser between the free lead and the point where it was originally connected, so that the small condenser is in series with the original coupling condenser.

Turn on the set. Examine the pattern you see carefully.

Notice the definite smear from the dark portions of the picture across the rest of the picture. There is a similar smear from the lighter portions. A reduction in the capacity of the coupling condenser as when it is open reduces the response at the low frequencies, but the small remaining capacity (simulated by the small condenser) provides enough capacity to give reasonable high-frequency response. As a result we have a low-frequency smear.

This same low-frequency smear might be the result of misalignment of the video i-f amplifier, or of a defect in any low-frequency compensating circuit. You will study such circuits in your Lessons.

To localize the source of this trouble, make an alignment check in the video i-f, or check low-frequency response of the video amplifier. Use an audio signal generator and an output meter for the latter test. Or, since there are so few condensers likely to be defective, you can also try shunting each coupling condenser with another.

TOO MUCH CONTRAST

In addition to the foregoing, we have two other conditions that should be classed as poor picture quality—too much contrast, and low brilliancy. To simulate the first of these, proceed as follows:

On the Hallicrafters, short-circuit the contrast control by running a wire from terminal 7 of tube V_{11} to the chassis. It may be more convenient to put this wire right across the active terminals of this control.

In the Stromberg-Carlson, locate condenser C-285. You can find it by tracing from the center terminal on the contrast control through resistor R-231 to the condenser. Simulate leakage by placing a resistor across this condenser. The size of the resistor depends on the strength of your local signals. If they are quite powerful, a resistor of 500,000 ohms may be suitable. For weaker signals, smaller resistances may be necessary.

In the RCA series, locate condenser C122. You can find it by tracing from the control grid terminal 1 on the third picture i-f tube V112, through resistor R125 to the condenser. A resistor of about 1000 ohms across this condenser will simulate leakage.

In each instance, it is advisable to set up the receiver to get a normal picture, introduce the simulated defect, and observe the reaction without changing the contrast-control setting.

You should find that the picture has entirely too much contrast if you are in an area with reasonably strong signals.

With excessive contrast, the picture will tend to be all black and white without intermediate shades of gray. If the signal is strong enough, the video amplifier stages may be overloaded so that clipping occurs and the sync pulses are lost, resulting in tearing or movement of the picture as well.

In each instance, you should try adjusting the contrast control. In the Hallicrafters, you will find that adjusting the contrast control does not affect the picture at all, leading you to suspect this control or its associated circuit.

In the other two receivers, adjusting the contrast control will have some effect, but the control will not be able to cut the contrast down sufficiently. This, too, would lead one to suspect a defect in the contrast control network. In these two receivers, this network is much more elaborate. There are quite a number of decoupling circuits in which a leaky condenser or an open resistor might be found. It may be necessary to go over these circuits individually by disconnecting them from each other to find the defect.

As a supplementary experiment in both the RCA and Stromberg-Carlson receivers, it is possible to get about the same effect by introducing leakage in the coupling condensers in the video i-f stages controlled by the contrast control. Such leakage will tend to oppose the bias normally delivered by the contrast control, and can result in excessive contrast.

To check for a leaky coupling condenser in the video i-f stages, you can try using a dc meter to measure across the various grid resistors to determine whether a dc voltage is present. There should be none, as long as the coupling condenser is not leaky. However, this measurement may not necessarily be indicative because the resistances of the

grid resistors are very low so an RC tester may be needed to check the condensers for leakage.

LOW BRILLIANCY

To simulate this condition, proceed as follows:

Locate the filter resistor in the high-voltage supply. The set should have been turned off for a considerable time to allow the filter condensers to discharge. Then, before touching anything in the high-voltage supply, use a test lead with high-voltage insulation to short-circuit the filter condenser in the high-voltage supply to be very certain it is not storing a charge.

In the Hallicrafters receiver, the filter resistor is R_{90}, in the high-voltage compartment. Connect in series with this resistor a 1- or 2-watt resistor of about 10 megohms.

In the Stromberg-Carlson receiver, the filter resistor is R-303, and it is connected to the filament of the high-voltage rectifier V-222. Connect a resistor of about 10 megohms in series with R-303.

In the RCA, the resistor used as a filter is R235, and it is connected to the filament of the high-voltage rectifier V127. Disconnect one end of this resistor and connect a 10-megohm, 2-watt resistor in series with it.

Turn on the set. In each instance, we have lowered the high voltage. The picture may be somewhat larger than normal, and will be less brilliant. In addition, it may have a yellowish cast. In addition, the focusing may be poor. However, an important clue is the fact that if the condition were just a lack of proper focusing, the brightness control would operate normally. Therefore, these several conditions, when tied together, indicate improper operating voltages on the picture tube, or a defective picture tube. A check should be made of all low voltages applied to the picture tube to be sure they are normal. Then, if you have a high-voltage multiplying probe for your multimeter, you can measure the high voltage at the picture tube, in which case you would find it below normal. However, don't attempt to make this measurement without such a multiplier probe.

If you find all operating voltages are normal, then the remaining suspect would, of course, be the picture tube itself. Of course, if the tube is defective, you will notice only a loss of brilliancy; if the high voltage is below normal, you should observe that the image is increased in size (blooming) also.

Elsewhere, we have given a number of reasons for lower than normal high voltage—improper excitation of the rectifier tube, a defective rectifier tube, or a defect in the filter circuit. Going at this problem so as to check the easiest suspects first, you should start with the filter condensers. If they are good, you might check the filter resistor and rectifier tube. Finally, you would check the excitation source.

In the Hallicrafters, the oscillator in particular may be the source of trouble because of improper operating voltages, a defective oscillator tube, or just simple mistuning. In this set, one winding of the oscillator coil must be tuned to resonance with the high-voltage secondary for maximum output. If you find this adjustment should be made, you should use an insulated alignment tool to reach the trimmer through the hole in the top of the high-voltage compartment. You can make this adjustment only if you have a high-voltage multiplying probe. To do so, connect the multitester and probe across the output filter condenser C_{82}. Then, with the brightness control set at minimum, adjust condenser C_{80} until you get a reading of about 4700 volts.

It is possible to get a somewhat higher voltage, but the oscillator will be unstable in this region, and the horizontal sweep may "fold." It is preferable to tune to the maximum-capacity side of true resonance. Thus, you may notice two positions at which you get the desired voltage, with a somewhat higher peak in between. The correct one to use is the one with the adjusting screw turned in the most. You may have to adjust to a slightly lower voltage to prevent folding of the raster.

There may or may not be a discoloration of the image when the high voltage drops. Picture tube manufacturers strive to make tubes that will give a reasonably pure black-and-white image. However, to get a white, they have to mix two phosphors, one producing blue light and the other a yellow or brownish light. When both these phosphors are excited to the proper degree, the result will be a black-and-white image. If the operating voltages change enough, it is possible for the yellow phosphor to predominate, giving a yellow or brown-tinted image. However, this depends on the condition of the phosphors and may not always happen. Sometimes you will find blue or yellow pictures without any voltage change because the phosphors were mixed in the wrong proportion, or one phosphor has lost its ability to operate properly. Replacing the picture tube is the only cure for this.

Before you restore the set to normal, be sure you allow plenty of time for the filter condensers to discharge. Then, short them, to be absolutely certain it is safe to remove the resistors you have inserted. Restore connections to normal and check the set to be sure everything is normal before going on.

Interference Patterns On Pictures

Ordinarily, when you find an interference pattern over the picture, something outside the set is producing the pattern. Noise, for example, may produce streaks in the picture. A mismatched transmission line, or reflections from nearby objects, may cause ghosts to appear on the screen. Even more prevalent are interferences from diathermy machines or FM or AM transmitters.

However, there are a few conditions within the receiver that will cause such overlay patterns. Misalignment, for example, may cause a condition very similar to the ghosting that is due to external causes. Also, the 4.5-megacycle beat that is produced between the sound and picture carriers at the video detector will produce a grain effect on the picture. Many sets have 4.5-megacycle grain traps in the video amplifier. If these traps are misadjusted, the grain pattern will appear on the picture. These two conditions are alignment faults, which we are not covering in this text.

The remaining two receiver defects that are likely to cause an overlay pattern are hum and oscillation. Unfortunately, we cannot demonstrate that oscillation will produce such a pattern because it happens only with certain degrees of oscillation and these depend upon the frequencies to which the affected circuits happen to be tuned, and to the exact gain and supply voltages at that moment.

Since so many degrees of oscillation are possible, it is exceedingly difficult to classify. A certain type of mild oscillation will produce an overlay pattern very similar to that produced by FM interference, and many servicemen have undoubtedly been misled by this pattern. If you find this interference on *all* stations, it is quite possible that one or more of the video i-f stages are involved.

This oscillation may be tunable if the front end is involved. The only probable clue here is that the interference exists even when the set is moved to a different locality, which is rather unlikely for most interference. That is, you may find the set apparently has interference in the home of the customer, and also at your shop. If these two points are separated by several miles, a check for oscillation is in order.

Severe oscillation will usually completely blank the picture. However, even here one has to be careful, because the picture may blink in and out, or may tear up like a picture that is badly out of both horizontal and vertical synchronization.

Whenever oscillation occurs whether a signal is tuned in or not, its presence can be determined by short-circuiting the input of the set, and then measuring for signal voltage across the video detector load. If you find such a voltage when there is no signal coming in, then oscillation is to be suspected. Unfortunately, sometimes oscillation occurs only when a signal comes in. If you suspect this, you can use a signal generator as a signal source, and may thus be able to localize the oscillation.

Since in this section we want to demonstrate overlay patterns, we will use hum instead of oscillation as our example. Before doing so, however, here are a few general rules that apply to all overlay patterns —whether produced within the set or by outside interference.

If the frequency of the interfering signal is less than the horizontal sweep frequency, the result will be alternate light and dark horizontal bars or lines across the picture. The frequency of the interference can be found by multiplying the number of dark bars by the vertical sweep frequency (60). Thus, two bars are caused by an interference at 2×60, or 120 cycles.

If the frequency of the undesired signal is higher than that of the horizontal sweep, there will be vertical bars or lines on the screen. These bars may be directly vertical, or may slant either to the right or to the left. If the frequency of the signal producing the lines or bars varies rapidly, wavy lines will be produced. This is characteristic of FM interference. The number of lines or bars multiplied by the horizontal frequency (15,750) gives the frequency of the interference but since they tend to move, this isn't an easy check to make.

The brightness of the bars or lines depends on the relative amplitudes of the interfering signal and the desired signal. If the interference is small in amplitude with respect to the picture signal, the bars will be faint.

HUM IN THE PICTURE

To simulate this condition, proceed as follows:

In the Hallicrafters receiver, simulate an open output filter condenser by disconnecting the positive lead of condenser C_{60B}. This is the output filter condenser connected to one terminal of choke coil L_{25}.

In the RCA set, simulate cathode-to-heater leakage by connecting a 500-ohm, 1-watt resistor between pins 7 and 8 of the 6K6 second video tube V116.

In the Stromberg-Carlson receiver, locate the dc restorer tube V-204B, and connect a 1000-ohm, 1-watt resistor between pins 3 and 1 of this tube.

After introducing the defects, you may find it necessary to readjust the hold controls or to adjust the brilliancy and contrast controls for a normal picture. When you do, you should find that there is a broad dark bar horizontally across the picture.

The fact that there is only one bar indicates that the frequency is 60 cycles. This is sometimes an important clue to the trouble.

The RCA and Stromberg-Carlson receivers use full-wave rectification, so hum due to filter troubles should be 120 cycles. Hence, a 60-cycle hum, as in this case, would generally be caused by cathode-to-heater leakage. It could be caused by half-wave rectification, but since in these receivers, half of each rectifier tube is used on each side of the circuit, half-wave rectification is very improbable—even if one rectifier tube fails, the other still operates on each half cycle. Only a defect in the power transformer is likely to cause half-wave rectification.

Therefore, in these sets, 60-cycle hum ordinarily means cathode-to-heater leakage, whereas 120-cycle hum (two bars) means a power-supply defect.

In the Hallicrafters receiver, this is not true. Here, the voltage-doubling system is essentially a half-wave rectifier, so 60-cycle hum is the only kind that can be produced by either filter-circuit troubles or by cathode-to-heater leakage in the amplifier.

Ordinarily, if hum is the result of a power-supply defect, it will show up in the sound channel also, whereas cathode-to-heater leakage in a stage that handles only the video signal or sweep signals is less likely to affect the sound.

In most of the earlier TV sets, as in the RCA and Stromberg-Carlson series that we are using, the filter condensers are multiple units, and are connected so that hum from a power-supply defect is very unlikely until several condensers have gone bad. This is particularly true in the RCA receiver, which has numerous condensers of high capacity connected in parallel.

More recent TV receivers are not quite so well filtered, so are somewhat more likely to have hum.

When you have examined the pattern and have run tests to localize the trouble, restore your set to normal.

Additional Experiments

You have now completed demonstrating the more common TV service complaints (excluding those due to misalignment). There are, however, certain obscure complaints that you may find in other receivers, as well as a few odd ones that are hard to classify.

Therefore, we are now going to list several additional experiments you can perform. We shall not attempt to discuss the reasons for the conditions demonstrated in each experiment, nor will we try to indicate the servicing technique to use. These experiments are designed solely to demonstrate some of the complaints you may find in your service work, so study the picture tube image carefully.

First remove any previous defect you have introduced before carrying out each experiment. After adjusting all the controls for a good test pattern and good sound, unplug the power cord, then introduce the defect. Plug in the set again and notice the results. It may be necessary for you to readjust controls in order to see better how the reception is affected.

Because these experiments cannot be carried out in the same way on all the receivers, we are giving a list for each set. Go to the list that is given for the set you have.

HALLICRAFTERS MODELS

Experiment 1: After adjusting the receiver for a good test pattern and good sound, disconnect the power plug and open R_{73}. Plug the set back in and observe the picture, making any necessary readjustments of the controls.

Experiment 2: Try shunting, in turn, a 1000-mmf and a 250-mmf condenser across diode-load resistor R_{53}, watching the picture as you do so.

Experiment 3: Change the value of the video second-detector diode load resistor by shunting a 1000-ohm resistor across it. Readjust controls if necessary. Arrange the resistors so that you can alternately make and break the connection, observing the change in the quality of the picture as you push the resistor into position.

Experiment 4: Connect a 250-mmf condenser from pin 1 of the video i-f amplifier tube V_9 back to pin 1 of the video i-f amplifier tube V_8.

Experiment 5: Connect a 250-mmf condenser from pin 1 of the video i-f amplifier tube V_9 back to pin 1 of the video i-f amplifier tube V_7.

Experiment 6: Connect a short piece of wire across R_{63}, shorting this resistor to ground.

Experiment 7: Connect a 100-mmf condenser in parallel with C_{96}, observing the change in the quality of the picture.

Experiment 8: Connect a 1-megohm resistor in parallel with condenser C_{96}, observing the change in the pattern.

Experiment 9: Simulate leakage in condenser C_{17} by shunting it with a 40,000-ohm resistor.

Experiment 10: Try opening condenser C_{54}, then try readjusting the controls to see if you can get a good-quality, stable picture.

STROMBERG-CARLSON SERIES

Experiment 1: Try shunting a 10-ohm (10-watt) resistor across C-215, simulating a partial short in this condenser.

Experiment 2: Connect a 100,000-ohm resistor across condenser C-283, simulating leakage here.

Experiment 3: Connect a 250-mmf condenser from

the juncture of R-219 and L-214 to ground.

Experiment 4: Connect one end of a test lead to ground. Connect one end of another test lead to pin 1 of V-202. Now, couple these two test leads closely together—don't actually connect them but simply twist the insulated leads together so that there is a certain amount of distributed capacity. Here, you are essentially increasing the distributed capacity from the grid of tube V-202 to ground. .

Experiment 5: Simulate a change in the value of R-221 by shunting a 4700-ohm, 2-watt resistor across it.

Experiment 6: Simulate a change in the value of R-293 by shunting a 10,000-ohm, 1-watt resistor across it.

Experiment 7: Try shunting condenser C-267 with a .05-mfd, 600-volt condenser.

Experiment 8: Connect a 100,000-ohm, 1-watt resistor from pin 5 (grid) of the 6BG6-G tube to ground.

Experiment 9: Open condenser C-256.

Experiment 10: Disconnect the end of condenser C-223, which connects to the juncture of R-235 and the lower terminal of the first sound i-f transformer. Arrange the end of this condenser so that you can push it over and make contact, using an insulated screwdriver or alignment tool. Turn on the set and observe the operation. Then push the condenser over to make contact, still watching the operation of the set.

RCA SERIES

Experiment 1: Connect a .0005-mfd condenser from the juncture of R140 and L190 to ground.

Experiment 2: Connect a 1000-ohm, ½-watt carbon resistor to ground and arrange the other end so that it can be touched to the juncture of R137 and L188. This resistor can then be used to shunt the video second detector load resistor and to lower its value. Use an insulated screwdriver or alignment tool to push this resistor in position, shunting R137, while watching the test pattern.

Experiment 3: Remove the 1000-ohm resistor and substitute, in its place, a 50-ohm, ½-watt carbon resistor. Connect it acros R137 as you did the 1000-ohm resistor and observe the test pattern. This shows a lack of low-frequency response. When carrying out experiments 2 and 3, be sure to use a carbon resistor.

Experiment 4: Connect a .005-mfd condenser from the juncture of L118 and R137 to ground. Readjust any controls necessary.

Experiment 5: Simulate leakage in condenser C222B by shunting a 1000-ohm, 2-watt carbon resistor across it.

Experiment 6: Remove the 6AL5 video second detector tube and insert a 6AG5. Readjust any controls necessary to get a reasonably stable picture. This experiment shows what may happen if a serviceman inadvertently places a wrong tube in a particular socket. Unless you make a careful check to be sure that the correct tubes are in the sockets, you may spend considerable time trying to service a set that has no actual defect in it whatsoever.

Experiment 7: Show the effect of an open in the screen by-pass condenser of the 6K6 horizontal oscillator tube by disconnecting the end of condenser C175 connected to pin 4 of this tube.

Experiment 8: Connect a 100-mmf condenser from the juncture of R148 and C141 to the juncture of C138, L188, R136 and L187 (input to the first video amplifier).

Experiment 9: Remove the 100-mmf condenser that you connected in the previous experiment, and connect a 1-megohm, ½-watt resistor in its place. Both of these experiments demonstrate the effect of oscillation in the video amplifier.

Experiment 10: Connect a 100-mmf condenser from pin 1 of V104 (grid of first sound i-f amplifier) to pin 1 of V106 (grid of last sound i-f amplifier). This simulates oscillation in the sound i-f amplifier.

AUDIO CIRCUIT TROUBLES

Thus far, we have discussed troubles that primarily affect the picture. It is possible, however, for a defect to affect only the sound. In general, however, you will find the same type of defects in the audio system of a TV receiver as in an AM or FM radio, so we will not discuss them in detail.

We have already mentioned the possibility of a dead sound system or weak sound. There may also be distortion, oscillation, or hum.

In most cases, distortion is due to some defect in the audio amplifier circuit or in the loudspeaker. Defects in the sound i-f amplifier seldom, if ever, cause distortion. Defects in the frequency discriminator or ratio detector sometimes will; however, defects other than misalignment in this circuit are the exception rather than the rule.

The usual causes of distortion are: bad tubes, incorrect operating voltages, defective output transformer, and defective loudspeaker. Two common examples are a leaky coupling condenser or a gassy output tube. Either can be checked by measuring for dc voltage across the grid resistor of the output tube. If there is a dc voltage across this resistor, with the grid end positive, the output tube should be removed (or the coupling condenser disconnected if the set has a filament string). If the dc voltage disappears when the tube is removed we know that it is gassy and should be replaced regardless of how it checks in a tube tester. If the dc voltage remains, we know the coupling condenser is leaky and should be replaced. In a set with a filament string, if the voltage is present with the coupling condenser disconnected, we know

that the output tube is gassy.

Distortion may also be caused by improper bias voltage, but a check on the dc operating voltage will usually indicate this.

If there is any question as to where the distortion is occuring, a high-impedance headphone or an audio-signal tracer may be used to check the quality of the sound at different points in the set. If you use headphones, be sure to use a blocking condenser in series to avoid passing dc through the headphone.

Oscillation may occur in either the audio i-f or the audio circuits because of open plate or screen by-pass condensers. Incorrect lead dress (positioning) may also cause oscillation, particularly in the audio i-f amplifier.

When there is oscillation in the audio circuit, it may sometimes feed into the video circuit, producing sharp lines or bars on the screen of the tube.

Hum (as well as distortion) may be introduced by an open grid circuit or by heater-to-cathode leakage in one of the tubes. It may also be caused by an open filter or by-pass condenser, but this will usually introduce hum in some other portion of the receiver as well.

The primary consideration when servicing the sound system of a TV receiver is the possibility of common coupling between the video and audio portions of the receiver so that a defect in one affects the operation of the other.

CONCLUSION

You have learned that the professional servicing technique for TV receivers is a composite of many separate servicing methods, together with a large measure of effect-to-cause reasoning. You have found that no one servicing method alone will always enable you to localize trouble.

If you have faithfully carried out the experiments as outlined, the skills you have acquired will be of tremendous value to you in future service work.

Although we have outlined many experiments, there are still many others that you might perform. You may continue to introduce different defects in your receiver to see how the defects affect set operation, if you wish.

Be careful, however, not to introduce any defect that will harm major parts in the set. Do not short out a filter condenser if there is danger of burning open an expensive filter choke or causing a rectifier tube to burn out. Similarly, do not apply positive voltage to the grid of the picture tube, since this may damage it.

Avoid introducing defects or changing parts in the front-end of the receiver; this may change the alignment and may make it difficult to pick up all channels. Re-alignment of the front-end is rather difficult.

In addition, you should make an effort to carry out this series of tests on at least one other set, preferably on one of a widely different type. By doing this, you can acquire a knowledge of the operation of each of the basic types of circuits that you will encounter in television work.

Of course, if you use a receiver that is quite different from the types we have suggested, you can expect to get entirely different results with many of these experiments. This in itself is very good training —it shows you more definitely what you can expect from particular defects in widely differing circuits.

PRACTICAL TRAINING IN
TV SERVICING

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ANALYZING TYPICAL
TV RECEIVERS

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PIONEER HOME STUDY RADIO SCHOOL

STUDY SCHEDULE

This text is not intended as a regular study Lesson—it outlines a Practical Training Plan for getting practical experience in television servicing. We recommend that you follow this plan if you expect to do TV service work.

ANALYZING TYPICAL TV RECEIVERS

IF you plan to do television service work, you must get practical experience on commercial TV receivers, so that you can learn to apply the knowledge you are gaining from your NRI Course.

It is possible to get this experience by serving an apprenticeship with an established service shop, but there you are likely to be hampered in your attempts at getting experience because the serviceman in charge may have fixed ideas as to the methods of servicing, and business reasons such as the need for rapid service may prevent you from carrying out tests in such a way as to get the most benefit from them. Furthermore, you have no assurance that you will get a truly diversified training this way unless you serve a long period of time—sets with the rarer defects may not come in for months.

The same thing is true in radio servicing—for this reason we suggested early in the Course a Practical Training Plan for radio sets. If you have carried out this training plan on one or two radio receivers, you have gained the equivalent of at least a year of practical radio-servicing experience.

Since this plan has proved so successful on radio receivers, we are introducing it for television receivers, also. By following almost the same procedures that we gave for use on a radio receiver, you can demonstrate to yourself on a TV set just what will happen when various defects are introduced, and you can learn to find your way around in a commercial TV receiver. When you introduce defects yourself, you are in complete control of the situation and can thus get the varied experience it might take you many months of apprenticeship to accumulate.

What the NRI Plan Is. In review, the NRI Practical Training Plan is one in which you obtain a standard receiver, and are then instructed in the methods of introducing defects and of localizing these defects in that set.

It is desirable that you carry out this series of experiments on a standard commercial receiver of the type you are going to meet in your service work. Far less can be learned from an experimental set-up or from a non-standard kit that you may have assembled. As an important step in putting your theoretical knowledge into actual use, you should get a set that you are not particularly familiar with, and then learn how to locate sections, stages, circuits, and parts, by working from the schematic diagram of this set, just as you would have to do if you were doing TV service work. Then, when you can find your way around in that set, you or someone else can introduce

specific defects, and you can follow standard servicing procedures to localize the source of difficulty. By trying all types of servicing techniques, you will learn which one works best for each particular complaint.

In summary, the steps of this plan are:

1. Obtain a suitable receiver of the type recommended later in this book.
2. Use the service information contained in this book, or obtain the manufacturer's manual on the set so that you will have complete service information on it.
3. Analyze the circuit diagram to find out how the set works.
4. Check the operation of the set and learn just what all the controls are for.
5. Use the circuit diagram to learn how to locate sections, stages, and parts in the set.
6. Follow a step-by-step procedure to introduce defects in the set.
7. Observe the effect of each defect on the operation of the receiver, and see how effect-to-cause reasoning can be applied.
8. Use each of the basic methods of localizing defects (such as signal tracing, stage blocking, voltage measurements, etc.) to see which one is best for a particular defect.
9. Restore the set to its original condition and practice alignment techniques in getting it back to normal operation.

This workbook is intended to cover the first five steps, and another will give the rest of this Practical Training Plan. If you will carry out the steps outlined in these books, you will gain the same kind of practical experience on a television set that you did on a radio receiver.

Of course, you are not *required* to carry out this plan, but we strongly advise you to do so to get the greatest good from your Course. Also, to get the most benefit from this instruction in TV servicing, you should first have carried out the corresponding plan on a radio receiver. A radio receiver is simpler to work on than a TV set, so you can learn how to find your way around in the radio set much more easily. Then, once you have learned how the various service techniques are applied to the radio, it will be far easier to apply this knowledge to a TV set.

Now that you have an understanding of the basic plan, let's go on to details for each of these steps.

RECOMMENDED RECEIVERS

In the Practical Training Plan for radio servicing,

we did not have to specify a particular receiver for you to work on, because radio sets are so standardized that practically any superheterodyne of the types recommended would be certain to have circuits that would permit you to carry out the steps outlined.

Turning to television sets, however, we find that at present, there is a fair amount of developmental work still going on, so television receivers are not as settled in their characteristics as are radio receivers. There are quite a number of variations in the circuits used; some types do not lend themselves very well to our training plan, and others contain rarely used circuits. For this reason, we are forced to recommend specific receivers for the plan outlined in this text.

Therefore, after making a careful study of the receivers available, we have chosen three receivers that are representative of the circuits in use in the majority of TV sets. These sets differ considerably from each other, but any one will be suitable for carrying out the training plan. Later, you may want to run through the plan on another of these types, to round out your experience.

Best Sets to Use. The three models we recommend are:

(1) RCA Model 630TS.
(2) Stromberg-Carlson Model TV-12.
(3) Hallicrafters Models T54 or 505.

The circuits used in these sets were also used in a number of other sets: Table I gives a list of equivalent sets. Each of these sets is enough like its corresponding recommended model that (with a few modifications in certain experiments) any one can be used for the experiments we shall describe. If you

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TABLE I

Equivalent sets that may be used are as follows:

Equivalent to RCA 630TS:
  Airking Model A-1000
  Ansley Models 701, 702
  Crosley Model 307 TA
  DeWald Models BT100, BT101
  Fada Model 799
  Hoffman Models CT-800, CT-801, CT-900, CT-901
  Mars Television Co. Model 1200
  Multiple TV Mfg. Co. Model M-1500
    (Also Model M-2000, but has H.V. Doubler)
  Nielsen Model 1018
  RCA Model 8TS30
  Regal Model TV-1030
  Televista Model TV-1030
  Philmore Kit Model P30
  Tech-Master Kit Model 630TK

Equivalent to Stromberg-Carlson TV-12:
  Crosley Model 9-407 Series
  DuMont Model RA-103

Equivalent to Hallicrafters T-54 or 505:
  Airline Model 84HA 3002A
  Airline Model 84HA 3002B
  United Motors Model TV-71

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try to use sets other than these, however, you must realize that you may not get the same results, and you must be careful not to introduce defects that may damage the set.

Set Types. The Hallicrafters receiver (and its equivalents in Table 1) is typical of the smaller (portable) electrostatic tube receivers. It uses an r.f. high-voltage supply, a transformerless low-voltage power supply with doubler and tripler circuits, and has a series-parallel filament string. This type of power supply is found in most smaller receivers using electrostatic picture tubes, and in some of the inexpensive sets using electromagnetic picture tubes. In addition, it uses an intercarrier sound system, in which the sound signal is obtained from the 4.5-megacycle beat signal between the video i.f. and audio i.f. carrier signals.

The Stromberg-Carlson (and its equivalents) uses a conventional low-power supply having a power transformer and rectifier tubes. A continuous tuning front-end is used that allows reception of both the upper and the lower TV bands and the FM band. It uses a fly-back high-voltage supply, which is typical of the majority of sets with electromagnetic picture tubes. A complex coupling network is used in the video i.f. amplifier to give the desired broad band-pass characteristic. An a.f.c. (automatic frequency control) circuit keeps the horizontal sweep frequency in step with the incoming sync pulses, and a separate sound i.f. channel is provided.

The RCA has some features similar to those in the Stromberg-Carlson. However, the video i.f. amplifier has coils tuned to different frequencies—the popular "stagger-tuned" i.f. system. The front-end uses a step-switch arrangement rather than continuous tuning. There are also minor circuit modifications that differ from the Stromberg-Carlson. Although this set is probably the most complex one of the three, it is the most representative of today's TV sets, and is also the most widely available. We recommend that you look for this set (or one of its equivalents in Table 1) first.

OBTAINING YOUR TEST RECEIVER

An important factor in our choice of these three sets (and their equivalents in Table 1) is their wide availability. All these sets were produced in comparatively large quantities and have received fairly wide distribution. Some are still in production; others are now being "unloaded" because of newer models, and a few may now be available second-hand because of trade-ins for later models or ones with larger screens.

In addition to the manufactured receivers, the RCA circuit received wide distribution in kit form. We do not recommend that you assemble a kit in order

to carry out this Practical Training Plan, but a standard kit assembled by someone else will be quite satisfactory. Remember that one purpose of this Plan is to make you familiar with working on a commercial receiver. In addition to learning servicing techniques, you will also learn the technique of identifying circuits and parts by using a schematic diagram. In a receiver you built from a kit, you would already know the location of every part, so its training value would not be as great.

You can get your test receiver from your local radio store, from mail-order or local wholesale supply houses, or by purchasing one from a neighbor. If you already have one of these three sets, you can use it; the Practical Training Plan will not damage it.

It is not necessary for you to purchase a *new* receiver. A used set is perfectly all right. *It is essential, however, that the set be in good condition.* Otherwise, when introducing a defect, you cannot be sure whether the results are due to the defect that you introduce or to some other defect already in the set. If the set is not in good condition, take it to some reliable TV service technician and have him put it in first-class shape.

Then, be sure that your set is correctly installed so that it is operating perfectly on at least one local TV channel. Your set should be working at least as well as other receivers in the locality. If you cannot get help in making this possible, wait until you master the Lessons on TV receiver installation before carrying out the Training Plan.

SERVICE MANUALS

Most manufacturers publish a service manual for their sets which contains the schematic diagram, sometimes a pictorial lay-out, a tube location chart, and pictures showing the location of the various adjustments and controls. Detailed instructions are usually given for adjusting the controls and for setting up the receiver. These service manuals are quite valuable to the service technician.

It will *not* be necessary for you to get a service manual for your receiver if you use one of the three recommended sets, as most of this information is in this workbook. If you find it necessary to carry out this Plan on a different set, then you should certainly obtain the manufacturer's service manual for your receiver and read it through. If you cannot get a service manual from the set manufacturer or his local distributor, write to us. In most instances we can furnish a folder containing the diagram and service instructions for your set for a charge of $1.00.

GENERAL PRECAUTIONS

Now, if you have obtained a suitable TV set, you are ready to proceed to analyze the circuit and to learn to find your way around in your set. Before you do so, however, let us go over certain precautions that you should follow when working with any TV receiver.

First, remember that there are two dangerous power supplies in a TV receiver. One is the high-voltage supply used for accelerating the electron beam (voltages between 4000 and 30,000 volts) ; the other is the "normal" B voltage supply. Although the B supply voltage may be only about 300 volts or so, this supply is just as dangerous as, if not more dangerous than, the high-voltage one, because the low-voltage supply in most TV sets (and for that matter in ordinary radios) can deliver a fairly high current. Thus, there is danger not only of shock, but even of electrocution. With the high-voltage supplies, there is danger of a severe shock, but because the power supplies are, in most instances, the high-impedance type, there is less danger of a fatal shock.

Because of the possibility of shock, you should be careful while working on a TV receiver. When working on a "hot" set, make it a practice to keep one hand in your pocket so that there is less danger of setting up a complete path through the body. Also, when you first turn off the set, allow some time to elapse before working on it, so that condensers will have time to discharge. You may even wish to use a screwdriver to short the high-voltage and power-supply condensers as a precautionary step.

Definitely do not work on your TV receiver while standing on a basement floor or on a damp floor. This is particularly true of receivers of the Hallicrafters type since the chassis is connected to one side of the power line. (Many servicemen use a 1:1 isolation transformer between such sets and the power line to reduce the shock hazard. For TV receivers, these transformers must be rated at least at 300 watts, and preferably at 400 watts or more.) Do not touch a radiator, a cold-water pipe, or any other ground while working on such a set.

There are also certain precautions to follow when handling the picture tube. First, remember that the picture tube is a large mass of glass; therefore, you should observe all precautions that you would normally follow in handling any large glass object. Use as much care in handling the picture tube as you would a large fishbowl.

Also remember that a very high vacuum exists within the picture tube. Because of this, if the tube should be broken, there is danger that the glass will all collapse upon itself, causing an "implosion" (as distinguished from an "explosion"). The glass will fly all over the room.

Therefore, handle the picture tube with extreme care—do not scratch the surface of the picture tube as this will weaken it, do not strike the tube a hard

blow, and do not put any undue strain or pressure upon it. You should always wear shatter-proof goggles and heavy gloves when handling picture tubes. Many servicemen use thick vests or heavy canvas shop aprons also.

Notice that a picture tube has a very narrow neck with respect to the large glass funnel. This neck is comparatively weak and the tube should definitely *not* be handled by it. Handle the tube by the funnel and the edges; touch the neck only to guide the tube into position.

When placing a tube in a TV receiver, do not force it into position. If it does not slip into place easily, find the obstruction, and remove it.

Most of the glass electromagnetic tubes have an outer "aquadag" coating. There is also an inner coating of similar conductive material. The capacity between the inner and outer coatings is used as the output filter condenser for the high-voltage supply. Because of this, even when the tube is disconnected, a considerable charge may exist between the inner and outer coatings. This charge may be held for a long period of time and may not be completely removed even by momentarily shorting between the high-voltage terminal and the outer coating (because of dielectric hysteresis).

Although such a charge is not normally sufficient to be dangerous in itself, it might give you enough of a shock to cause you to drop the tube and break it. Whenever you are removing a tube from a set, after disconnecting the high-voltage terminal, use a test lead to short between the outer coating and the high-voltage terminal as a precautionary move. Hold the test lead in place for several seconds, break contact, and short again for some time to be sure of discharging the capacity.

Follow this procedure even on a new tube before handling it. They are tested at the factory, and may come to you with a charge still in them. Hence, be careful when unpacking a new tube not to touch the high-voltage terminal until you have discharged it.

Finally, when working with a TV receiver, remember that some of the parts get very hot and you may be burned if you touch them. This is particularly true as far as rectifier tubes and bleeder resistors are concerned.

Because considerable heat is generated in a television receiver, it should not be placed in a hot location such as near a radiator or a hot-air register. Adequate ventilation should be provided around the receiver—do not jam a TV receiver against a wall or place it in between other heavy furniture so that there is little air space around it.

When unpacking a receiver, be sure to check all shipping tags and the labels for special instructions before removing them.

GENERAL INSTRUCTIONS

As we have mentioned, if you obtain one of the three sets that we recommend, complete service information is in this text. Their schematic diagrams are on the large sheets labeled A, B, and C, stapled into the center of this book. Open these staples carefully, and remove these three large sheets so you will have them separate for convenient reference. As these are to be used with both this workbook and another one, be sure to keep them.

Although you will naturally concentrate on the section of this book that covers your set, it is a good idea to study the other sections as well. In this way you can become familiar with other commercial sets.

The technical details in this text are brief, because the complete details of circuit operation can best be covered in your study Lessons. If you do not understand certain details now, remember to restudy this book after you have finished the Lesson on that section of the TV receiver.

If your set is not one of the three recommended, study the section that most closely corresponds to your set, then use the manufacturer's service information to make a similar study of yours.

The Hallicrafters Series

This section is basically written for the Hallicrafters models 505 and T-54, which differ only in their cabinets—the 505 has a wooden cabinet and the T-54 has a metal one. This information applies in general to the Hallicrafters equivalents in Table 1, and much of it can be used for other models that are similar. However, on sets other than the models mentioned above, don't overlook basic changes that may completely change the operation of certain of the stages. As a matter of fact, it is well to be careful on

any set, since there may be certain minor changes that make it different from the schematic. Many manufacturers make changes in their models during production, and they don't always make corrections on their diagrams.

HALLICRAFTERS BLOCK DIAGRAM

In studying this set, let's first run through the technical details of its operation, then go on and learn the operation of the controls, how to remove it from
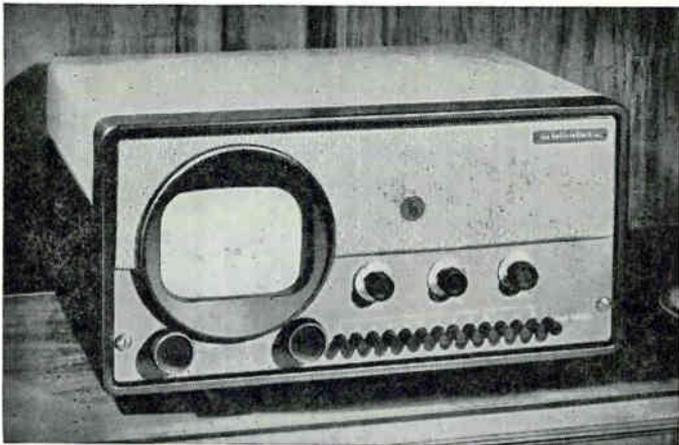
FIG. 1. Front view of the Hallicrafters receiver recommended for this text. This is the metal cabinet model—the one in the wooden cabinet is quite similar in its appearance and uses the same chassis.

its cabinet, and how to locate circuits and parts on the chassis.

A front view of this set is shown in Fig. 1. This Hallicrafters is a.c. operated and has a 7-inch electrostatic-deflection picture tube. The set uses the intermodulation (intercarrier) sound system. Tuning is by means of 13 push buttons. Twelve of them tune the 12 TV channels. The first push button does not tune in a channel—it was provided for channel 1,

which has since been discontinued as a TV channel. Another knob resembling a push button is actually on a trimmer; rotating it provides fine tuning on all channels. The antenna input for the receiver is designed to match a 300-ohm transmission line. A "power inter-lock switch" cuts off all voltages when the back panel is removed in the Model 505; in the Model T-54, voltages are removed when the cabinet lid is opened.

This receiver uses a transformerless power supply and a series-parallel filament string. Although no power transformer is used, there are voltage doubler and voltage tripler circuits; therefore, the set will operate on a.c. only.

A functional block diagram of the Hallicrafters receiver is given in Fig. 2. Such a diagram is often valuable in diagnosing receiver troubles, since it enables you to see at a glance the signal path through the receiver. Thus, when there is some trouble that kills one or more sections, you can better apply effect-to-cause reasoning in isolating the trouble to a section of the set.

Looking at the functional block-diagram, it is easy to see how the receiver operates. When the receiver is tuned to a TV station, the picture and sound carrier signals are picked up by the antenna and delivered through the 300-ohm antenna transmission line to the r.f. amplifier. Here, they are boosted in
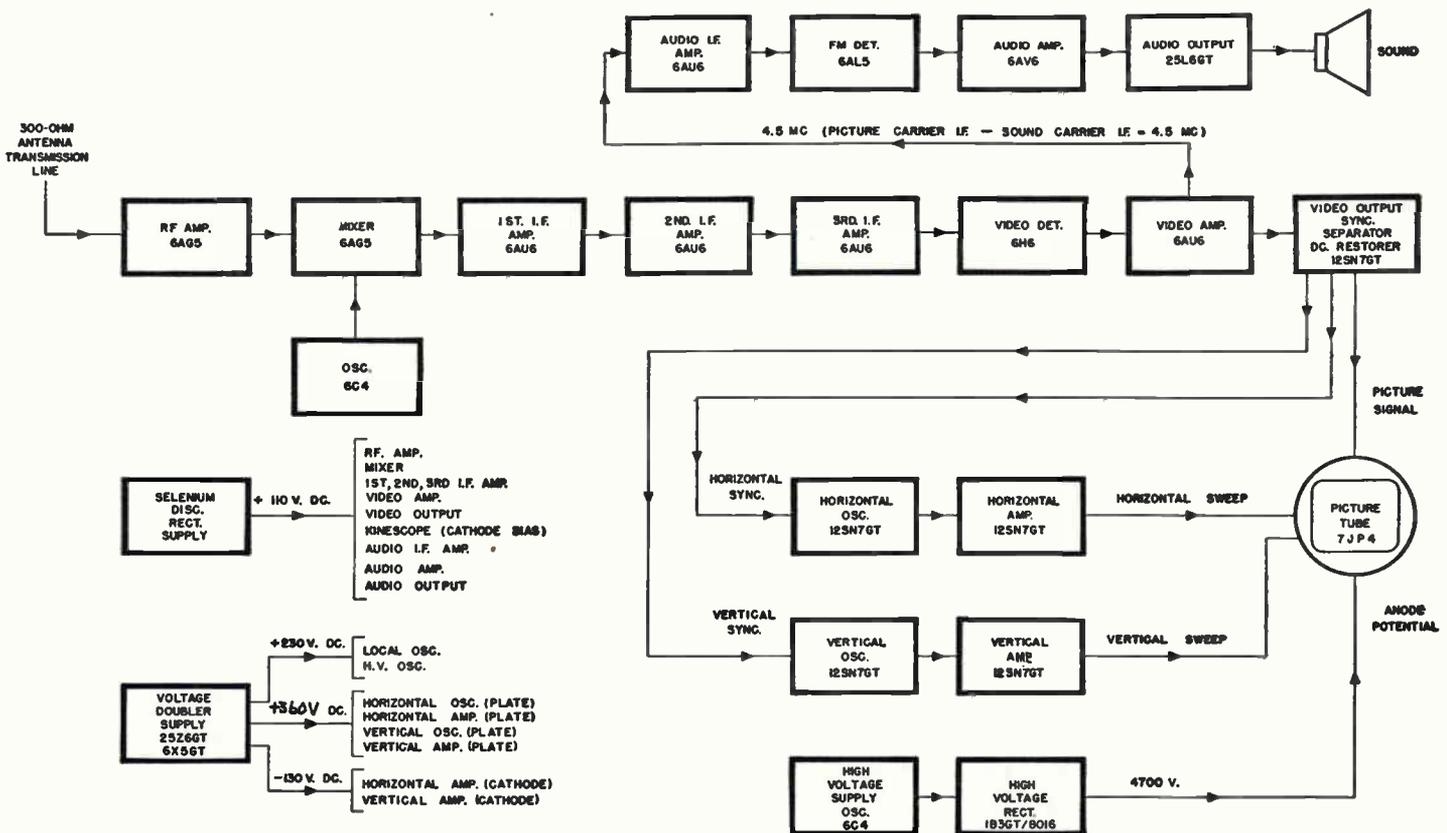
FIG. 2. A block diagram of the Hallicrafters series.

amplitude in order to improve the signal-to-noise ratio at the input of the mixer. At the same time, the tuned r.f. stage rejects certain interfering signals.

In the mixer, the two carrier signals beat with the signal from a local oscillator to form the picture and sound i.f. carrier signals. The picture carrier i.f. frequency in this set is 26.25 megacycles, and the sound i.f. carrier frequency is 21.15 megacycles. Note that the separation of the i.f. carrier signals is exactly 4.5 megacycles. This is always true in any TV set regardless of the exact i.f. values and regardless of the adjustment of the fine tuning control, because the station's sound and video carriers are exactly 4.5 megacycles apart.

The i.f. carrier signals are amplified by three stages of i.f. amplification. These stages are sufficiently broad to pass both the sound and the picture i.f. carriers, although the sound-carrier amplification is low.

At the video detector, the video signals are stripped from the picture carrier and fed through the video amplifier and video output to the picture tube.

Since both the picture i.f. carrier and the sound i.f. carrier are fed into the video detector, they beat together to produce a 4.5-mc. difference frequency. This difference frequency is modulated with the FM sound signal and a certain amount of the video AM signal. At the output of the video amplifier, this 4.5-mc. carrier is fed through the audio i.f. amplifier, which is tuned to 4.5 megacycles. This stage acts partly as a limiter, thus removing part of the video AM modulation. The signal is then injected into the FM ratio detector where the sound signals are stripped off the carrier and fed through the audio system to the loudspeaker. The FM detector used in this set is insensitive to amplitude modulation, so the video signal does not normally come through to the loudspeaker.

Sync separation and d.c. restoration take place in the video output stage. The horizontal and vertical sync pulses are then fed to the horizontal and vertical sweep oscillators, respectively. The signals from the sweep oscillators are fed through amplifiers and applied to the picture-tube deflection plates.

The high second-anode potential is obtained from an r.f. oscillator which supplies high r.f. voltage to a half-wave rectifier. This voltage, after filtering, is applied to the second anode of the picture tube.

. Three rectifiers supply the B-supply operating voltages that are fed to the stages indicated in the block diagram.

DETAILED ANALYSIS

The complete schematic diagram for the Hallicrafters receiver is given on the enclosed large schematic, Fig. A. Open up this diagram, and use it in the following detailed analysis.

Front End. Looking at the upper left of the schematic, we can see that the receiver tunes to the various channels by means of push buttons. As we pointed out previously, although thirteen push buttons are provided, only No. 2 through No. 13 are used. No. 1 may or may not be connected; it can be ignored, as there is no station on channel 1.

Fig. 3 shows the circuit of the front-end when the push button for channel 13 is depressed. The trimmers that now tune the r.f., mixer, and oscillator stages to resonance are marked C_{1M}, C_{2M}, and C_{3M}.

Sound and video carrier signals coming down the 300-ohm transmission line appear across center-tapped choke L_{28}, which balances the line to the chassis (ground). Blocking condensers C_{28} and C_{29} keep the antenna from being hot with respect to the chassis even though the chassis is connected directly to one side of the power line.

The TV signal is applied through blocking condensers C_{30} and C_{31} so that half appears across R_{26} and half across R_{27} in the grid and cathode circuits of r.f. amplifier tube V_5. Initial bias is obtained by means of the drop across R_{27} and the grid-return path is through R_{26} and R_{28}. A.V.C. voltage is applied across R_{28} as shown.

We have a parallel resonant circuit as the plate load, consisting of L_9, C_{12}, C_{1M}, and the capacity existing between the plate and the cathode of the tube. The presence of R_{27} in the cathode circuit (effectively in series with the plate-cathode capacity) broadens the response of the circuit by lowering the Q.

The exact resonant frequency is determined by the value of C_{1M}, an adjustable trimmer. With the proper push button engaged, this trimmer is adjusted to resonance with the station desired. (Other trimmers replace this one as other push buttons are engaged; each can thus be adjusted for the station corresponding to its push button.) Resistor R_{10} has a resistance of 1 megohm and has no electrical effect on the circuit. It is simply used as a form on which to wind L_9. Resistors R_{11} and R_{12} are used in the same way with coils L_5 and L_1.

The signal present across L_9, C_{12}, and C_{1M} is applied through coupling condenser C_{33} to the parallel-resonant circuit consisting of L_5, C_{13}, C_{2M} and the grid-to-cathode. capacity of mixer tube V_6. At the same time an r.f. signal from the ultra-audion oscillator V_{14} is fed through coupling condenser C_{35} to the grid of the mixer tube V_6. This signal causes V_6 to draw grid current, so the tube self-biases itself via the drop across R_{31}. After the mixing and detecting actions, the difference frequency signals are also present across plate load L_{14}, which is tuned to the video i.f. frequency by the tube output capacity (plate-cathode plus stray plate-chassis capacities).

A particular channel (13 in this case) is approxi-

mately tuned in by preadjustment of trimmer C_{3M}, and fine tuning is accomplished by means of trimmer C_{37}, which is separately controlled from the front panel.

The I.F. Amplifier. Two i.f. signals are produced in the mixer. One is the sound i.f. carrier signal and the other is the picture i.f. carrier signal. Both are


FIG. 3. The schematic of the tuner section of the Hallicrafters receiver. Shown here are the r.f. tube, the first detector, and the oscillator. The parts for only one channel are shown in the tuning circuits.

present across tuned load L_{14} and are transferred to the next stage through coupling condensers C_{38} and C_{42}.

Referring to the large schematic diagram, we see that the signal appears across R_{33} and is applied to the grid of the first i.f. amplifier tube V_7. The amplified signal appears across tuned plate load L_{15} and is sent through C_{39} and C_{43} to the grid-cathode of second i.f. tube V_8.

The two i.f. carrier signals are amplified still further by this stage and appear across tuned plate load L_{16}. The signal is then transferred through C_{47} and C_{44}, appearing across the input of the third i.f. tube V_9.

Again the signals are amplified and appear across plate load resister R_{117}. They are transferred through C_{48} and C_{45}, appearing across the tunable input of V_{10}.

The Video Detector. V_{10} is the video detector. The input is tuned by tube capacitance and variable inductance L_{17}. When the video signal drives the cathode of V_{10} negative with respect to its plate, the tube conducts. The detected video signal together with the 4.5-megacycle beat signal of the two carriers appears in the plate circuit of V_{10}, across the load L_{19} and R_{43}.

The d.c. component of this detected signal, which appears across R_{43}, is used for a.v.c. purposes; this voltage is filtered by R_{42} and C_{51} for application to the grids of the second i.f., first i.f., and r.f. stages.

The video signal across R_{43} and L_{19} is transferred through C_{50} and appears across R_{44} in the grid circuit of first video amplifier V_{11}. The 4.5-megacycle beat signal also appears here. The gain of V_{11} can be varied by adjusting its cathode resistor R_{48}. Thus, R_{48} is used as a Contrast control.

The Sound Channel. In the plate circuit of the first video amplifier V_{11}, the 4.5-mc. signal is taken off through C_{27} and applied to the resonant circuit created by L_{23}, C_{15}, and the grid-to-cathode capacity of tube V_1.

This signal at the input of the first audio i.f. amplifier again undergoes selection in the tuned plate circuit, which is adjusted to 4.5 megacycles. This i.f. amplifier has comparatively low plate and screen voltages, so it acts partly as a limiter stage. Thus, it tends to suppress amplitude variations in the FM signal.

The 4.5-mc. signal across the primary of T_1 is induced in the secondary and is then fed to ratio detector V_2. The resulting audio signal appears across condenser C_{22}. From here it is fed through condenser C_{21} to the volume control. The remainder of the audio circuit works in a conventional manner. Bleeder resistor R_{21} connects to the cathode of audio amplifier tube V_3 to supply additional bias on this stage.

The Video Amplifier. Returning to tube V_{11}, we know that the video signal as well as the 4.5-mc. beat
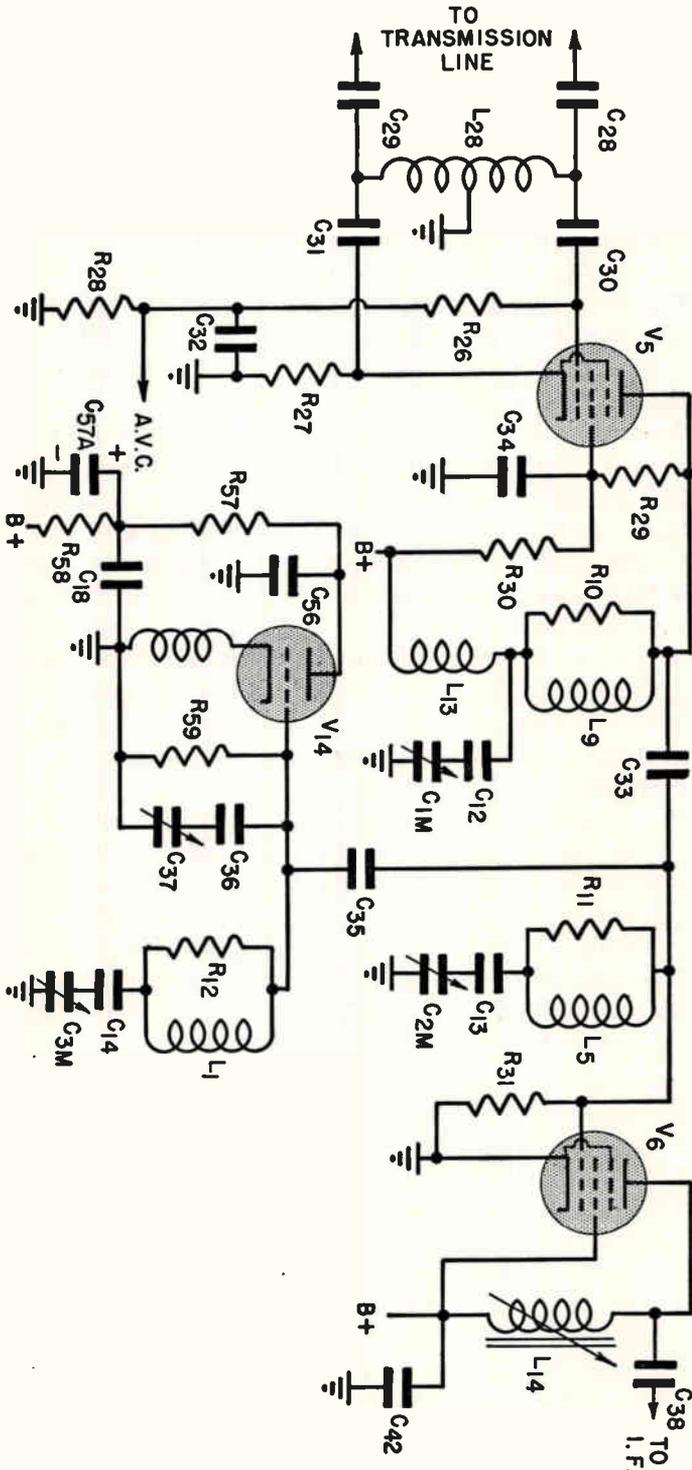
is present in the plate circuit, appearing across peaking coil L_{21} and plate load resistor R_{47}. Peaking coil L_{20} isolates L_{21} and R_{47} from the output tube capacity of V_{11}, thus increasing the high-frequency response. The signal across L_{21} and R_{47} is applied to the input of one section of V_{12}. This section uses a cathode-follower circuit, and the video signal developed across cathode resistor R_{53} is applied through condenser C_{17} to the cathode of the picture tube.

A fairly high signal voltage is necessary to drive the picture tube properly, so a large cathode resistor (R_{53}) is used. To prevent the high bias voltage across R_{53} from cutting off this section of V_{12}, the grid is made somewhat positive with respect to ground by its connection to B+ through R_{49}. Therefore, a normal grid-to-cathode voltage relationship is obtained for class A amplification.

Sync Separation. From the cathode resistor R_{53}, the coupling network C_{53}, R_{54}, R_{113}, and C_{55} applies the video signal to the grid of the sync separator and d.c. restorer section of V_{12}. This section is purposely overbiased to clip the video signal, amplifying only the sync pulses. The voltage across cathode resistor R_{52} and condenser C_{54} follows the average level of the sync pulses and is the d.c. restoration bias for the picture tube. For all practical purposes, the grid of the picture tube is at video ground potential but not at d.c. ground potential.

Sync pulses are removed from the plate of the sync separator section of V_{12} and are then separated into horizontal and vertical pulses by means of the proper networks at the inputs of V_{17} and V_{18}. Thus, R_{62}, R_{115}, and L_{22} in the V_{17} input act as a filter so only horizontal pulses appear across R_{115} and L_{22}. At the same time C_{66}, R_{76}, R_{75}, and C_{61} act as a filter so the vertical sync pulses appear across C_{61} at the input of V_{18}. Any horizontal pulses across this condenser are further reduced by the network consisting of R_{80} and C_{62}. Across C_{62} we have only vertical sync pulses.

The Horizontal Sweep Circuit. V_{17} is a multivibrator incorporating an R-C discharge circuit to form the necessary saw-tooth sweep voltage for horizontal deflection. C_{69} is the horizontal discharge condenser.

Horizontal saw-tooth signals are fed through C_{70} to the input of the horizontal amplifier V_{19}. By adjusting R_{114} in the plate circuit of the second half of V_{17}, the amplitude of these saw-tooth signals can be controlled. The left-hand section of V_{19} steps up the saw-tooth voltages to the necessary value for deflection of the electron beam in the picture tube. Part of this signal is tapped off from the plate load by means of parallel condensers C_{96} and C_{97} and is fed to the grid of the right-hand section of horizontal amplifier V_{19}. This tube section acts as a phase inverter and amplifier, so the signal across its plate load R_{68}

equals that across R_{67}, but is 180° out of phase. The sweep signals are applied to the horizontal deflection plates through coupling condensers C_{72} and C_{71}.

Vertical Sweep Circuit. The vertical sweep uses a multivibrator V_{18}. The vertical saw-tooth signal developed across discharge condenser C_{64} is applied to the height control through coupling condenser C_{65}. By varying the slider arm of the height control potentiometer, any amount of the available signal may be applied to the input of the left-hand section of the vertical amplifier V_{20}. This tube is biased by resistor R_{87}. There is no by-pass condenser, and the degeneration makes the amplifier more linear.

The amplified saw-tooth signal appears across plate-load resistor R_{85} and is applied to one of the vertical deflection plates through coupling condenser C_{74}. Part of this signal is taken off through coupling condenser C_{75} and through resistor R_{88} for application to grid resistor R_{91} of the right-hand section of the vertical amplifier V_{20}. The resistors R_{88} and R_{91} form a voltage divider to control the amount of signal reaching the grid of this section. The amplified signal across plate load resistor R_{86} is applied to the other vertical deflection plate through C_{73}.

The High-Voltage Supply. Tube V_{21} is the high-voltage oscillator tube employing a tickler in the grid circuit. The plate load of the tube is tuned to the proper oscillator frequency (in the vicinity of 300 kc.). The high-voltage winding shown opposite the tank winding consists of several sections called "pi's," giving a high-step-up ratio. As a matter of fact, approximately 4500 volts at 300 kc. may appear across this winding.

The filament winding for the rectifier tube consists of one turn around the coil form below the high-voltage winding. Sufficient current is induced in this winding to light the filament of rectifier tube V_{22}. The tube conducts when the plate becomes positive, thus placing approximately 4700 volts across input filter condenser C_{81}.

Resistor R_{90} and condenser C_{82} filter the r.f. ripple, leaving practically pure d.c. across condenser C_{82}. This is applied directly to the second anode of the 7JP4 picture tube.

So that the centering controls can have a neutral level about which to vary, one of the vertical and one of the horizontal plates connect to the junction of R_{101} and R_{102} through resistors R_{99} and R_{100}. The other deflection plates connect to the vertical and horizontal positioning controls. By moving these controls the picture may be moved up or down or to the left or right, because they apply a d.c. higher or lower than the level at the R_{101}-R_{102} junction, so there is a d.c. difference between the deflection plates.

A voltage-divider network is connected from the end of resistor R_{102} to the chassis, and resistor R_{94}

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in this network is a potentiometer to provide a variable voltage to the first anode of the 7JP4. This is the focusing voltage and by varying the slider arm of resistor R_{94}, a sharp, bright picture can be obtained.

The Low-Voltage Supply. The power supply for the low d.c. voltages of this receiver deserves special consideration and is reproduced separately in Fig. 4. Two tubes, V_{15} and V_{16}, and a selenium rectifier, CR_1,
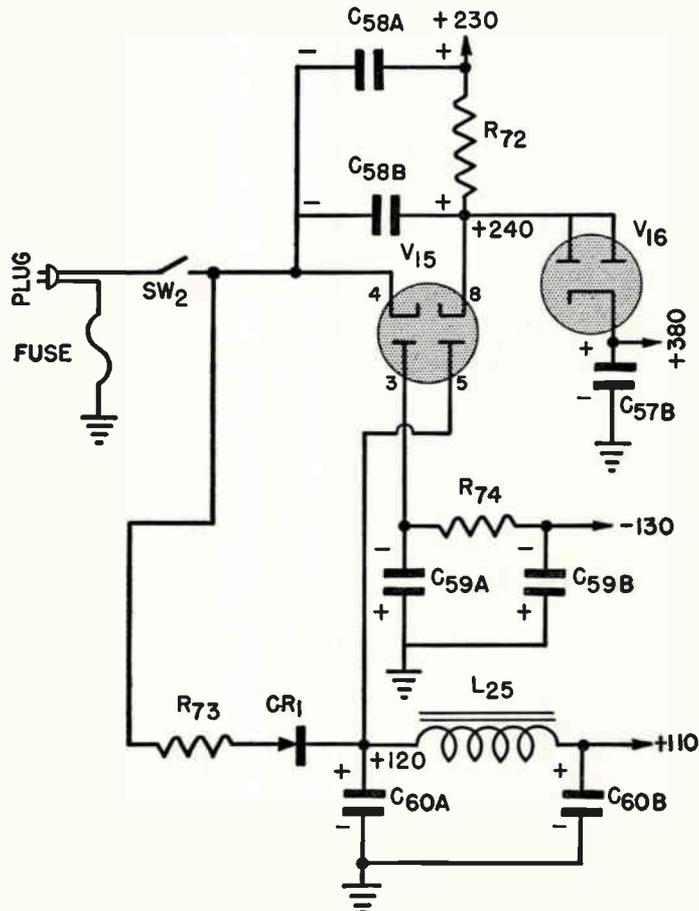
FIG. 4. The power-supply section of the Hallicrafters receiver.

are used in this supply circuit. One of the tubes used, V_{15}, is a dual diode, the left-hand section of which is used in a negative voltage supply. The cathodes of the sweep amplifiers are returned to this supply rather than to ground, thus increasing their effective plate-to-cathode voltage. The negative supply delivers approximately 130 volts.

The right-hand section of V_{15} is used with diode V_{16} and the selenium rectifier in a voltage tripling supply. This supply is tapped at 3 points to deliver approximately 110, 230, and 380 volts. The selenium rectifier acts as a half-wave rectifier and develops about 120 volts across C_{60A}. The filter L_{25} and C_{60B} filters this d.c. voltage to produce a 110-volt output.

The voltage across C_{60A} is also applied to the right-hand plate of tube V_{15}. When this tube conducts, the C_{60A} voltage is added to the line voltage, so that a charge of approximately 240 volts is placed on C_{58B}.

There is a voltage drop in filter resistor R_{72}, so only about 230 volts appears across condenser C_{58A}.

The 240 volts across condenser C_{58B} is added to the line voltage and is applied to the plate of tube V_{16}. When this rectifier conducts, this voltage charges C_{57B} to about 380 volts. For the B supply of the horizontal and vertical amplifiers, we thus have approximately 380 plus the —130-volt output, or about 510 volts.

Circuit Variations. The chief variation you will find between Hallicrafters receivers with this model number is that the earlier models used type 6SH7 tubes in the video and sound i.f. stages in place of the 6AU6 miniature tubes shown in the diagram. A few other minor changes have been made from time to time, but these are mostly changes in part values and are not very important.

LEARNING THE CONTROLS

Now that you have had a brief technical description of the set, we shall assume that you have a Hallicrafters receiver before you. If this is your own set, you will naturally be rather familiar with its operation. However, as it may be one that you have obtained for practice purposes, we shall assume that you know nothing about it.

You should always read carefully the manufacturer's operating Instruction Booklet that accompanies the set, as it contains rather complete information on the proper adjustment of the operating controls that are on the front panel. The semi-adjustable (non-operating) controls on the back of the receiver are normally set up so as to give the proper picture size and positioning at the time the receiver is installed, and they then will not require another readjustment for a fairly long time.

The first step in putting the set into operation is to connect to it the 300-ohm transmission line from the antenna. There is a length of transmission line protruding from the back of the set to which the antenna transmission line is connected. The power line cord is then stretched out to its full length and is plugged in.

The controls on the front panel of the set are pictured in Fig. 1, and of course are described in the manufacturer's Instruction Booklet accompanying the set. They, as well as the back controls, are identified in Fig. 5. This is a layout view of the set as you would see it when looking straight down on the chassis.

If the set has been adjusted previously so that it is operating properly, all that is necessary is to turn the Contrast control to the right to turn on the switch. After the set is warmed up, the Contrast control is advanced to near its full range, and a local station known to be on the air is tuned in. This is done by

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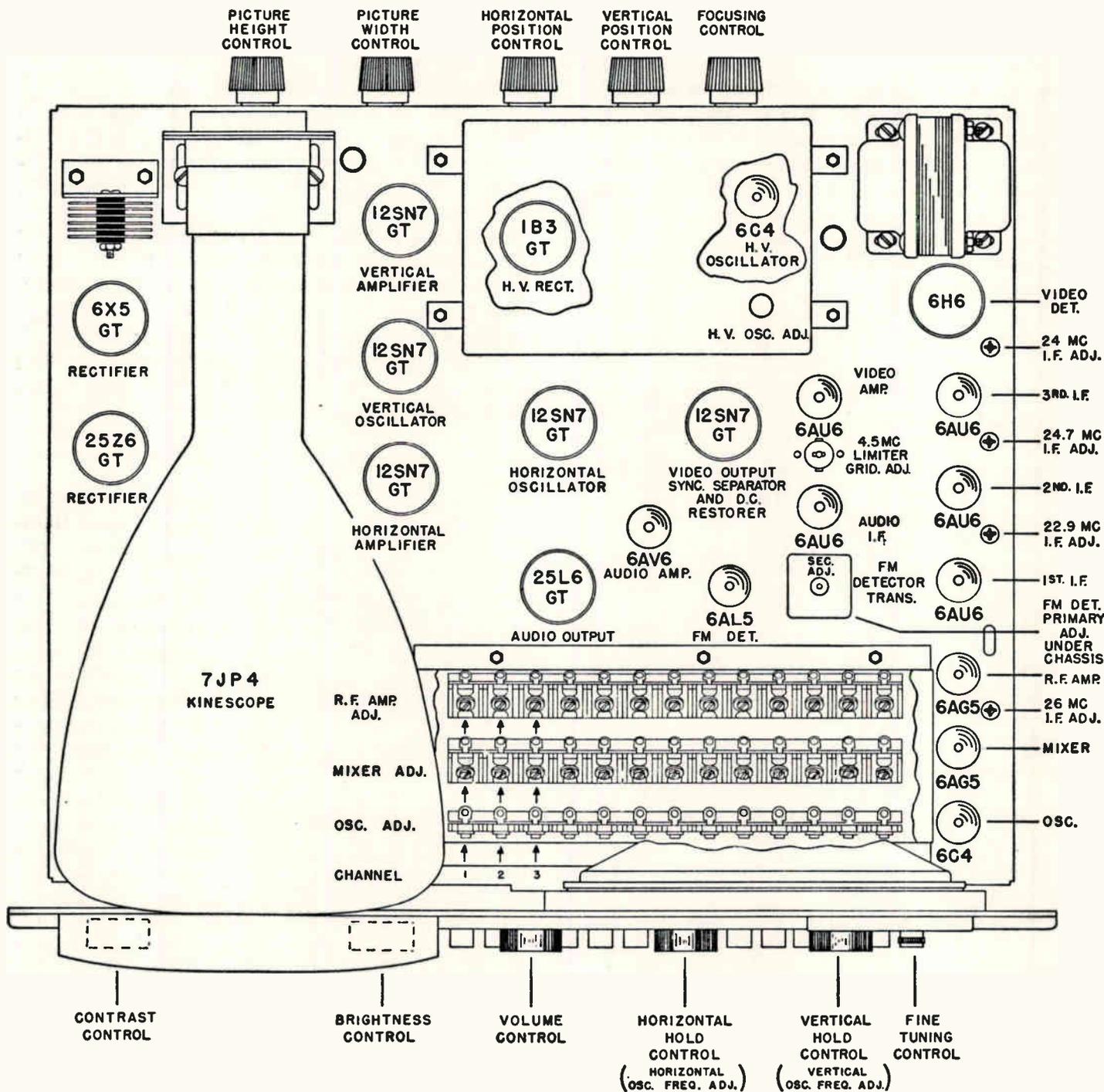
FIG. 5. This is the lay-out of the Hallicrafters receiver, as it would be seen looking down on top of the chassis. The various operating controls as well as the tubes and other important parts on top of the chassis are identified.

depressing the push button corresponding to that station channel. Then, with the Volume control somewhat advanced, the Fine Tuning control is rotated until best sound is heard. At that point, the Contrast control is readjusted as necessary to get a clear, steady picture. The Contrast control adjusts the gain of the video section, and hence acts somewhat like a volume control of a radio set. In this receiver, ad-justing the Contrast control may change the volume somewhat, so the Volume control should be readjusted to a pleasing level.

If the set is not in perfect adjustment, or after a period of time, the Brightness control may need readjusting, as well as the hold controls.

If the picture appears too dark and gray, or too light and washed out, the Brightness control should

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be readjusted. The proper setting for this control depends on the Contrast-control setting and on the room illumination.

Although it is possible to determine the proper setting of the various controls while a regular program is on, it is somewhat easier to work while a test pattern is being transmitted. You can then concentrate on the lines and shades in the pattern, without having to follow variations such as may be present in a regular program. Wait until one of your stations is sending its pattern to carry out the following experiments.

Each station has its own test pattern, and some give more information than others. One style is shown at A on page 44. This style gives a great amount of information about the ability of the set— proper interpretation shows the contrast range, linearity, frequency response, etc. Some station patterns aren't quite so useful, but any will be satisfactory for the following tests.

Through the remainder of this section, we shall refer to the test patterns that are on pages 44 and 45. Study and compare these with each other, then see what happens on your local station patterns as you make each test.

The test pattern at A (page 44) is perfect, and no set is likely to reproduce the pattern this well. However, the more nearly perfect the reproduction, the better the set adjustment. You must become acquainted with a particular pattern to be able to judge the quality of the reproduction.

The test pattern at B (page 44) shows a picture that is too light, and C shows a test pattern that is too dark. A light picture is caused by too high a setting of the Brilliancy control, or by a low setting of the Contrast control (or both). A dark picture is also caused by misadjustment of either of these two controls.

When the video amplifier is a.c. coupled (uses coupling condensers between stages) as in this set, it is possible to get approximately the correct setting of the Brilliancy control by turning the Contrast control all the way down, then adjusting the Brilliancy control until you can barely see light on the face of the picture tube. Then, to get a normal picture, turn the Contrast control up until overloading is indicated by a twisting or tearing of the picture. Then turn the control back far enough to get rid of the overloading.

With a set that uses a d.c.-coupled video amplifier, however, you cannot use this method, because the tube remains lighted until a signal is tuned in, then the signal drives the average brightness level down. In this case, it is necessary to adjust the Brilliancy and Contrast controls at the same time until you get the best picture.

If the Fine Tuning control is mistuned, sound bars may show up in the test pattern as shown at D on page 44. Sound bars are a series of more or less horizontal bars that vary in step with the audio modulation. When a test pattern is tuned in, the audio modulation is usually a fixed tone, so there will be a fixed number of bars. Multiplying the number of visible bars by 60 will give the approximate frequency of the tone.

Mistuning in the other direction may cause distorted sound with a loud buzzing noise. In tuning a TV receiver, it is important to tune for the best sound quality.

The remaining controls on the front panel are the Horizontal Hold and Vertical Hold controls. These controls set the sweep-oscillator frequencies so that these oscillators will lock in with the synchronizing pulses transmitted by the TV station. If the controls are not set properly, or if the oscillator frequencies have shifted outside the normal holding range, then the picture may tend to run either horizontally or vertically. If your set is adjusted properly, you may not need to adjust these controls when initially tuning in a picture. However, by all means experiment with them to see what happens. When the Horizontal Hold control is far out of adjustment, the picture will tear up completely as shown at E on page 38. However, when the control is near the right range, the picture will tend to jump into synchronization and thus stand still. (When only slightly out, you may see the picture drift slowly from side to side, although this is rare.)

Similarly, when the Vertical Hold control is far out of adjustment, the picture will run rapidly up or down. When this happens, you will see a large number of test patterns one on top of the other much as shown at F. As you bring this control nearer to the correct adjustment, you will eventually see a picture as at G, drifting slowly up or down. With this control properly adjusted, the picture drifts upward and then locks into position.

Experiment with first one of these controls and then the other. Finally, turn them both out of adjustment to see what happens when the set is completely out of synchronization. By experimenting this way, you will soon learn just how to adjust them. At the same time, examine the picture carefully so that you will learn to recognize the characteristics of a set out of synchronization. Many TV set owners do not know how to adjust these controls properly, and when once they get out of adjustment, a serviceman may well be called upon to readjust them. Also, if anything happens to destroy the synchronizing signal before it reaches the sweep oscillators, these circuits will not hold very well: the picture will be unsynchronized and it will be impossible to get it back into synchroniza-

tion, except momentarily, by adjusting the hold controls.

Non-Operating Controls. When you have become thoroughly familiar with all the controls on the front panel of the set, it is time to learn about the ones in the back. These controls are identified in Fig. 5, and are repeated in Fig. 6. The two Positioning (or centering) controls are for centering the picture in
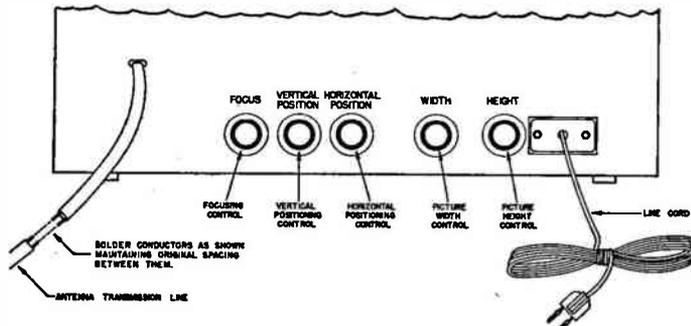
Courtesy The Hallicrafters Co.

FIG. 6. This rear sketch shows the semi-adjustable controls on the back of the Hallicrafters chassis.

the mask. Moving the Vertical-Position control moves the picture up and down, moving the Horizontal Position control moves the picture from side to side. Several cases of improper centering are shown on page 38 at H, I, J, and K. Try out the controls on your set to see exactly what they do, then re-center the picture.

The Width and Height controls set the picture's width and height. When these size controls are improperly set, the picture may be too wide, too narrow, too high, too short, or too small or large in both directions. Effectively, these controls change the amount of sweep voltage, and hence change the size of the picture as shown on page 45, in pictures L, M, N, and O. Try them one at a time to see exactly what they do, then misadjust both, and finally restore the picture to normal. Notice that with a test pattern it is rather easy to tell when you have it exactly right because you can tell when the circles are truly circular. With an ordinary picture, it is not quite so easy to see except that people seem thinner or fatter than normal.

Incidentally, sometimes servicemen adjust the Width and Height controls so that the picture is somewhat larger than it should be so that it more than fills the mask on the face of the picture tube. The more important central portion of the picture will be made somewhat larger, but part of the edges will be lost behind the mask. Some people seem to like this adjustment because there is very little detail out at the edges of a scene anyway.

The remaining control on the back of the set is the Focus control. When it is out of adjustment, the picture will be blurred as shown at P (beside A on

page 44 for comparison). You should experiment with the focus control to be sure exactly what it does, then readjust it for the best picture definition.

Remember, these controls are intended to be adjusted. You cannot harm anything in the normal set by running them through their ranges. Do not hesitate to experiment with the settings of each control, one at a time, to see exactly what each one does. Study the picture carefully and compare it with the normal test pattern, so that you will know on a service call just which control may be out of adjustment by looking at the picture. Finally, try misadjusting groups of controls, so as to see what complex defects look like.

There is one other picture defect, but it is likely to occur only when you are changing the picture tube. This is a tilted picture, such as shown at Q on page 45. In a set having electrostatic deflection, such as this one, the picture will be tilted only when the picture tube has been rotated from its normal position, and is likely only when you are changing the picture tube—you may put in the new tube with the deflection plates so aligned that the picture is tilted. To correct the tilt, rotate the entire tube until the picture lines up with the mask. On receivers of the Hallicrafters type, it is necessary to turn off the set, remove the back panel (or the top lid, if the cabinet is of that type), then loosen the screws on the plate on which the tube socket is mounted, so that you can rotate the tube and socket in the proper direction. Retighten the screws, replace the back, and turn on the set once more to examine the picture. When it is properly placed, the adjustment is complete.

The foregoing procedures will take care of all adjustments ordinarily required, except aligning the set and adjusting the high-voltage oscillator so that it delivers proper voltage. Instructions on making such adjustments will be given elsewhere. You should never attempt them without the proper equipment.

REMOVING THE SET

Now that you have become reasonably familiar with all of the external controls of your set, the next step will be to become familiar with the set itself. In order to carry out the experiments in the next workbook, you will have to have the set outside the cabinet.

Before attempting to open the cabinet and remove the receiver, remember always to unplug the power cord and to wait for several minutes for the filter condensers to discharge. When you have the set out, observe all the safety precautions that were given earlier in this workbook.

The exact procedure for removing the chassis from the cabinet varies with the set, depending on whether you have the model T-54 or the Model 505 Hallicrafters. If you have a set made by a different company,

refer to the manufacturer's manual and the following discussion for help.

Model T-54. On this model, you first remove the front-panel control knobs and the front panel. The control knobs can be removed by pulling them straight off their shafts. The panel is fastened to the cabinet with two panel screws accessible from the outside and two screws accessible from inside the cabinet. Remove the outside screws, then open the top lid to reach those inside.

The speaker is fastened to the front panel; leave it attached to the panel but disconnect it from the set by unplugging the speaker connector mounted on the speaker frame. Leave the rubber mask fastened to the picture-tube face for protection. Before the chassis can be removed from the cabinet, it is necessary to detach the interlock receptacle (in the power supply cord) from the cabinet. This interlock is a switch located in the power cord in such a way that power is automatically cut off when the cabinet lid is opened. The interlock receptacle is held in place by two machine screws; take them out.

Release the chassis from the cabinet by removing the four rubber mounting feet on the bottom of the cabinet, then pull the chassis straight out. Now detach the cover half of the interlock connector from the cabinet cover and put the interlock switch back together so that power can be applied to the receiver while it is being serviced outside the cabinet. Remember, however, don't connect the power now.

Model 505. Remove the five front-panel control knobs by pulling them off. Then remove the back cover; it is fastened in place with wood screws. The line cord and half the interlock connector will come off with the back cover.

Detach the cabinet half of the interlock connector where it is fastened to the cabinet by two wood screws. (In some models of this set, you may find that the interlock connector is mounted on the chassis instead of on the cabinet; don't remove it in this case.)

Unplug the loudspeaker, then release the chassis by removing the four mounting screws at the bottom of the cabinet, and pull the chassis out of the cabinet.

Leave the rubber mask on the picture tube when removing the set from the cabinet. You may find it necessary to pull the rubber mask loose from the front panel in order to release it as you pull the set out. It is perhaps easiest to do this by pushing the rubber

mask from the front of the panel.

Reconnect the interlock connector but don't apply power.

EXAMINING THE SET

In the foregoing, we told you to put the interlock switch back together. This takes time, so servicemen handling sets of this kind frequently make up another power cord with an interlock plug on it, so that they will not have to bother with the section on the cabinet.

You can clean the plastic window in the front of the rubber mask with a soft dry cloth, but you should not use any cleaning solution on it. Certain cleaning solutions will permanently fog some plastics.

Once you have the set out of its cabinet, refer to Fig. 5, and learn the location of each tube. Notice that the purposes of the tubes are given on this figure. From this, and from the large schematic diagram (Fig. A), try to follow the signal path around the top of the set.

Now, unplug the picture tube and put it in a safe place. Leave the rubber mask on the tube face for extra protection. Be very certain you put the tube where it cannot fall or be broken.

With the picture tube out, you can stand up the set so that you can examine the under side. Using the layout in Fig. 5, the block diagram, and the schematic diagram, find your way around in the circuits to the best of your ability. Try picking out parts on the schematic diagram and then locate these parts from their connections to tube sockets, or to other parts that you can identify. This will be valuable training for you.

Once you are reasonably adept at locating parts and circuits, you can then put the picture tube back into the set, disconnect the interlock connector, and put the set back in its cabinet. This is just the reverse of the procedure used in getting it out. It would not be a bad idea to put it in and out of its cabinet several times in carrying out the series of experiments we are going to give you, in order to get practice in quickly inserting and removing the set chassis. Learning how to save time in this operation is in itself valuable service training.

After you have carried out the foregoing steps carefully, you are ready for the next workbook. However, it would not be amiss to read the following sections on other receivers, as this will give you a good general understanding of other types of TV sets.

The Stromberg-Carlson Series

The TV-12 receiver chassis was used in a number of cabinets, including the TV-12PGM radio-phono combination, the TV-12L console, and the TV-12H table cabinet. This information also applies basically to the equivalents in Table 1, although there are certain differences. You should be careful even in applying this information to a set bearing the proper model number, as there may be changes that make your set different. Many manufacturers make production changes and they don't always make diagram corrections.

STROMBERG-CARLSON BLOCK DIAGRAM

Let's first run through the technical details of the operation of this receiver, then go on and learn the operation of the controls, how to remove it from its cabinet, and how to locate parts and circuits on the chassis.

A front view of this set is shown in Fig. 7. This set is an a.c.-operated type using 27 tubes in addition to a 12½-inch electromagnetic picture tube. A flyback high-voltage power supply furnishes approximately 9000 volts for the picture-tube accelerating anode. Both the high and the low TV band, as well as FM sound (radio) stations, can be tuned in on this receiver, since tuning is continuous over this entire range of frequencies.

The antenna input is 75 ohms, unbalanced. This means it is intended to be used with a 75-ohm coaxial cable lead-in from the antenna, and such a lead-in should be provided for proper operation of the set. A functional block diagram of this receiver is given in Fig. 8. Such a diagram often proves valuable in diagnosing receiver troubles, as it enables you to see

NRI TV Lab. Photo

FIG. 7. This view shows the table model of the Stromberg-Carlson series recommended in this text.

the signal path through the receiver. Thus, when there is some trouble that kills one or more sections, you can better apply effect-to-cause reasoning in isolating the trouble to a particular section.

Starting from the antenna at the upper lefthand corner of this diagram, the entire TV signal is picked up and fed through an r.f. amplifier that serves to boost the amplitude in order to improve the signal-to-noise ratio at the input of the mixer-converter. At the same time, the r.f. amplifier tends to reject certain interfering signals.

In the converter, the incoming sound and video signals beat with the signal from the local oscillator to form separate picture and sound i.f. carrier signals. The sound-carrier frequency is 21.9 megacycles, and the picture-carrier frequency is 26.4 megacycles. The picture carrier contains not only the video signal but also the horizontal and vertical synchronizing signals.

Both these r.f. carriers pass through the first video i.f. stage, but at the output of this stage, the sound carrier is separated from the picture carrier. The sound carrier now proceeds through its own sound i.f. amplifier, then through a limiter stage, which removes amplitude variations. The sound signal is then fed to an FM detector, and the resulting audio output goes through an audio amplifier to the loudspeaker.

Returning now to the video i.f. signal—we find that it proceeds through the second and third video i.f. amplifiers, then is fed through a video detector. The signal next passes through a video amplifier, after which it is applied to the control grid of the picture tube. Notice that the horizontal and vertical sync signals, together with their blanking pedestals, are applied along with the video signal to the picture tube.

At the output of the video amplifier, the vertical and horizontal synchronizing signals are tapped off so that copies of these signals can be fed through the sync clipper. This clipper serves to separate these sync signals from the video signal, so that only the vertical and horizontal sync signals are applied to a second clipper. At the output of this stage, the path divides. The vertical sync signal is applied to the vertical buffer, which removes all traces of the horizontal signal, and the remaining vertical sync signal is used to control the vertical saw-tooth generator. This generator in turn drives an amplifier stage that delivers a signal having the proper shape to the vertical deflection yoke.

The horizontal sweep signal is generated in a horizontal oscillator, which is controlled by an automatic frequency control (a.f.c.) system from the horizontal sync signal. In other words, the output of the hori-
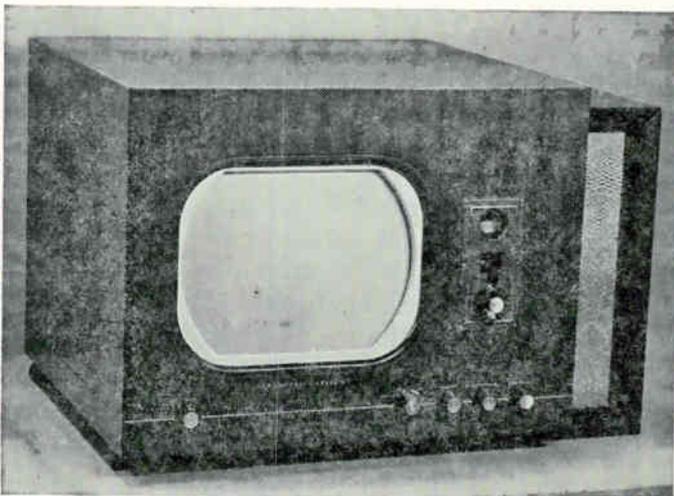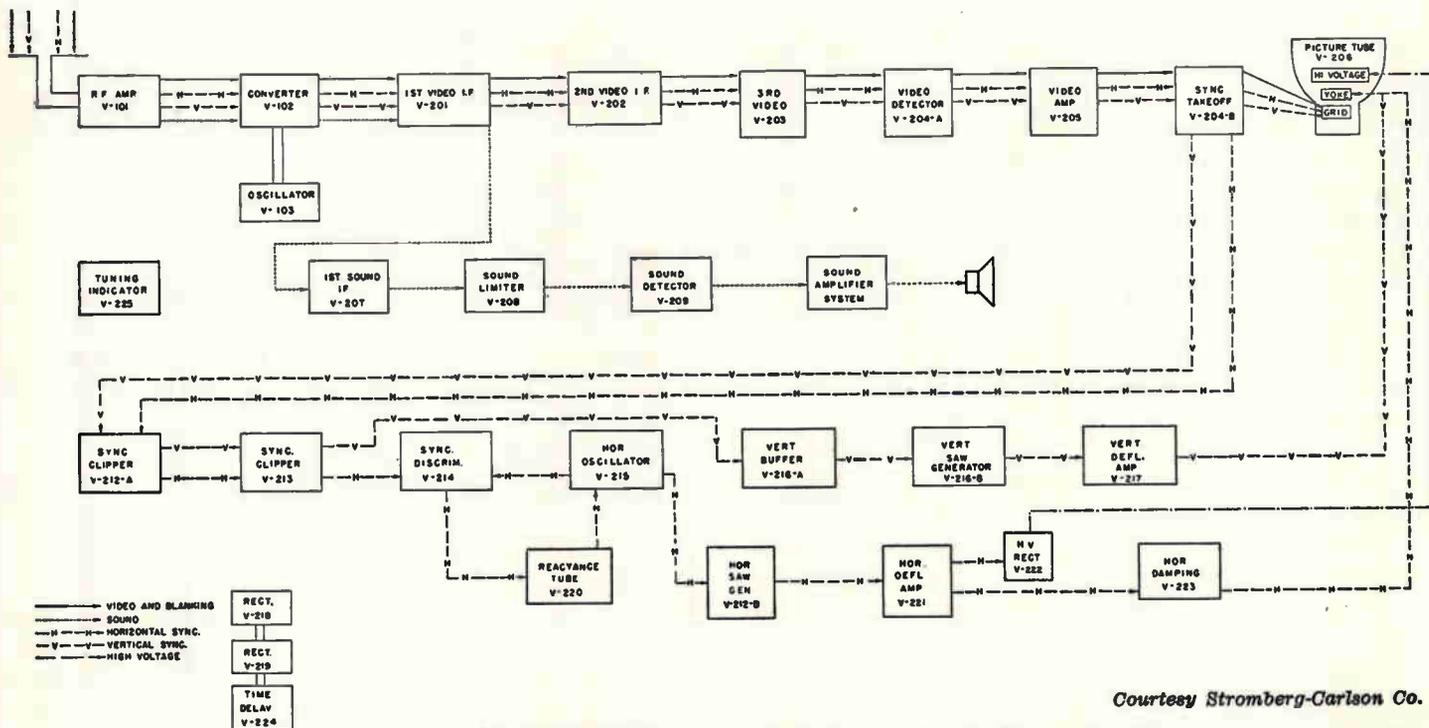
FIG. 8. This block diagram shows the signal paths through the Stromberg-Carlson receiver.

zontal oscillator and the horizontal sync signal are fed into a discriminator circuit, which produces a voltage proportional to their difference in frequency. This difference voltage is fed into a reactance-tube circuit that re-tunes the horizontal oscillator to the proper frequency.

The output of the horizontal oscillator then goes through a shaping circuit, called a saw generator in Fig. 8, after which it is applied through a horizontal deflection amplifier to the horizontal deflecting yoke. A damping tube is connected across this yoke to absorb energy at the proper moment and to prevent oscillation from continuing in the yoke beyond a specified time.

The high-voltage supply is obtained from the horizontal deflection amplifier for application to the picture tube.

In addition, there is a low-voltage B supply for all the tubes.

DETAILED ANALYSIS

A complete schematic diagram of the Stromberg-Carlson receiver is given on the enclosed large schematic, Fig. B. (This diagram is stapled in the center of this book. If you have not already done so, open up the staples and remove this diagram.) Open up this diagram, and use it for the following detailed analysis.

Front End. For convenience in studying, the schematic of the front end is reproduced in Fig. 9. However, you should also refer to the large diagram, Fig. B, as this is the kind of diagram you will meet in your service work.

The television signals picked up by the antenna are transferred by means of a 75-ohm coaxial cable to the input of the TV receiver and appear across the terminating inductance L-106. This inductance, in parallel with the antenna input, provides a high-pass r.f. filter that suppresses broadcast-band or other low-frequency interference that may arise when the TV receiver is located close to an AM broadcast station. The untuned input circuit has been designed so that a proper impedance match to the transmission line is maintained over the entire tuning range (44-216 megacycles).

The signal appearing across L-106 is capacitively coupled through C-101 so that it is applied across resistor R-101 in the cathode circuit of a grounded-grid r.f. amplifier. The two sections of tube V-101 are in parallel; this cuts the plate resistance in half, permitting a lower load value to be used without sacrificing too much gain.

The plates of the r.f. amplifier V-101 are coupled to the grid of converter V-102 by a band-pass coupling network made in two sections.

One section consists of the variable inductance L-102A, plus L-101, C-105, C-107, and the output capacities of the r.f. stage; the other section contains the variable inductance L-102B, plus L-104, C-106, C-107, and the input capacities of V-102. Resistors R-110 and R-104 reduce the Q of the circuit to give a pass band 6 megacycles wide. The variable-inductance tuning provides continuous tuning over the TV-FM bands.
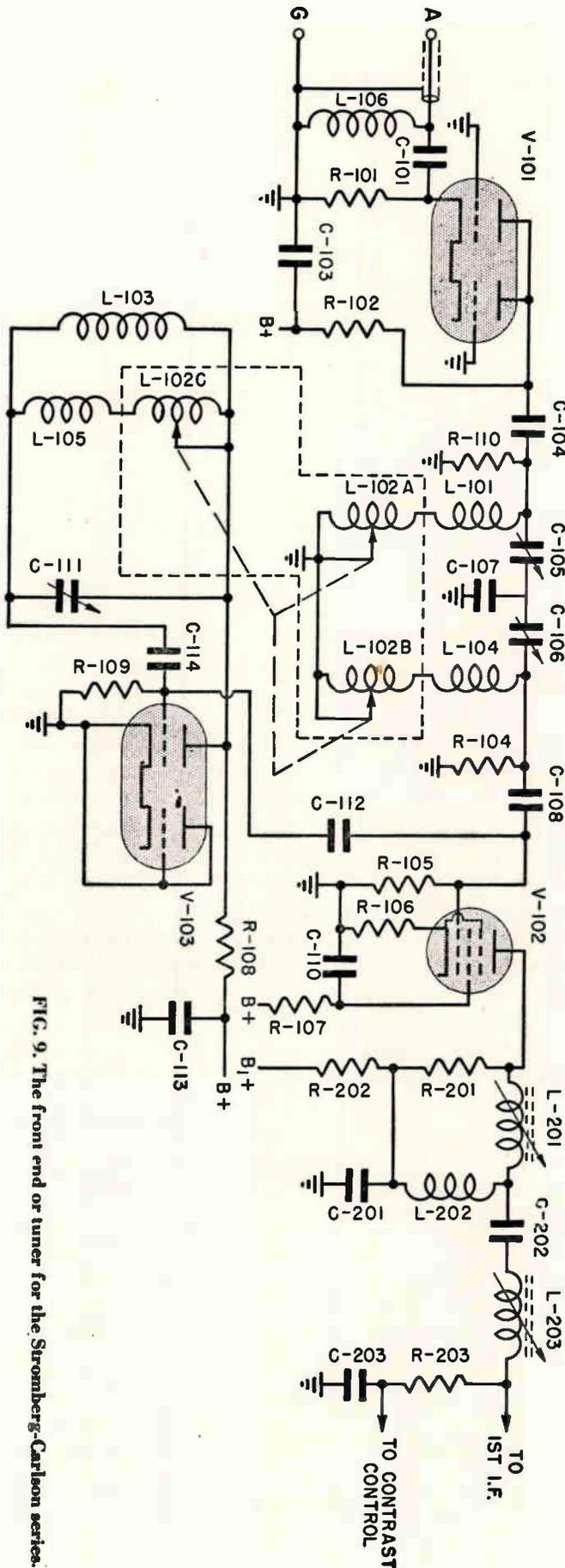
FIG. 9. The front end or tuner for the Stromberg-Carlson series.

The local oscillator consists of one section of a twin triode tube V-103 connected in a modified Colpitts (ultra-audion) oscillator circuit. Feedback voltage for the oscillator is obtained by means of voltage division among the interelectrode capacities of the vacuum tube. (The grid and the plate of the other section of the twin-triode tube are connected to ground and are not in the circuit electrically.)

The oscillator frequency is tuned by the variable inductance L-102C. Since L-102C is similar to L-102A and L-102B, the oscillator would operate at the same frequency as that of the incoming signal. To avoid this, L-103 is inserted in parallel with L-102C and L-105, thus reducing the net inductance. This is tuned by the tube capacities plus that of the trimmer C-111.

The output from the local oscillator is coupled to the grid of converter V-102 by C-112. The incoming signal is fed to the grid of V-102 through C-108. The two i.f. signals are produced in the mixer-detector. One is the sound i.f. and the other is the picture i.f. Both appear in the plate circuit of converter V-102 and feed into a video i.f. transformer consisting of L-201, L-203, and L-202.

Sound Channel. Referring again to the large Fig. B, you will find that C-222 is coupled to the plate of the first video i.f. amplifier; the sound signal is taken off through this condenser, and appears across the primary of the first sound i.f. transformer Z-201. This transformer is tuned to the sound i.f. of 21.9 megacycles.

The sound i.f. signal appears across the transformer secondary and is applied to the grid-cathode circuit of the first sound i.f. amplifier V-207. An amplified sound i.f. signal appears in the plate circuit of V-207 across the primary of the second sound i.f. transformer Z-202. The sound i.f. signal appearing across the secondary of the second sound i.f. transformer is applied to the grid circuit of sound i.f. limiter tube V-208, which is operated at low plate and screen voltages and with a low bias so it overloads easily; therefore, it tends to remove amplitude variations from the FM sound signal.

The d.c. voltage developed when the tube V-208 draws grid current appears across R-322 and C-227. This d.c. voltage is applied through R-238 as a.v.c. for the first sound i.f. amplifier.

The FM sound i.f. appearing across the secondary of the discriminator transformer Z-203 is applied to the sound detector V-209. The audio signal appears across R-242 and R-243. The d.c. component of this signal is fed back through R-244 and R-320 as a control bias on tuning indicator tube V-225 (at the left in Fig. B).

The sound signal is fed to the function-selector switch S-202 and to the volume control (when the

function-selector switch is in either of the TV positions or in the FM position).

The rest of the sound amplifier circuit up to the loudspeaker is conventional, so we need not discuss it in detail here.

Video I.F. Amplifier. The video i.f. amplifier consists of three stages, using tubes V-201, V-202, and V-203. Each video i.f. coupling network consists of two adjustable coils that are resonant with their respective tube capacities and coupling networks. The video i.f. coupling between V-102 and V-201 utilizes shunt inductive coupling; thus, the voltage across L-202 is that fed through the two sections of the network. The other video i.f. coupling networks use a series type of inductive coupling that corresponds to a tuned-plate load coupled to a tuned-grid circuit by a coupling network.

To prevent the sound carrier of the desired channel and the sound carrier of the adjacent channel from passing along with the video signal, two parallel-resonant traps are used in the series arm of the pi network in the coupling between V-202 and V-203. These are the traps consisting of L-222 and C-209, and of L-209 and C-211.

As shown in the large diagram Fig. B, the bias of the first and second video i.f. tubes can be varied by adjusting the Contrast control R-232. Condensers C-203 and C-285 are used as by-passes to avoid feedback through the Contrast control. Also, R-207 and C-206 form a decoupling network for the same purpose. As the bias on the first two video i.f. stages is varied, the gain of the stages changes; thus it is possible to regulate the signal applied to the picture tube. However, the third video i.f. amplifier V-203 is operated at a fixed bias and at maximum gain.

From the third video i.f. amplifier the signal is fed through condenser C-288, which consists of a piece of 72-ohm "twin lead," to video detector V-204A. This capacity C-288, plus L-210, and L-212, form the video coupling network between V-203 and V-204A.

Video Detector. Tube V-204A is the video detector. The signal it receives from the video i.f. section should contain little of the sound carrier; it should be mostly the video i.f. signal. The signal across L-212 is rectified, and the resulting signal appears across the diode load R-219 and peaking coils L-213 and L-214.

Video Amplifier. The video signal across L-214 and R-219 is applied directly to the grid of video amplifier tube V-205. The d.c. voltage drop across R-233 and R-220 is used to provide bias for the video amplifier. These two resistors are in the B— circuit.

An amplified video signal appears in the plate circuit of V-205 and is coupled to the picture tube V-206 through coupling condenser C-218, and through a 4.5-mc. trap consisting of L-216 and C-217. This trap

serves to eliminate the 4.5-mc. beat between the sound and video i.f. carriers, which would otherwise cause a grain-like effect on the screen, so it is often called a "grain" trap.

Peaking coil L-215 is used in the plate circuit of the video amplifier to give a broad-band response. The signal in the plate circuit of the video amplifier is also coupled through C-283 to d.c. restorer tube V-204B and its associated circuit consisting of R-256, R-225, and C-282. This tube acts to rectify the video signal, and the resulting d.c. component is applied to the grid of the picture tube to set the average brilliancy level.

Returning to the picture tube, we find that the video signal appears across R-226 and R-256. The re-inserted d.c. component appears across R-256 and is fed through R-226 to the grid of the tube, so that the signal finally appearing on the grid of the picture tube consists of both a d.c. component and an a.c. video signal.

The positive d.c. bias on the cathode of the picture tube can be varied by adjusting Brightness control R-227, and this acts to vary the picture background brightness. The Bias control R-229 varies the positive voltage on the second grid of the picture tube and is used to adjust the second grid voltage of the picture tube so that it will have a standard grid-control characteristic when used in this particular set.

Sync Chain. The sync signals appearing across R-225 in the circuit of V-204B are applied through C-219 to the first sync clipper V-212A (at the left in Fig. B). The amplified and clipped sync pulse signal appears in the plate circuit of this stage (across R-257), and is coupled to the grid-cathode circuit of the second clipper amplifier through condenser C-244 (and C-216C) so that the signal appears across R-259. The sync pulse signal is further amplified and clipped in the second stage.

Thus, the two clipper-amplifier stages serve to amplify both the vertical and the horizontal sync pulses, and to clip both the tops and the bottoms of these pulses so that those in the plate circuit of the second stage remain substantially constant in amplitube over a fairly wide range of input signal level.

Vertical Sweep Chain. The vertical buffer amplifier V-216A is coupled to the plate of the second sync clipper through C-252. The amplified sync pulses appearing in the plate circuit of V-216A are integrated by the network consisting of R-271, R-272, R-273, C-253, and C-254 so that only the vertical pulses appear in the primary circuit of T-201. In other words, this network acts to filter out the horizontal sync pulses and only the vertical pulses remain to be applied through transformer T-201 to the vertical sawtooth generator V-216B. The pulses here lock the
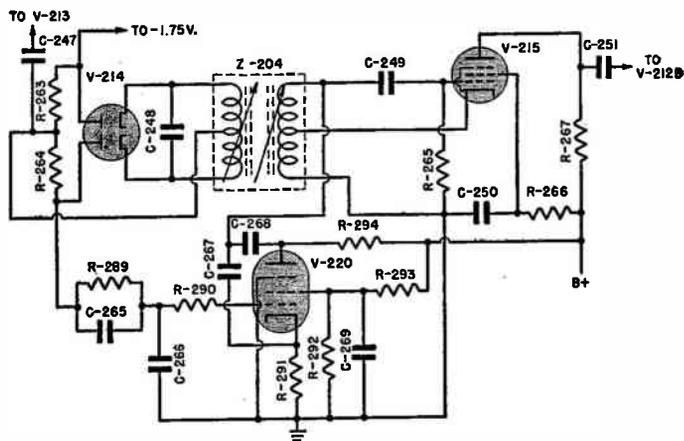
FIG. 10. The horizontal-hold control arrangement for the Stromberg-Carlson series.

vertical saw-tooth generator to the correct frequency.

The vertical saw-tooth generator consists of a blocking oscillator V-216B, and an output wave-shaping circuit containing C-257 and R-278. The pulses produced by a blocking oscillator can be shifted over a narrow frequency range by adjusting the grid R-C time constant. As the grid resistor R-275 (Vertical Hold control) is varied, the time-constant of the grid circuit changes, varying the blocking rate of the blocking oscillator.

Vertical Size control R-277 varies the resistance through which C-257 charges, and thus varies the amplitude of the vertical signal appearing across C-257 and R-278. This signal is fed through C-258 to the grid circuit of the vertical deflection amplifier, which amplifies it sufficiently to deflect the electron beam in the picture tube.

Vertical Linearity control R-281 varies the cathode bias of the vertical deflection amplifier and thus allows the technician to adjust the bias for most linear amplification. This control interacts, to some extent, with the Vertical Size control.

The amplified vertical deflection signal appearing in the plate circuit of V-217 is fed to the vertical deflection coils by means of vertical output transformer T-202.

The amount and polarity of direct current through the deflection coils can be changed by adjusting the Vertical Positioning control R-284 and the Vertical Positioning switch S-203. By varying these two adjustments, the picture can be centered vertically on the screen of the picture tube.

A high-capacity condenser C-259 is used across R-284 so that its resistance will not affect the vertical deflection signal. Otherwise, as the value of R-284 was changed, the impedance of the secondary circuit of T-202 would change. Condenser C-259 acts as a short circuit across this control as far as a.c. is concerned.

Horizontal Sweep Chain. The horizontal synchro-

nizing circuit is of special interest and is illustrated in simplified form in Fig. 10.

The output from the second sync clipper V-213 is fed to the horizontal sync discriminator stage V-214 through resistors R-264 and R-263 and condenser C-247. The time constant of this combination is so chosen that if either a wide vertical pulse or a narrow horizontal pulse is applied, only sharp "pips" or pulses will result. These pips are applied to the diodes of V-214 so that both conduct simultaneously.

A sine-wave signal is developed across the sync transformer Z-204 by sine-wave horizontal oscillator tube V-215. The winding of Z-204 that is connected to V-214 is resonant, and across it is produced an alternating voltage that is also applied to the diodes of V-214.

On rectification, d.c. voltages are developed across the resistors R-263 and R-264, which depend upon the position of the sync pulses along the sine-wave signal. The two d.c. voltages are opposite, and will be equal if the sync pulses occur at the exact time that the sine-wave signal is passing through zero. If the sync pulse moves with respect to the sine-wave signal (as it will if the sine-wave signal goes out of sync), the pulse will tend to ride up on one sine wave and to move down on the other. Thus, the amplitude of the d.c. voltage across one resistor (R-263 or R-264) increases while that across the other decreases. Since the d.c. voltages across these two resistors are no longer equal, they will no longer cancel, and a resulting net d.c. voltage will be developed across the pair of resistors. This d.c. voltage is applied through the filter network consisting of C-265, R-289, and C-266 to the grid of reactance tube V-220. This tube is connected across the tuned circuit of the oscillator. It is arranged so that it appears to be a reactance— its plate current is 90° out of phase with its plate voltage. Hence, the change in grid voltage changes its apparent reactance, which retunes the oscillator V-215. The connections are such that the frequency of the tuned circuit is changed to bring it back into step with the incoming sync pulses. Thus, once the horizontal oscillator is locked in at the correct frequency it is extremely stable.

The resting frequency of the horizontal sine-wave oscillator is determined by the resonant frequency of the tuned circuit consisting of the transformer Z-204 and its associated capacities, including distributed capacities in the circuit. This frequency can be changed by adjusting the inductance of the transformer; this is done by means of an adjustable iron core. The adjustable iron core serves as a Horizontal Hold control and is used to bring the horizontal signal in step with the sync pulses. Once this is done, the sync discriminator circuit and the reactance tube holds the oscillator "on frequency."

The other iron core adjustment of Z-204 serves as a Phase control and adjusts the phase of the sine wave with respect to the sync pulses. This is adjusted so that the horizontal sweep of the picture tube will start at the correct moment to keep the blanking interval out of the picture portion of the raster. If this control is misadjusted, a vertical bar will appear in the picture.

Returning to the schematic diagram in Fig. B, we see that the output signal in the plate circuit of the horizontal oscillator V-215 is fed into a differentiating network consisting of condensers C-251 and resistor R-268. The output of this circuit consists of a series of sharp pulses that are fed through coupling condenser C-270 and act to allow the horizontal sawtooth generator tube V-212B to conduct. When this tube conducts, it discharges condenser C-271, which has been charging through resistors R-296 and R-315. The horizontal sweep voltage appears across the series network of C-271, R-315, and R-297.

The lower end of this network is returned to the cathode bias resistor R-300. Resistor R-297 serves as the Horizontal Drive control and adjusts the shape and amplitude of the wave applied to the grid of the horizontal deflection amplifier V-221. It affects, to some extent, the horizontal linearity as well as the horizontal amplitude.

The signal applied to the grid of V-221 allows the tube to conduct only on the positive peaks; the tube is cut off sharply by the negative swing of this signal. When this tube cuts off suddenly, the magnetic field of the deflection yoke collapses, causing an oscillatory cycle to start. The first third of a cycle produces the return trace or flyback of the horizontal sweep.

To prevent this oscillation from continuing, horizontal damping tube V-223 and damping resistor R-304 are connected across the circuit. This tube conducts when its plates are driven positive with respect to its cathode and acts to damp out any tendency towards oscillation. By allowing the oscillatory energy to be gradually dissipated, the first portion of a line sweep is linearly produced. As this energy dies out, it is replaced by energy from tube V-221, which now begins to conduct.

To assure greater linearity in this change-over action, the voltage produced by the damping network is added to the B voltage applied to the plate of V-221. By properly adjusting the phase of this voltage in the network L-219, C-275, and C-276, the tube characteristic is shaped to give a linear deflection.

The Horizontal Positioning control R-305 varies the direct current through the horizontal deflection coils and thus the horizontal position of the picture.

High Voltage. The oscillatory pulse produced by the half-cycle oscillation in the horizontal yoke causes a high-voltage pulse to appear in the primary of T-

204. It is possible to use this pulse to obtain the high d.c. voltage necessary for the picture tube. Additional turns are provided in the primary of T-204 so that this voltage can be stepped up. Then, this high-voltage pulse is rectified by V-222, filtered by R-303 and C-277, and applied to the accelerating anode of the picture tube. The capacity between the inner and outer coatings of the picture tube acts as the output filter condenser.

Filament voltage for the high-voltage rectifier tube is obtained by means of an additional winding on the horizontal output transformer. Resistor R-302 limits the filament current of the high-voltage rectifier tube.

Low-Voltage Supply. A portion of the low-voltage power supply is shown in Fig. 11. This supply uses two parallel tubes for full-wave rectification. A conventional condenser input filter is provided, consisting of C-241, C-262, L-217, R-285, and C-264A. Since B— is not at ground potential in this circuit, condenser C-263 is connected from B— to ground to provide additional filtering.

The voltage at the input of the power supply exceeds the voltage rating of commonly available electrolytic filter condensers, so two condensers (C-241 and C-262) are connected in series. To equalize their voltage drops, two equal resistors R-316 and R-317 are connected across these two condensers.

A time-delay relay is used to prevent the application of B voltages to the circuit until after the tubes have had a chance to warm up. (Once the tubes have had a chance to warm up, they act as a load on the power supply and prevent the d.c. voltage from exceeding the working voltage of the condensers used.) Relay K-201 closes and applies B-supply voltage to the set when time-delay rectifier V-224 heats up and draws current through the relay coil. The heating of
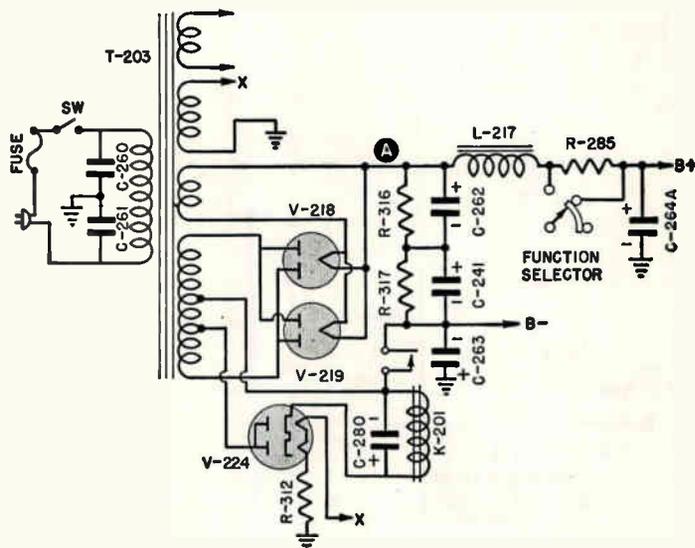

FIG. 11. The power supply of the Stromberg-Carlson series. Sometimes the starting relay K-201 is in the positive or B+ side of the circuit at point A instead of in B— as shown here. This does not change the operation of the circuit.

the cathode of V-224 is delayed because it operates with reduced filament current. The filament current is lowered by R-312 in the filament circuit of V-224. Condenser C-280 is provided across the relay coil to remove a.c. ripple so that the relay will not chatter.

This receiver can be used as an FM sound radio, or to play phonograph records as well as for television reception. When it is to be used in one of these other ways, the TV portions are killed—one section of the Function switch removes plate voltage from the second and third video i.f. stages, the video stage, the horizontal sweep oscillator and the second sync clipper. (Killing the horizontal sweep also removes the high voltage.) Thus, when the function selector switch is not on "TV", the picture tube does not light and the horizontal sweep circuit as well as the video circuits are inoperative and do not act as a B-supply load. To compensate for the reduced drain, additional resistances are added when the Function switch is set for phono or FM.

The Focus coil L-218 (see Fig. B) is in series with the section of the power supply that delivers current to most of the circuits, so the current drain of these circuits energizes the focus coil. This current is adjusted to bring the electron beam in the picture tube to accurate focus by adjusting Focus control R-288, a variable resistor shunted across the focus coil together with R-286B.

Circuit Variations. A number of minor variations will be found in different runs of this receiver. One common variation is the placement of the power-supply relay in the B+ side of the power supply, at position A in Fig. 11, rather than in the B— side.

Some of the first run of the equivalent DuMont Model RA-103 used a ratio detector rather than a conventional discriminator for the sound channel. Also, the second sound i.f. amplifier was connected as an i.f. amplifier rather than as a limiter. These changes are shown in Fig. 12.

There may be other minor variations in some runs. Therefore, if you find that the circuit of your particular set does not agree *exactly* with the schematic diagram given in Fig. B, do not be alarmed.

LEARNING THE CONTROLS

Now that you have had a brief technical description of the set, we shall assume that you have the set before you. If this is your own receiver, you will naturally be familiar with the operating controls. However, since you may have just acquired it, we shall assume that you know nothing about it.

You should always read carefully the manufacturer's Instruction Booklet that accompanies the set because it contains complete information on the proper adjustment of the operating controls on the front panel. The semi-adjustable (non-operating) controls on the back of the receiver are normally set up to give the proper picture size and positioning at the time the receiver is installed, and will not require another readjustment for a fairly long time. However, you need to know what each of these controls does so that you will know just what adjustment is needed if you find a set having a defect that could be caused by a misadjusted control.


NOTE: ALL CAPACITOR VALUES ARE MICROFARAD UNLESS OTHERWISE SPECIFIED. ALL RESISTORS 10% TOLERANCE UNLESS OTHERWISE SPECIFIED.

Courtesy Allen B. DuMont Laboratories

FIG. 12. Some sets of the Stromberg-Carlson series or its DuMont equivalent use the ratio detector arrangement shown here as the sound detector.

The first step in putting the set into operation is to connect it to a 75-ohm coaxial cable lead-in from the antenna. Next, plug the line cord into a wall outlet. Finally, turn the set on, tune in the station, adjust for best picture, and adjust the sound volume. The controls for this are shown in Fig. 13.

If the receiver is a table model, it is turned on by
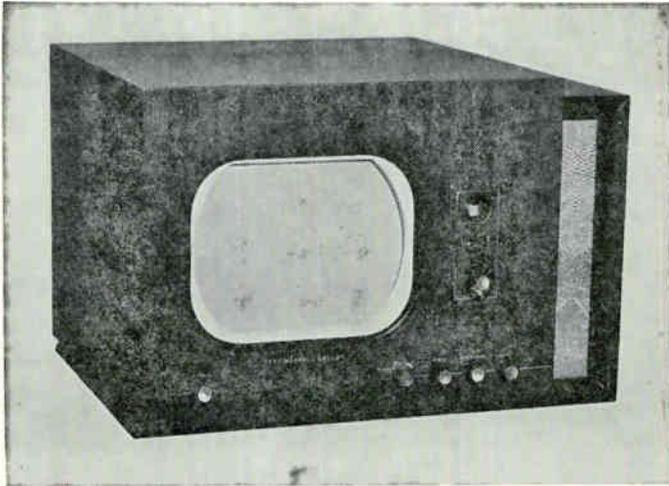
NRI TV Lab. Photo

FIG. 13. The controls on the front of this Stromberg-Carlson receiver are, from left to right: focus, function (also called the phono-band switch), volume, brightness, and contrast. The tuning control is in the right center, just under the tuning eye.

rotating the Volume control clockwise until a click is heard. (If it is a combination model, the Master control switch is turned to the TV-FM position to turn on the television set.) With the set turned on, turn the Function (or selector) switch on the television control panel to the first TV position. This lights up the tuning eye and illuminates the tuning dial.

The tuning control is now rotated until the desired channel number appears under the cross-hair indicator.

If the tuning eye on the set you have is of the usual round type, you adjust the tuning selector for maximum closure of the eye. However, if the tuning eye is of the square-face type, adjust the receiver to the point where the two green strips are even in length, as shown in Fig. 14. If the set is adjusted properly, this should be the tuning position that gives normal sound and picture. Adjust the Volume control for the desired level and retune if necessary for clearest sound.

To adjust the picture, turn the Contrast control all the way down, and turn up the Brightness control until the picture tube just begins to show light. Then, turn up the Contrast control until the picture appears normal. If necessary, readjust the Focus control for a sharp, high-definition picture. When you adjust the Focus control, you may find it necessary to readjust the brightness and contrast.

If you do not want the tuning indicator illuminated while viewing the picture, rotate the Function switch one more position, and the dial light and the tuning eye will be extinguished.

You should experiment with the front panel controls until you are thoroughly familiar with their range of adjustment and just what each one does. The best time to do this is when one of the local stations is transmitting a test pattern. Since the test pattern is a fixed picture, it is much easier to determine just what the controls are doing.

Each station has its own test pattern, and some give more information than others. A group of typical test patterns is shown on pages 44 and 45 of this workbook, and we shall refer to these throughout the rest of this section.

The test pattern at A (refer to pages 44 and 45 whenever we mention test patterns) is a "perfect pattern." No set is likely to reproduce a pattern this well. However, the more nearly perfect the reproduction, the better the set adjustment. Since the test patterns used by your local stations may not look at all like the one at A, you will have to become familiar with the patterns of your local stations to be able to judge what represents normal reproduction.

The test pattern at B (page 44) shows too light a picture, and the one at C shows too dark a picture. A light picture is caused by too high a setting of the Brilliancy control or by a low setting of the Contrast control (or both). A dark picture is also caused by misadjustment of either or both of these two controls.

Notice that we gave the correct procedure for adjusting the Brilliancy control when we described how to turn on the set; that is, turning the Contrast control down, adjusting the Brilliancy control until you can just begin to see light on the face of the tube, and then bringing the Contrast control up to a normal


MISTUNED   TUNED   MISTUNED
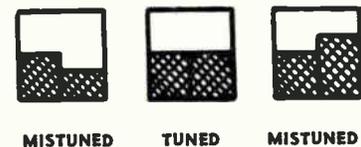
FIG. 14. When the tuning eye is one of the types showing two bars of light, the bars should be equal in length when the set is correctly tuned, as shown in the center picture. If one bar is longer than the other, as in the other two pictures, the set is mistuned.

setting. This procedure is all right when the set uses a video amplifier that is a.c. coupled as in this receiver. If d.c. coupling is used, however, you cannot use this method, because the tube remains lighted until a signal is tuned in, then the signal drives the average brightness level down. In that case, it is necessary to adjust the Brilliancy and Contrast controls at the same time until you get the best picture.

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This set uses a continuous-tuning control, rather than a switch-type tuner with a fine-tuning control. In other words, the Tuning control acts as both the coarse-tuning control and the fine-tuning control. Mistuning by improper adjustment of the Tuning control has the same effect as an improper adjustment of the fine tuning control on other sets has. In one direction, sound bars may show up in the picture as in the test pattern at D (page 44). These are a series of more or less horizontal bars that vary in number in step with the audio modulation. When a test pattern is tuned in, the audio modulation is usually a fixed tone, so there will be a fixed number of bars. Multiplying the number of visible bars by 60 will give the approximate frequency of the tone. Mistuning in the other direction may cause distorted sound. In general, if the set is tuned for best sound, and is in proper alignment, the picture should be at its best also.

A misadjustment of the Focus control may produce a fuzzy picture such as that shown in the test pattern at P (located beside A on page 44 for comparison). When adjusting the Focus control, try to get the clearest possible picture. Sometimes, even with a test pattern, it is rather difficult to make this adjustment. In such cases, turn the Contrast control all the way to zero, then turn up the Brightness control until the raster is reasonably visible. Don't turn the Brightness control up too high. Now, adjust the Focus control until the lines near the center of the raster are clear and sharp on close examination. When you have made this adjustment, turn the Brightness control back down to where the raster is just barely visible, then bring up the Contrast control to its normal setting. After you have made this adjustment, the Focus control will be somewhere near the right point, although it may not be exactly so, because the changes in current involved in different settings of the Contrast control may slightly defocus the image again. For this reason the best method is that of adjusting while viewing a test pattern, but you should try the other method to see just what happens to the line structure as the Focus control is turned.

Non-Operating Controls. In addition to the controls on the front panel of the set, there are quite a number arranged along the rear, either above or below the chassis. Since these controls are not normally used in tuning in a signal and adjusting for best picture, they are referred to as non-operating controls. The non-operating controls are adjusted at the time of the set installation, and generally will not need readjustment for a long time. However, once they get out of adjustment, you must know which one to readjust to restore the picture to normal. The locations of the controls along the rear apron

of the chassis are shown in Fig. 15. In addition to those shown, there are three other adjustments on the chassis; two of them are underneath, and the third is up front under the large funnel of the picture tube. To adjust any of these three, you must remove the chassis from the cabinet. However, it is seldom necessary to adjust them. The one at the front of the chassis is the Bias control, which is adjusted only when the picture tube is replaced. Underneath the chassis is the Phasing control for the horizontal synchronization circuit, and the Horizontal Linearity control. We shall describe their adjustment later.

Two controls that may require adjustment from time to time are the Vertical Hold control and the
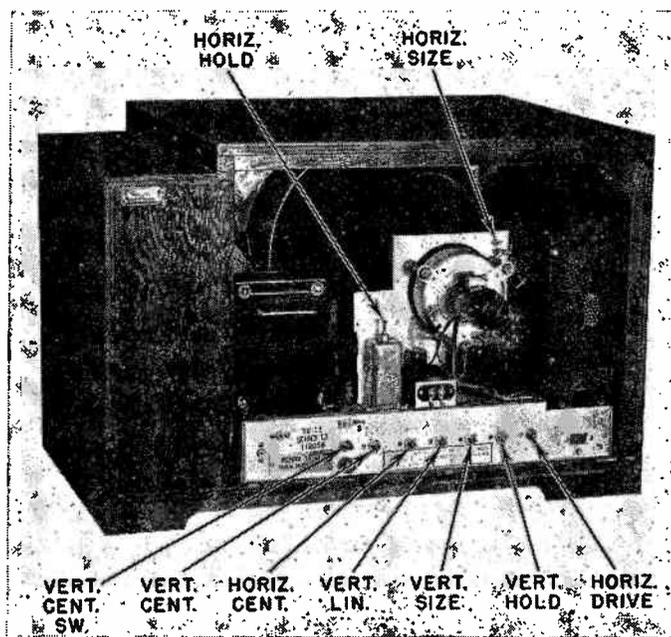
NRI TV Lab. Photo
FIG. 15. In this view you will find the controls identified for the rear of the Stromberg-Carlson series.

Horizontal Hold control. Locate these in Fig. 15. The Vertical Hold control is on the rear apron, the second one from the right. The Horizontal Hold control is a screw protruding from a can that resembles an i.f. transformer can.

These two controls set their respective sweep oscillator frequencies so that these oscillators will lock in with the synchronizing pulses transmitted by the TV stations. If the controls are not set properly, or if their oscillator frequencies have shifted outside the normal holding range, then the picture may tend to run either horizontally or vertically.

When the set is out of horizontal synchronization, the picture will tend to tear up more or less as in the test pattern at E (page 44). To adjust the Horizontal Hold control, turn it through its range. You will find that there is a rather wide range over which the picture will stay in synchronization. Determine

the two extreme adjustments at which the picture falls into sync, and set the control halfway between these two positions.

Similarly, when the Vertical Hold control is **far** out of adjustment, the picture will run rapidly up or down. When this happens, you will see a large number of pictures one on top of the other, much as is shown at F (page 44). As you bring the Vertical Hold control nearer to the correct adjustment, you may find a condition such as shown in the test pattern at G, in which you have a picture that drifts slowly up or down. With this control properly adjusted, the picture should drift upward and then lock into position.

The Phasing control is located underneath the chassis almost directly under the horizontal hold control, and it rarely requires adjustment. However, when it does, the test pattern may appear as shown at R. Adjustment of the Horizontal Hold control will make the picture stand still, but the phase may be shifted slightly so that the blanking bar (a dark gray or black vertical stripe) appears in the picture area. When this occurs, the Phasing control must be readjusted until the blanking bar moves to the right and off the visible portion of the raster. (The set must be out of its cabinet to make this adjustment.)

The Centering controls are for centering the raster in the mask in front of the picture tube. There are limits to how far the Centering controls can move the picture, and in electromagnetic sets of this kind, it is first necessary to have a proper mechanical adjustment of the Focus coil positioning and ion trap magnet on the picture tube itself. However, let's assume for now that these are all right (we'll give their adjustments later). Improper centering is indicated in the test patterns at H, I, J, and K. Experiment with the Vertical and the Horizontal Centering controls to see just how the picture is moved up and down and from left to right. Notice that on this set the Vertical Centering control will move the picture in one direction but not very well in the other. If it is necessary to move it in the other direction, the Vertical Centering switch (on the rear apron of the chassis) must be thrown. This reverses the connections so that the Vertical Centering control will move the picture in the other direction but not very well in its original direction. The arrangement on this set is somewhat unusual—in most instances the Vertical Centering control will move the picture in either direction equally well.

The Width and Height controls set the picture's width and height. When these size controls are improperly set, the picture may be too wide, too narrow, too high, too short, or too small or large in both directions. In general, these controls change the amount of sweep, and hence may change the picture

size more or less as shown in the test patterns at L, M, N, and O. However, since this is an electromagnetic sweep system, it is impossible to change the size of the picture without affecting its linearity at the same time. For this reason, there are several linearity controls that usually must be adjusted at the same time as the corresponding size controls.

For example, the Vertical Size control is properly adjusted when the height of the picture equals the height of the mask opening in front of the picture tube. In attempting to adjust the picture in this direction, you may find that the top or bottom half is somewhat cramped. The Vertical Linearity control on the rear apron of the set has the effect of expanding the picture at an increasing rate from the bottom to the top. Adjusting this control has the greatest effect at the top, some effect at the middle, but very little effect at the bottom of the picture. A test pattern with vertical non-linearity is shown at S.

In general, therefore, you will have to adjust the Vertical Linearity and Vertical Size controls at the same time, until you get the picture the right size with a reasonable degree of vertical linearity. (If you find that the picture tends to go out of synchronization, readjust the Vertical Hold control.) Try these controls, one at a time, until you see what each does, then adjust both together.

The horizontal sweep system is even more involved. There is a Horizontal Size control, a Horizontal Drive control, and a Horizontal Linearity control.

The Horizontal Size of the picture is adjusted with the size control so that the width of the picture equals the width of the mask opening. This may or may not make the picture non-linear horizontally as shown in the test pattern at T. If it does, then either the Horizontal Drive or the Horizontal Linearity control or both must be adjusted. The Horizontal Drive control has the effect of spreading or compressing the right side of the picture with respect to the left side. At the same time, this control affects the size of the picture and the picture brightness. Hence, when its adjustment is changed you may have to readjust the Horizontal Size control and the Brilliancy control. The Horizontal Linearity control has the effect of expanding or compressing the middle portion of the picture with respect to the two sides. It is fortunate that this control does not need adjusting very often, because it is below the chassis, so it is necessary to remove the chassis to make an adjustment.

Of course, if the Horizontal Linearity control is properly adjusted, it will be perfectly all right for you to adjust the Drive and Size controls throughout their range, because you get the picture back without having to touch the Horizontal Linearity control.

The remaining control is the Bias control. This ordinarily is not touched unless the picture tube is being replaced. At that time, the Contrast control is turned counter-clockwise as far as it will go, so that no picture appears. The Brightness control is set to where a bias of 50 volts on the picture tube can be read with a high resistance voltmeter or a vacuum-tube voltmeter. Then the bias control (on the front of the chassis under the funnel of the picture tube) is adjusted to where the raster first becomes invisible. That is, you turn the bias control up to a point where you can just see the raster and then turn it back until the raster disappears.

It is important for you to experiment with the settings of the controls on the front panel and on the rear apron of the chassis to find out just exactly what each one does. Not only will you learn how to make adjustments of these controls, but also you will see what happens to the picture when they are out of adjustment and can thus determine when a service complaint might be caused by an improperly set control.

Mechanical Adjustments. The positioning of the deflection coil, the focus coil, and the ion trap on the neck of the picture tube as well as the positioning of the regular controls will have much to do with the quality of the picture.

The deflection coils are nearest the front of the picture tube. In general, if these coils are rotated from their proper position, the picture will be tilted as in the test pattern shown at Q. To square up the picture in such a case, it is necessary to loosen the screws holding the deflection coil assembly, and to rotate the coil assembly to the right or left as necessary until the picture is square.

Another important adjustment is that of the focus coil. Improper positioning of the focus coil will not only throw the picture out of focus to such an extent that the focusing control cannot bring it in, but there may even be a shading in one corner of the test pattern as at U. In either case, the focus coil itself is moved physically until the raster is properly centered and in focus. Moving the coil will throw the original adjustment of the focus control off somewhat, so you will have to make several trial adjustments of positioning the focus coil and readjusting the focus control for best focus. There are two types of focus-coil mounting used in this series of receivers. In one type, the focus coil is mounted by means of three studs or bolts, with a nut on either side of the focus-coil mounting bracket. When a focus coil with this type of mounting is to be adjusted, both nuts on each of the three studs must be loosened so that the coil can be shifted along the neck of the tube. In the other type of mounting, there is a spring between the bracket and the base of the stud, and a nut is on the outside of the bracket. The coil can be drawn back against the springs. You can see if this is the right direction, and can then retighten the nuts to hold the coil in the proper position. Of course, if the coil must go in the opposite direction, you will have to loosen the nuts first.

There may or may not be an ion-trap magnet on the neck of the picture tube. If there is an ion-trap magnet, it will be mounted on the neck of the tube behind the focus coil. A picture of a typical ion-trap magnet is shown in Fig. 16A. When an ion-trap magnet is used, its adjustment is critical, and its initial adjustment must be carried out quickly to avoid damaging the picture tube.

The normal starting position for the ion-trap is with the larger magnet (if there are two) over the "flags" on the electron gun structure inside the picture tube. Fig. 16B shows where these flags are. If the ion-trap has only one magnet, it is initially aligned over the flags.

To adjust the ion-trap magnet, slide it forward and backward and rotate it on the neck of the tube with the set turned on, watching the raster as you do so. In general, you adjust for brightest raster. If the raster tends to get quite bright, turn down the brilliancy somewhat, and repeat the adjustment. Use the focus control to get the finest focus, and then make a final touch-up adjustment of the ion-trap magnet until the raster is as bright as you can get it.

The adjustment of the ion-trap magnet may affect the focus. However, remember that the initial ion-trap adjustment must be made quickly. If you take a long time in making this initial adjustment to where you get a raster, you may burn the second anode in the tube. Therefore, always be sure to start from the correct initial position, and to adjust the trap quickly until you can get a raster. Then, you can take more time in getting the brightest raster.

Incidentally, when replacing the picture tube, you usually have to make the ion-trap adjustment first, then adjust the focus and deflection coils.

REMOVING THE SET

Now that you have become reasonably familiar with all of the external controls of your set, the next step will be to become familiar with the set itself. In order to carry out the experiments in the next workbook, you will have to have the set outside the cabinet.

Before attempting to open the cabinet and remove the receiver, always remember to unplug the power cord and to wait for several minutes for the filter condensers to discharge. Also, when you have the set out, observe all the safety precautions that were given earlier in this workbook.

The exact procedure used in removing the set from its cabinet depends on the particular set you have.

If you have the manufacturer's instructions, be sure to refer to them for additional information on this subject.

In general, the following rules will apply:

First, you should remove the knobs from the front panel. The small knobs are held on the shafts by springs, so you can pull them off. Be careful, so that the retaining springs do not leap from the knob, because they are easily lost. The large tuning knob has set screws holding it on its shaft, that must be loosened. Some of these receivers use set screws
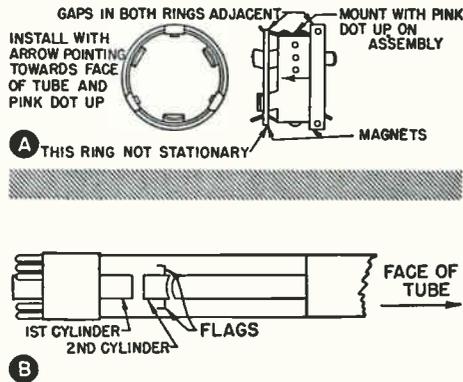
FIG. 16. An ion-trap magnet, such as shown in A, goes over the flags that are observable inside the gun of the picture tube. The position of the flags is shown at B.

with Allen heads, so the proper Allen wrench is necessary. A screwdriver does not fit.

Next, remove the screws fastening the back grille or panel to the cabinet.

There are four screws holding the receiver in the cabinet. With a table model set, don't turn the cabinet on its side or its back to remove these screws. You can do it most easily simply by moving the cabinet to the edge of the table so that one side projects and you can reach two of the screws. After removing these screws, you can shift the cabinet around until the other side projects and you can reach the other two screws.

Before taking the chassis from the cabinet, reach inside the cabinet and unplug the loudspeaker. Also remove the tuning-eye tube from the clamp holding it to the front panel. Be careful to remove the tuning-eye tube either by unloosening the small mounting thumb screw for the clamp, or by pulling the tube straight down. Do not pull the tube back as the clamp may slip off the base of the tube onto the glass part and break it.

With the speaker unplugged and the tuning-eye tube released from the front panel, you can slide the chassis completely out of the cabinet.

EXAMINING THE SET

Once you have the set out of its cabinet, refer to Fig. 17, and learn the locations of each tube. Note

the purposes of the tubes as listed on this layout diagram, and refer to the large schematic diagram (Fig. B) to study just how the circuits are arranged.

Next, remove the picture tube. Be sure you handle it with care because there is danger from flying glass if you break it. Never lift the tube by the neck or allow pressure to be exerted on the neck.

To take out the picture tube, disconnect its socket, and pull out the anode high-voltage lead, which plugs into a connector on the side of the tube. There is a large bracket around the picture tube. Use a screwdriver to remove the screws that fasten this bracket around the tube, and remove the bracket. On some sets these screws have a Phillips head so a Phillips screwdriver will be necessary.

If an ion-trap magnet is used on the picture tube, remove it by sliding it off the base end of the tube. Now, grasp the tube firmly with both hands along its outer edge and gently slide it out of the focus coil and deflection yoke. Be sure you hold the tube by the outer edge or by the funnel only. Don't place any strain on the neck of the tube.

Carefully put the tube face down on a soft cloth in a safe place.

With the picture tube out, you can stand the set
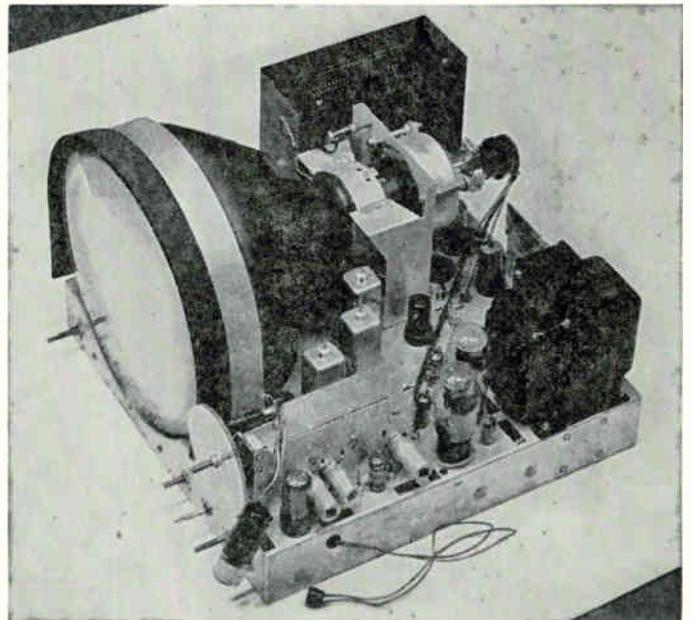
NRI TV Lab. Photo

This top view of the Stromberg-Carlson receiver shows how it looks when it is taken from its cabinet.

up so that you can examine it underneath. Make full use of your schematic and block diagrams, and learn to find your way around in the circuits to the best of your ability. Try picking out parts in the schematic diagram and then locating these parts from their connections to tube sockets or to other parts you can identify. This will be valuable training for you. You can undoubtedly spend quite a number of

FIG. 17. This is a top view of the Stromberg-Carlson series. Indicated in this view are the various tubes, and their functions.

evenings examining the set in this way.

Once you are reasonably adept at locating parts and circuits, put the picture tube back in the set. You do this by reversing the procedure for getting the tube out. Slide the tube neck back into the deflection yoke and focus coils until the center of the face surface extends about 3/16 of an inch beyond the front edge of the chassis. The deflection yoke should be as far forward as possible while you are inserting the tube.

Next, place the bracket over the tube, making sure that the soft sponge-rubber pad is underneath the bracket. Adjust the screws that hold the bracket in place, but do not tighten them until the tube is properly centered in the focus coil. Do not allow pressure to be exerted on the neck of the tube.

If there was a corrugated cardboard inside the focus coil, make sure that it is replaced. With the deflection yoke as far forward as possible, adjust the focus coil so that it is perpendicular to the axis of the tube and is about 1/8 inch from the deflection yoke. Rotate the tube so that the ion-trap flags are in the position shown in Fig. 16B, and the high-voltage connector comes up to the position it was in before,

then you can tighten the screws holding the mounting bracket. Replace the ion-trap magnet and then plug in the socket and the high-voltage lead. Turn on the set, adjust the ion-trap magnet to an initial adjustment for brightest raster, and finally adjust the focus coil and deflection yokes as we have previously described.

When you have finished examining the set, replace it in the cabinet by reversing the process of removing it. Be sure the tuning-eye tube is on top of the set and not in front of it where it may be crushed. Insert the chassis in the cabinet and replace the four screws that hold the chassis to the cabinet. You may then replace the tuning eye in its bracket, and plug in the speaker again.

The small knobs are pushed onto their shafts, but the tuning-control knob must be refastened to its shaft by tightening the set screws in it. The receiver is again ready to be turned on and operated.

After you have carried out the foregoing steps carefully, you are ready for the next workbook. However, it would be a good idea to read the sections of this text that cover other receivers, to get a general understanding of other types of TV sets.

The RCA 630 Series

The RCA Model 630TS was the forerunner of a large number of TV receivers. The information in this section applies to this set and to the later version, the Model 8TS30, as well as to most of the equivalent sets that are listed in Table I. Of course, there will always be differences, so you should be careful in applying this information even to a set bearing the proper model number.

A view of this set in its cabinet is given in Fig. 18. Even the cabinet styling was closely copied by many

FIG. 18. This is a front view of the RCA Model 630TS, in its cabinet.

manufacturers who made models of this type. The RCA 630TS is a 30-tube table model using a 10-inch electromagnetic picture tube. The same chassis was also used in certain radio-TV combinations.

The set is designed for a.c. operation. All TV channels can be received by a step-tuning arrangement; fine tuning is also provided. The antenna input impedance is 300 ohms, balanced to ground. The picture i.f. carrier frequency is 25.75 megacycles and the sound i.f. carrier frequency is 21.25 megacycles.

THE RCA BLOCK DIAGRAM

Let's first run through the technical details of the operation of this receiver, then go on and learn the operation of the controls, how to remove the set from its cabinet, and how to locate parts and circuits on the chassis.

First let's run through the operation using the block diagram of Fig. 19. A block diagram is often valuable in diagnosing receiver troubles, because it enables you to see at a glance the signal path through the receiver. Thus, when there is some trouble that kills one or more sections, you can better apply effect-to-cause reasoning in isolating the trouble to a particular section of the set.

Signals enter the set from the antenna and are then fed into a tuned r.f. amplifier. This r.f. amplifier

serves to boost the amplitude of the signal and thus to improve the signal-to-noise ratio at the input of the mixer. At the same time, the r.f. amplifier tends to reject certain interfering signals.

In the converter stage, the incoming signal is mixed with the signal from a local oscillator, and the resulting beat produces two i.f. carriers. The picture carrier contains not only the video signal, but also the horizontal and vertical synchronizing signals.

The two i.f. carriers are separated right at the output of the converter stage. The sound carrier runs through a sound i.f. amplifier that consists of two stages of amplification, a limiter stage, and an FM discriminator. The resulting audio output is then fed through an audio amplifier consisting of a voltage amplifier and a power output tube. The sound signal is then fed to the loudspeaker.

The video i.f. signal is taken from the output of the converter and goes through a 4-tube video i.f. amplifier. The video amplifier in this set is stagger-tuned; that is, each i.f. transformer is tuned to a different frequency within the pass band, so that their resulting over-all responses, plus that of traps in the video i.f. amplifier, give the desired response characteristic.

The signal at the output of the video i.f. amplifier is next passed through a video second detector. The demodulated video signal (plus the synchronizing signals) then passes through a two-stage video amplifier, which is a.c. coupled. At the output of this amplifier, the video signal itself is applied to both the picture tube and a d.c. restorer. The latter restores the d.c. level of the signal that was wiped out by the a.c. coupling in the video amplifier.

From this same point, a copy of the signal is taken off for extracting the synchronizing pulses. To suppress some of the effects of noise, the grid of the first video amplifier has a certain amount of limiting action. In addition, the signal that is taken from the output of the video amplifier passes through a sync amplifier tube, which is arranged so that the signal is fed to the amplifier with the polarity such that the
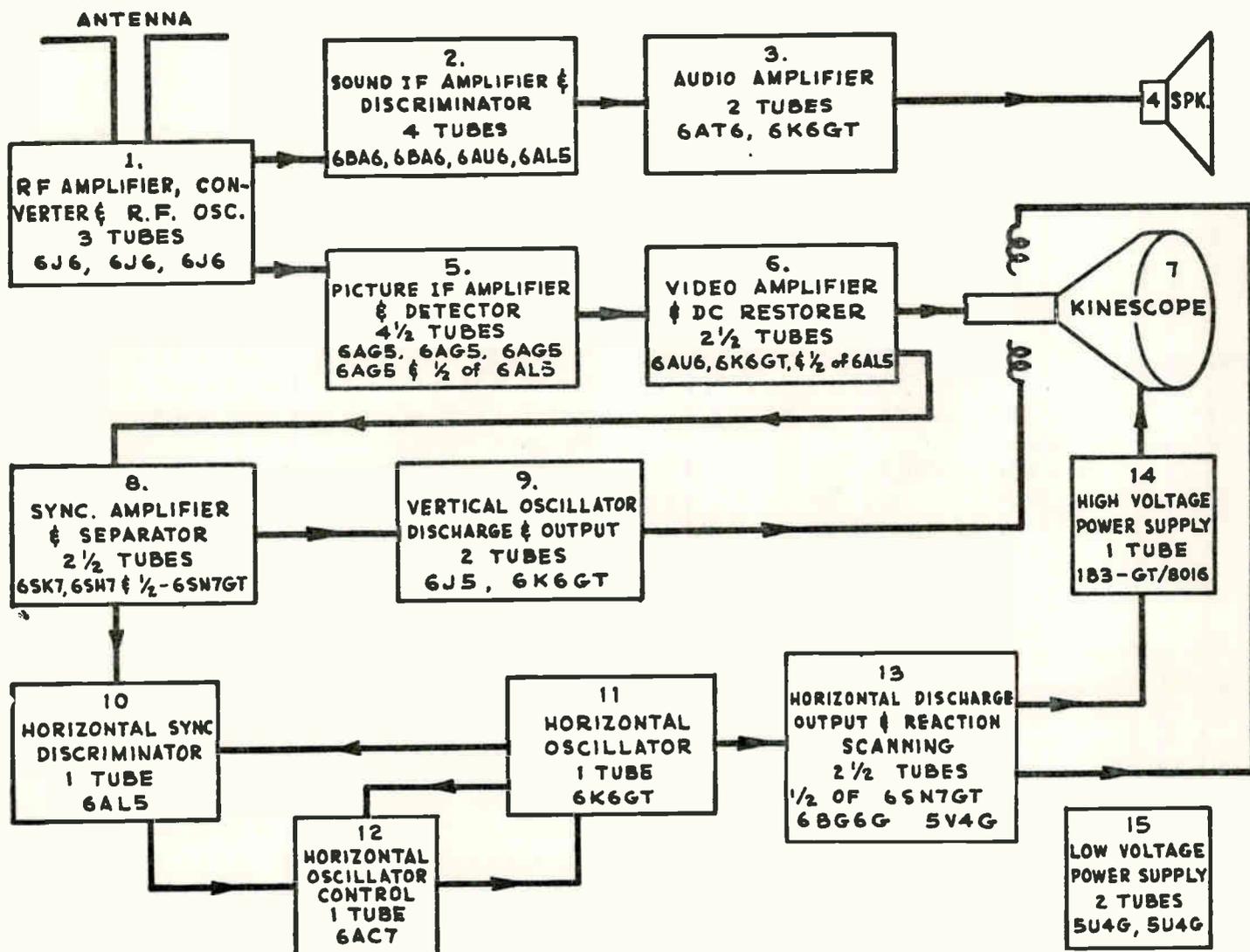

FIG. 19. A block diagram showing the functions of various sections of the RCA series.

28

sync signals project in the negative direction (positive picture phase). Noise pulses above sync level can only drive the tube beyond cut-off, so they are compressed or cut off and the signal-to-noise ratio is improved.

The amplified copy of the signal, with the sync pulses now swinging in the positive direction, is next applied to a sync separator or clipper stage. The operating voltages on this stage are arranged so that the negative portion of the applied signal is cut off. Thus, the video signal and the blanking level are removed and only the sync pulses appear at the clipper plate. Because the sync pulses coming out of the clipper have the wrong polarity for application to the sweep oscillators used, they are fed through an amplifier that again inverts their polarity. At the same time, this second sync amplifier tube is arranged to have a cut-off characteristic that tends to clip the sync pulses to further remove hum, noise, and video signals. Sometimes this second sync amplifier is called a second clipper.

At the output of the second sync amplifier, the vertical and the horizontal sync signals are separated from each other. An integrating network removes the vertical sync signal, which is then applied to a blocking oscillator stage (used as the vertical sweep generator) at the proper moment to unblock this stage to produce the vertical sweep pulses. In turn, these pulses are shaped and then passed through a vertical amplifier stage. The signal at the output of this stage is applied through a transformer to the vertical deflecting yoke for electromagnetic deflection of the electron beam in the picture tube.

The horizontal sync signal that is separated from the vertical sync signal is applied to the horizontal sweep oscillator through an automatic-frequency-control (a.f.c.) system. Both the output of the horizontal sweep oscillator and the horizontal sync signal are fed into a discriminator circuit, which produces a voltage proportional to their difference in frequency. This difference voltage is fed into a reactance-tube circuit that retunes the horizontal oscillator to the proper frequency. The horizontal oscillator produces a sine-wave signal at the right frequency, which is then fed through a stage that changes its shape.

The signal from the shaping circuit goes into the horizontal output stage. This stage in turn feeds the signal through a transformer to the horizontal deflection yoke. A damping tube is connected across this yoke to absorb energy at the proper moment and to prevent oscillation from continuing in the yoke beyond a desired time.

The high-voltage pulse coming back from the deflection yoke is utilized in getting the high-voltage supply for the picture tube. A step-up transformer applies this high-voltage pulse to a rectifier tube, and the high voltage is then passed through a simple filter for application to the picture tube.

The low-voltage supply uses two rectifier tubes connected in parallel. All tube filaments operate from the power transformer.

DETAILED ANALYSIS

Now that you have an idea of how the signals travel through the receiver, let us examine the schematic circuit diagram in detail, and see exactly how the signal travels from stage to stage.

Remove the large "pull-out" schematic diagram for this receiver (stapled in the center of this text; if you have not already done so, open the staples and remove the diagrams). This is Fig. C. Open up this diagram, and use it for the following detailed analysis.

Front End. For convenience in studying, the schematic of the front end is reproduced in Fig. 20. However, you should also refer to the large schematic diagram, Fig. C, as this is the kind of schematic you will meet in your service work.

The r.f. unit for this receiver is a separate assembly on its own chassis bolted to the main chassis. On the unit are the r.f. amplifier, converter, and oscillator stages, and the associated controls. The television signal picked up by the antenna is fed over a 300-ohm transmission line to the input of the receiver. The signals appear across T1, which is a center-tapped coil. This coil has a fairly high impedance for the television signals so that they are applied to the tube grids, but has a very low impedance at lower frequencies. Therefore, lower-frequency signals tend to be short-circuited by this coil, which reduces the amount of interference from broadcast signals or other low-frequency r.f. signals.

Coupling condensers C1 and C2 are used to feed the signal from this coil to the grids of the push-pull r.f. amplifier tube V1. These coupling condensers are needed to prevent the d.c. bias voltage that is applied to the tube grids through R3 and R13 from being short-circuited to ground by T_1. In the grid-return circuit from these resistors, you will find C5 and R12, which act as a decoupling filter to prevent signals from traveling in the bias network.

The resistance of R3 and R13 together equals 300 ohms, and properly terminates the 300-ohm transmission line.

Condensers C3 and C4 each run from the grid of one of the push-pull tubes to the plate of the other. The phases are such that these condensers act as neutralizing condensers to balance the grid-plate capacities in the triode tubes, and thus avoid self oscillation in this stage.

You will note that the input or grid circuit is un-

tuned, but that the plate circuit is tuned. In each plate circuit, there is a series of inductances that can be shorted out by the station-selector switch. The amount of inductance left in the plate circuit determines the resonant frequency of the plate circuit of the push-pull r.f. stage.

Coils L25 and L26 provide proper tuning for channel 13, the highest-frequency channel. As the tuning switch is moved along, additional coil sections are added so that lower and lower frequency signals can be tuned in. In order to make the jump between the lowest high-band channel (No. 7) and the highest low-band channel (No. 6), the coils L11 and L12 are inserted.

Plate voltage is supplied to each section of the r.f. amplifier through the resistors R1 and R2 through a decoupling network made up of R4 and C11.

The signal is transferred from the tuned-plate circuit of the r.f. unit to the tuned-grid circuit of the converter by means of a coupling link (inductive coupling) between the r.f. deck of the switch and the converter deck, and additional coupling is provided by the condensers C10, C12, and C13.

The grid circuits of the twin-triode converter tube V2 are also connected in push-pull and a tuning arrangement similar to that used in the plate circuit of the r.f. stage is provided. The plates of the converter sections are in parallel and apply the i.f. signals to the first i.f. (converter) transformer T2.

Since V2 is a triode tube, if the grid circuit becomes resonant at the i.f. frequency, the converter stage can oscillate. To prevent this, the grid circuit is kept at ground potential insofar as the i.f. signal is concerned. This is accomplished by making the grid circuit series resonant at the i.f. frequency. The tuning inductance, added to the inductance of L80, is tuned by condenser C14 to the i.f. frequency. This tuned circuit also acts as a trap to reject any interfering signals at the i.f. frequency that may arrive at the mixer grid.

The local oscillator tube V3 is a push-pull type utilizing a tuned-plate circuit. Condenser C15 is shunted across this tank circuit as a fine tuning control.

The oscillator signal is coupled to the grid circuit of the converter by means of an inductive link coupling. The oscillator tank inductances are designed so that the oscillator tunes automatically to the required higher frequency.

The converter tube connection of push-pull grids and parallel plates is quite effective in that the oscillator and incoming signals tend to be out of phase and cancel each other, whereas the required i.f. beat frequencies are in phase at the two plates of the converter. Therefore, they add together and appear across the first i.f. transformer. A secondary winding on this transformer is tuned to the sound i.f. carrier, and the signal appearing across a portion of this tank
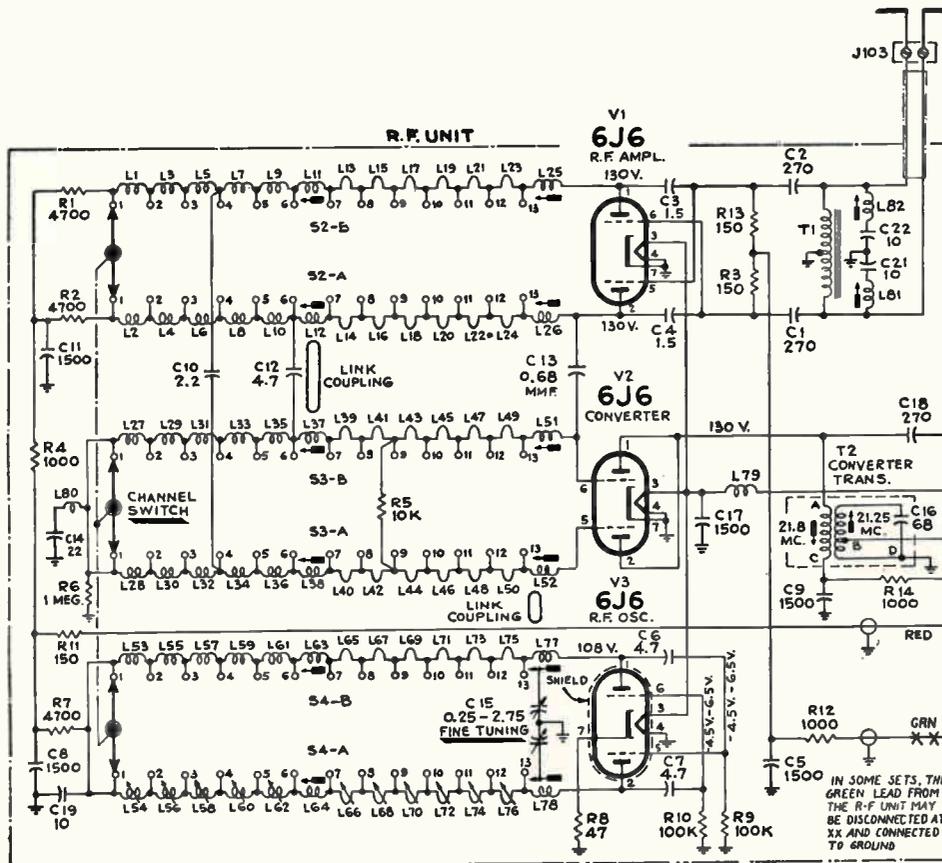

Courtesy RCA

FIG. 20. This schematic shows the front end or tuner section of the RCA receiver. Shown here are the r.f. stage, the converter, and the oscillator.

is used as the input signal for the sound channel. The video component appearing across the tuned primary winding of this transformer is applied through a coupling condenser to the grid of the first video i.f. stage.

The Sound Channel. The sound signal that is extracted from the secondary winding of the i.f. transformer T2 is applied to the grid of tube V104. (See the large schematic diagram, Fig. C.) A transformer T111, which is tuned to the sound i.f. carrier, transfers the signal from V104 to tube V105. Both these

Video I.F. Stages. You can study the video i.f. stages on the large schematic diagram, Fig. C, but for more clarity, we have reproduced this section of the set in Fig. 21. It is of considerable interest since it is typical of the stagger-tuned video i.f. amplifiers that are in common use in the majority of TV receivers.

An examination of the circuit will show that the signal path is rather straightforward. The signal applied to the grid of the first picture i.f. tube V110 appears in the plate circuit of this stage across the
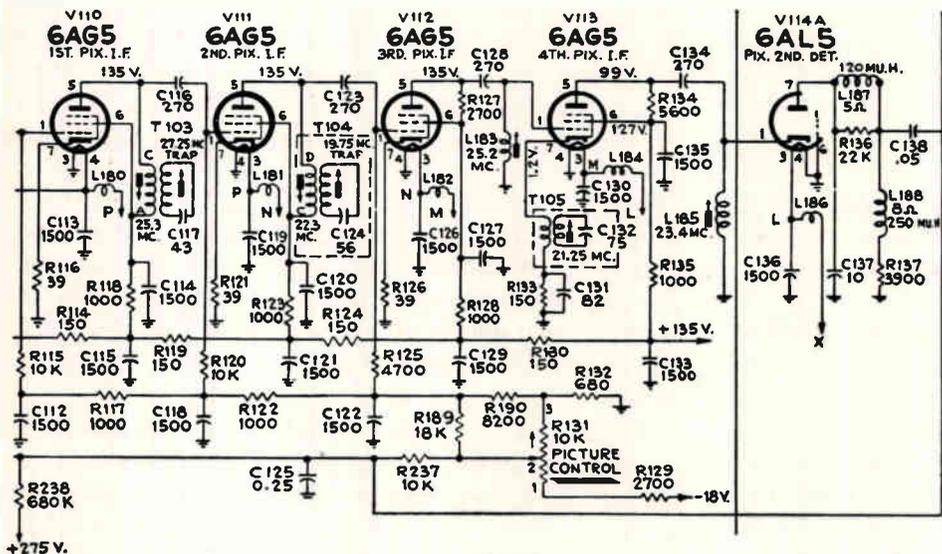
Courtesy RCA

FIG. 21. Here is the video i.f. section of the RCA receiver. The sound take-off is ahead of the portion shown here.

tubes are connected as standard i.f. amplifier stages.

The signal that appears at the plate of tube V105 is transferred by a tuned transformer to tube V106. This stage acts as a limiter. Note that a fairly large grid resistor R217 is used, and that there is no cathode bias. Hence, this stage biases itself by drawing grid current, which is proportional to the strength of the signal. Since the bias varies with the signal in a more or less linear manner, the signal level is held relatively constant.

Furthermore, the plate and screen-grid voltages on this tube are kept very low. When the grid signal moves in the positive direction, plate current saturation prevents any further increase, so this also acts as a limiting action. The result is that this stage prevents amplitude variations in the sound i.f. signal from being transferred to the sound discriminator stage.

This sound discriminator stage acts like any other FM detector to produce an audio output that follows the frequency modulation of the i.f. signal. This audio signal is fed through a volume control to the first audio stage V108. Finally, by means of resistance coupling, the signal is applied to the audio output tube V109, from where it goes through the output transformer to the loudspeaker.

primary of the transformer T103. Coupled to this primary winding is a trap circuit, which is made resonant to any particular frequency that is to be omitted (in this case, the adjacent channel sound signal) from the signal passed by the i.f. section. This trap absorbs energy at its resonant frequency and hence reduces the undesired component.

The rest of the signal appearing across T103 is transferred by capacitive coupling so it appears across the grid resistor and hence is applied to the second picture i.f. stage. Its plate circuit has a tuning arrangement similar to that of the first one, except that here the trap is tuned to a different frequency (the adjacent channel picture carrier). The remainder of the signal is amplified by the third picture i.f. stage, which has a coupling resistor in its plate circuit. However, the signal appears across a tuned-grid circuit consisting of coil L183 and the distributed capacities of the circuit, for application to the fourth picture i.f. stage.

A degenerative trap is in the cathode circuit of this fourth picture i.f. stage. That is, the primary winding of the transformer T105 is in the cathode circuit and tends to reduce the gain of the stage at all frequencies to a certain extent. However, the secondary winding of this transformer, which is tuned

to the accompanying sound carrier causes the degeneration to be worst at this undesired signal frequency. Therefore, this frequency is suppressed more than any other.

Finally, the signal appearing across the plate load resistor for the fourth picture i.f. stage is transferred to a tuned circuit (consisting of coil L185 and distributed capacities) for application to the picture second detector.

An examination of the biasing arrangement will show that the grids of the first three picture i.f. stages are all tied together through decoupling R-C networks to the picture (contrast) control R131. This control varies the bias on these three stages and hence varies the gain of the i.f. stages (as well as the r.f. stage). In this manner, the signal strength at the picture tube grid can be adjusted, and the contrast changed. A small minimum bias is provided by means of 39-ohm cathode resistors. The primary purpose of these resistors, however, is to make each stage more stable by adding a small amount of degeneration.

The fourth picture i.f. stage is not tied into the contrast control. Instead it supplies its own bias by means of a by-passed cathode resistor.

It is particularly important to notice the amount of decoupling in this TV set. Notice that in addition to all the R-C networks used in the grid circuit, an R-C network is used for decoupling in each plate and screen-grid circuit. There are further decoupling networks in the B-supply lead. Even in the filament circuits, choke coils and individual by-pass condensers are arranged to make certain that each stage is completely isolated from all others. In some of the more recent TV receivers, such extreme amounts of decoupling may not be found, but decoupling is still far more common in TV than in radio.

Each of the i.f. tuned circuits is tuned to a different frequency. Thus, the primary of T103 is tuned to 25.3 megacycles, the primary of T104 is tuned to 22.3 megacycles, coil L183 is tuned to 25.2 megacycles, and L185 is tuned to 23.4 megacycles. The first trans-

former—the one at the output of the converter, is tuned to 21.8 mc. Each of these coils is loaded by a resistor, but no two are loaded alike, so each has a different Q. The response from each circuit is quite different. Fig. 22A shows the responses that may be obtained from each of these coils.

The response to any one frequency is the sum of the responses of all of the coils in this i.f. amplifier. Proper loading of the individual coils gives a relatively flat-topped over-all response. The skirts of the over-all response would be relatively broad, however, if it were not for the presence of the three traps in the i.f. amplifier. The sound take-off coil, and the trap in the cathode circuit of the fourth picture i.f. stage are tuned to the sound carrier of the desired picture and reduce the amount of this sound carrier. Because of the use of two traps, tuned sharply, a notch is placed in the over-all response at the sound-carrier frequency as shown at B in Fig. 22. The other two traps are tuned to an adjacent-channel picture carrier and an adjacent-channel sound carrier and provide additional notching. As a result, the over-all curve shown dotted at A and solid at B in Fig. 22 is the sum of the responses of the individual tuned circuit and the traps.

Video Detector. The signal at the output of the video i.f. amplifier is fed to the picture second detector. The load for the detector is a complex one made up of coil L187, coil L188, and resistor R137. The load for low frequencies is, of course, the resistance. As the frequencies go higher, however, the two coils give the effect of an increasing load, to counteract the drop-off occurring because of distributed capacities in the circuit. As a matter of fact, these inductances tend to resonate with the distributed capacities and further improve the high-frequency response.

The Video Amplifier. The signal across the portion of the load made up of L188 and R137 is transferred to the first video amplifier through a coupling condenser C138. (See Fig. C.) The load for the first video amplifier is made up of a combination of coils and a resistor, much like the detector load. From this stage, the signal goes to a second video amplifier from whence the signal is applied to the grid of the picture tube. Part of the signal is also applied to a d.c. restorer, which is a rectifier tube arranged to produce a d.c. voltage that follows the average picture brilliancy. This d.c. voltage is added to the signal to replace the d.c. component that was in the original signal, but which was wiped out by the coupling condensers in the video amplifier. Hence, the signal applied to the grid of the picture tube consists of the a.c. portion of the signal as it was amplified by the video amplifier, plus a d.c. level from the d.c. restorer.

The brightness of the picture is adjusted by vary-
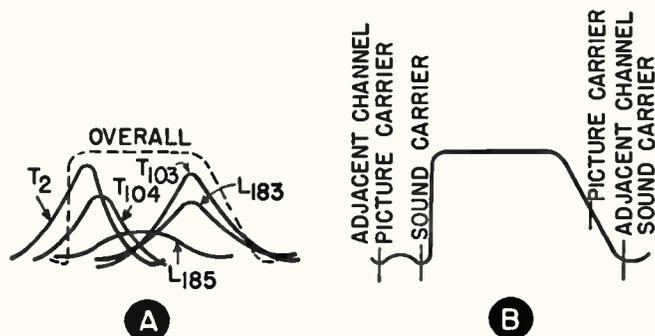
FIG. 22. This is the i.f. response characteristic of the RCA receiver. The over-all response is made up of the separate responses of each of the tuned circuits, plus the notches placed in a curve by the various traps.

ing the bias applied to the grid of the picture tube.

Sync Chain. A copy of the signal is obtained from the d.c. restorer circuit and is fed through a coupling condenser to the grid of tube V118, which acts as a first sync amplifier. Notice that, in effect, what we are doing is taking a copy of the video signal as it is applied to the picture tube for the purpose of stripping from it the synchronizing pulses. The signal that arrives at the grid of the first sync amplifier tube has the pulses going in the negative direction. When noise pulses try to increase the amplitude of the sync pulses, they exceed the cut-off level for the tube, so such noise pulses are removed. The entire signal is amplified by this tube, and is inverted in polarity. Hence, the signal that is fed to the actual sync separator or clipper tube V119 has the sync pulses going in the positive direction. Therefore, all of the video signal is beyond plate-current cut-off, so the tube effectively removes almost everything except the sync pulses. Of course, the voltages on the tube are carefully arranged to operate at a point where this action will be best accomplished.

In the plate circuit of the sync separator or clipper, the signal consists almost entirely of the sync pulses. However, this signal is fed through another sync amplifier stage to reverse the polarity. In passing through this second sync amplifier, the signal is again clipped because it exceeds the normal operating region for this tube. This further removes amplitude variations that may be caused by noise, hum, etc. Some manufacturers call this stage (V120-A) a second sync clipper.

Vertical Sweep Chain. The output of the second sync amplifier consists of both the vertical and the horizontal sync pulses. These must be separated from each other. All the pulses are therefore applied to two separating networks. One path is through condenser C149 into an integrating network consisting of resistors R163, R164, and R165, together with condensers C151, C152, and C153. This network is essentially a low-pass filter and allows only the vertical sync pulses to be applied through transformer T106 to the grid of the vertical sweep oscillator tube. More details on the operation of this kind of network will be found in your study Lessons.

The vertical sweep signal is generated initially in tube V121. This tube is operated as a blocking oscillator. The operating frequency of the blocking oscillator depends essentially on the time constant in the grid circuit, and in this particular case depends upon the value of C154 and on the value of the grid resistance made up of R171 and R172. By varying R172, it is possible to change the frequency of this oscillator and thus to bring it in step with the sync pulses. Thus, R172 serves as the Vertical Hold control. When the frequency of the oscillator is brought

near that of the sync pulses, the sync pulses will act to unblock the vertical oscillator at the proper time and thus will time the vertical sweep pulses.

The blocking oscillator tube regularly discharges condenser C157, which is charged through a series of resistors in a wave-shaping network. A signal of the desired wave shape is formed across this condenser, and this signal is applied to the vertical output tube V122.

The amplitude of the pulses across C157 depends upon the B voltage and the resistance through which C157 charges. These can be varied by adjusting R169. Thus this resistor acts as a Height control.

The amplified vertical sweep voltage that appears in the plate circuit of the amplifier tube V122 is coupled by the transformer T107 to the vertical deflection coil. To provide damping and thus prevent oscillation in the vertical coil, the output tube is connected as a triode so that it acts to load the deflection yoke through the output transformer.

The bias for the vertical output tube is provided by means of cathode resistors R177 and R178. Since the characteristic curve of this tube is not a straight line over its entire range, the effect of adjusting R178 is to produce slight variations in the shape of the sweep by shifting the operating point of the tube to different points along its curve. Therefore, since it is possible by adjusting this control to select an operating characteristic that gives more nearly perfect linearity to the sweep, this is known as the Vertical Linearity control. However, since adjusting this control changes the gain of the vertical output tube and hence the height of the picture, there is an interaction between the adjustment of these controls, as we shall explain later.

The amount of d.c. current through the vertical deflection yoke, and hence the vertical position of the raster, can be controlled by adjusting resistor R181, which acts as a Vertical Centering control.

Horizontal Sweep Chain. Returning to the output from the second sync amplifier V120-A, notice that a lead goes from the plate of this tube over to the left and down to condenser C166 near the 6AL5 sync discriminator tube V123. This small coupling condenser and resistor R229 together act as a filter that effectively passes only the high-frequency horizontal pulses. Actually, this is an R-C circuit so arranged that when pulses are fed to it, it responds by giving sharp high pulses as the current changes. You will study this, too, in your regular Lessons.

The horizontal oscillator tube V125 is connected to one winding on the transformer T108 in such a way as to form a Hartley sine-wave oscillator. This sine-wave signal is fed through T108 to the plates of the horizontal sync discriminator. At the same time, the sharp pulses obtained from the horizontal sync pulses

that are appearing across R229 are applied to the center tap of this transformer and hence also to both diodes simultaneously. Therefore, this voltage is added to the signal from the horizontal oscillator. When this series of pulses and the sine-wave voltage from the oscillator are properly phased, the diodes produce equal voltages across their load resistances R191 and R192. However, these voltages are of opposite polarity, so the sum of the voltages is zero. If the phase of the synchronizing pulses changes with respect to the sine-wave signal, one diode will produce more voltage across its load than the other will. The net voltage across R191-R192 can be either positive or negative, depending on which diode is passing the greater current, and its amount depends on the phase difference between the sync pulses and the sine-wave signal from the horizontal oscillator.

The net voltage produced by the sync-discriminator tube is applied to the grid of the horizontal oscillator control tube V124. This tube is arranged so that it draws plate current out of phase with its plate voltage, so it acts as a reactance across the winding of T108 that is in the grid circuit of the horizontal oscillator tube. The amount of current drawn by this tube depends on the net voltage it gets from the sync discriminator circuit, so it is possible to vary the reactance up or down. This will shift the frequency of the horizontal oscillator. As the frequency is shifted, the sine-wave signal is forced to move back more in phase with the sync signal. Thus, it is possible by this arrangement to synchronize the sweep signal with the incoming sync signal.

Tube V125 is arranged so that the sine-wave signal produced in the grid circuit is clipped on both ends; hence the plate current of this tube is approximately a square-wave signal. This signal is fed through the R-C network between this tube and the discharge tube V120-B so that a series of pulses is applied to this tube that serves to unblock it at the desired moments for horizontal sweeping.

An essentially saw-tooth wave is produced from the signal applied to the horizontal discharge circuit by the action of charging C179 through R204, then suddenly causing tube V120-B to conduct and discharge condenser C179. The setting of resistor R187 determines how much voltage will be applied to the grid-cathode of the horizontal output tube V126, so it is called the Drive control.

The amplified signal in this circuit is applied through the horizontal output transformer T109 to the horizontal deflection yoke. To provide the proper deflection, the current through the horizontal deflection yoke must follow a saw-tooth wave shape. The yoke draws current while the 6BG6 horizontal output tube is conducting. When the tube is suddenly cut off at the end of the sweep cycle, the horizontal deflection yoke starts into oscillation because there is no damping across it at that time. This oscillation is permitted to exist for less than half a cycle and furnishes the retrace stroke of the sweep cycle.

At the end of this retrace stroke, it is necessary to damp out the oscillation; this is done by tube V128. This damper, called a reaction scanning tube by RCA, begins to conduct at the end of the portion of the oscillation to be permitted. When it starts to conduct, it places a load across the yoke and absorbs the oscillatory energy. Hence, the damped oscillation causes the current flow through the yoke to assume the desired saw-tooth shape. As this energy is gradually used up, the horizontal output tube begins to conduct and continues to supply energy for the remainder of the sweep cycle, thus again storing energy in the yoke for a repetition of the cycle.

By varying the amount of voltage applied to the horizontal yoke, the width of the picture can be controlled. This is done by means of coil L196, a variable inductance across part of the secondary of the horizontal output transformer.

The way in which energy is absorbed from the yoke determines how nearly linear the trace will be. Therefore, a tapped resistor in the cathode circuit of the reaction scanning tube provides a load adjustment.

The energy coming back from the yoke is applied to the plate circuit of the horizontal output tube, and the coil L201 and the condenser C188 form a phase-shifting filter for this energy. By shifting its phase properly, the energy can be added to the supply voltage for the horizontal output tube in such a way as to cause its current to increase at the proper time to supply the energy needed by the yoke. This also affects the sweep linearity.

Direct current through the horizontal deflection coil sets the initial resting position of the electron beam, so the variable resistance R211 acts as a Horizontal Centering control.

High Voltage. The high voltage needed by the picture tube is obtained from the horizontal deflection system. When the yoke goes into oscillation, a very high-voltage pulse goes back through the horizontal output transformer. This energy can be put to use by using a horizontal output transformer with additional turns on the primary. This increases the voltage of the pulse, which is then applied to a rectifier tube V127. By passing the output of the rectifier tube through a simple R-C filter, it is possible to obtain about 9000 volts for application to the second anode of the picture tube.

Low-Voltage Supply. The B supply for all of the tubes is obtained from a low-voltage supply that is standard except that it contains two paralleled rectifiers, which permit the supply to have a very high current capacity and above-normal output voltage.

Notice that a bleeder is used across the output of this power supply. It is essential that the voltages remain constant in television receivers, so bleeders are more commonly found than they are in radio receivers.

Circuit Variations. The ion-trap magnet in a later version of this receiver, the RCA Model 8TS30, is a permanent magnet, so the electromagnetic type shown in the bleeder network is no longer used. Also, a permanent-magnet loudspeaker is used, and a filter choke is used in place of the field coil shown in the diagram.

Some manufacturers have built a 16-inch television receiver using the basic 630TS circuit. In these sets, different deflection yokes are used, and instead of a single rectifier tube, there is a voltage-doubling arrangement to give a high voltage of 12,000 or 13,000 volts.

The foregoing discussion of the RCA set is quite brief. Complete details on the operation of each of the circuits will be given in your later study Lessons. If there are any points that you do not understand now, they should be cleared up when you reach the proper point in your studies. At that time, it would be well for you to go back over this description again to tie together the facts you have learned.

LEARNING THE CONTROLS

Now that you have had a brief technical description, we shall assume that you have a set of this type before you. If this is your own receiver, you will already be familiar with the controls on the front panel. However, we shall assume that this is a receiver that you have just obtained for practice purposes and shall give details on its operation.

You should always read the manufacturer's instruction booklet that accompanies the set, because it contains complete information on the proper adjustment of the operating controls on the front panel. The semi-adjustable (non-operating) controls on the back of the receiver are normally set up to give the proper picture size and positioning at the time the receiver is installed, and will not require another adjustment for a fairly long time. However, you need to know what each of these controls does, so that you will know just what adjustment is needed if you find a set having a defect that could be caused by a misadjusted control.

This set was originally shipped with the picture tube removed, so the serviceman had to install the picture tube and to place the control knobs on the set. However, we shall assume that you have a set with the tube already installed—if you do happen to get a new one without the tube, have a serviceman assist in this installation and in the initial set-up of the set.

With the controls at the rear properly set, the operation of the receiver is simple. A 300-ohm transmission line should be connected to the antenna terminals of the set, and the line cord should be plugged into a power outlet. With the set adjusted so that it is in proper operating condition, you need to adjust only the controls on the front panel. The positions of these are shown in Fig. 23.

The on-off switch is on the Volume control, so turn the Volume control to the right to turn on the set. Wait for a minute or two to allow the set to warm up. As soon as a visible raster appears on the screen, check the setting of the Brightness (brilliancy) control by turning the Contrast control (called "Picture" control in Fig. 23) all the way to the left, then turn the Brightness control until you can just see illumination on the picture tube. Tune in the station you want by rotating the Selector switch to its channel, then adjust the Fine Tuning control (the knob around the Station Selector switch) for clearest sound, with the Volume control turned up reasonably high. When the sound is at its clearest, you can adjust the volume to suit yourself with the Volume control, then adjust the Contrast control for best picture.

To learn just what the controls on this set will do, you should experiment with them. The best time to do this is when one of the local stations is transmit-
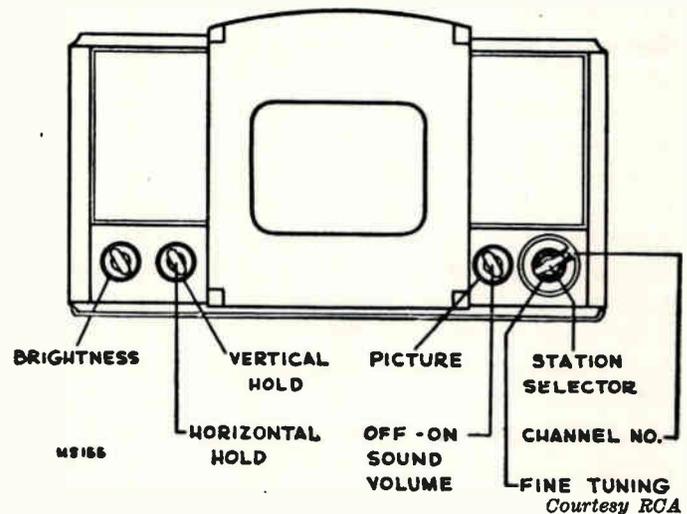

FIG. 23. This front view of the RCA series identifies the various operating controls.

ting a test pattern. Since the test pattern is a fixed picture, it makes it much easier to tell just what the controls do. Each station has its own test pattern; some give more information than others. A group of typical test patterns is shown on pages 44 and 45 of this workbook. We shall refer to these throughout the rest of this section.

The test pattern at A (refer to pages 44 and 45 whenever we mention test patterns) is a "perfect pattern." No set is likely to reproduce a pattern this well. However, the more nearly perfect the repro-

duction, the better the set adjustment. Since the test patterns used by your local stations may not look at all like the one at A, you will have to become familiar with the patterns of your local stations to be able to judge what represents normal reproduction.

The test pattern at B (page 44) shows too light a picture, and the one at C shows too dark a picture. A light picture is caused by too high a setting of the Brightness control or by a low setting of the Contrast control (or both). A dark picture is also caused by misadjustment of either one or both of these two controls.

We gave the correct procedure for adjusting the Brightness control at the beginning of this section—you turn the Contrast control down, then adjust the Brightness control until you can just begin to see light on the face of the tube, and then bring the Contrast control up to a normal setting.

This procedure can be used only when the video amplifier is a.c. coupled, as it is in this receiver. If it is d.c. coupled, you cannot use this method, because then the tube remains lighted until a signal is tuned in, and the signal drives the average brightness level down. In that case, it is necessary to adjust the Brightness and Contrast controls at the same time until you get the best picture.

The most obvious indication of a misadjustment of the Fine Tuning control is a distortion in the sound. However, a misadjustment in one direction will cause sound bars to show up in the picture as in the test pattern at D (page 44). These are a series of more or less horizontal bars that vary in number in step with the audio modulation. When a test pattern is tuned in, the audio modulation is usually a fixed tone, so there will be a fixed number of bars. Multiplying the number of visible bars by 60 will give the approximate frequency of the tone. In general, if the set is tuned for best sound, and if it is in proper alignment, the picture should be at its best also.

Two other controls on the front panel of the set are the Vertical Hold control and the Horizontal Hold control.

These two controls set their respective sweep oscillator frequencies so that these oscillators will lock in with the synchronizing pulses transmitted by TV stations. If the controls are not set properly, or if their oscillator frequencies have shifted outside the normal holding range, the picture may tend to run either horizontally or vertically.

When the set is out of horizontal synchronization, the picture will tear up as in the test pattern at E (page 44). Try turning the Horizontal Hold control. You will probably find that, if you are listening to a nearby station, you can turn the Horizontal Hold control throughout its range without the picture's tearing up at all. On a very weak distant signal, you

may find that near one or the other extreme, or both, the picture does tend to fall out of synchronization. If so, set the hold control at a half-way point between these extremes.

If you cannot get the picture to fall out of horizontal sync, or if the front-panel hold control cannot bring it back into sync, then an adjustment of the Horizontal Frequency control on the rear of the set will permit either condition. We will describe this adjustment among those made by the rear-chassis controls.

When the Vertical Hold control is far out of adjustment, the picture will run rapidly up or down. When this happens, you will see a large number of pictures one on top of the other, much as is shown by the test pattern at F (page 44). As you bring the Vertical Hold control nearer to the correct adjustment, you may find a condition such as is shown in the test pattern at G, in which you have a picture that drifts slowly up or down. With this control properly adjusted, the picture should drift upward and then lock into position. You will find that the Vertical Hold control can be turned a short distance before the picture runs, but that it is possible to make the picture run either up or down, depending on the direction in which you rotate this control. Try it. Then, run it through its range to find the points at which it can be locked in satisfactorily.

Experiment with each of the other controls on the front panel to find out exactly what each one does. Pay particular attention to the effect on the test pattern, as this will be your most accurate guide of proper and improper adjustment.

Non-Operating Controls. There are a number of controls on the rear of the set that require occasional adjustment. The position of these controls is illustrated in Fig. 24. The effects of each misadjustment can be seen from the test patterns on pages 44 and 45, to which we will refer.

At the extreme left, when facing the rear of the set, is the Horizontal Centering control. Misadjustment of it will cause the picture to move from left to right. Typical examples of such misadjustments are shown in the test patterns at J and K.

The Vertical Centering control moves the picture up or down; typical examples of misadjustment are shown in the test patterns at H and I.

Experiment with these two centering controls to be sure you understand exactly what they do. They move the picture on the face of the tube with respect to the mask in front of the tube, so by proper adjustment of the two controls, the picture can be correctly centered in the viewing area.

The next control is the Focus control. An improperly focused test pattern is shown at P (beside A on page 44 for comparison). If the ion trap and the

focus coil have been properly placed on the neck of the tube in the initial installation, this control should make it possible to reduce the spot size to give maximum detail. Experiment with this control while viewing a test pattern. Also, turn the Contrast control all the way down and the Brilliancy up so that you can just see the raster, and adjust the Focus control. In both instances, you will notice that the lines in the image become finer and the detail more


NOTE - T108 PHASE ADJ. IS UNDER CHASSIS
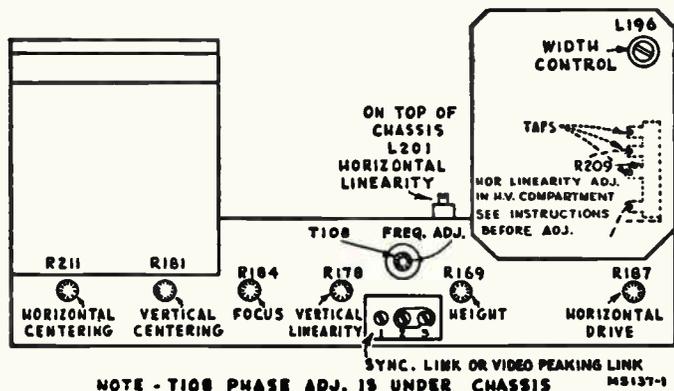
Courtesy RCA

FIG. 24. This view of the rear of the chassis of the RCA series identifies the non-operating controls.

definite as the Focus control is brought to the correct point. It may be that you will be unable to get an absolutely accurate adjustment of the focusing over the entire picture area. In such cases, it is usually desirable to get maximum detail near the center or the upper half of the picture. However, if there is any extreme in the focusing over the picture area—that is, if it comes into good focus at some points but very poor at others, it may mean that the focus coil is not correctly adjusted. We'll describe this adjustment later.

There are two controls that are to be used in conjunction with the Horizontal Hold control on the front panel of this set. When the frequency of the horizontal sweep oscillator drifts so far that the hold control will not lock it in properly, the Frequency Adjustment control T108 on the chassis apron (just above the small panel with the three terminals on it) must be adjusted. On the 630 chassis, the link between two terminals on the three-terminal panel must be between terminals 2 and 3, as shown in Fig. 24. However, on the 8TS30, and perhaps on other sets, this link panel is used for other purposes, and the position of the link is not critical to the horizontal adjustment.

To adjust the horizontal sweep oscillator when the Horizontal Hold Control does not lock it in properly, set the Horizontal Hold control on the front panel to the extreme end of its range at which the picture falls out of sync. Then, turn the frequency-adjusting thumb screw on T108 until the picture locks into synchronization. When it does lock, try the Hori-

zontal Hold control throughout its range. It should be possible for it to hold on to the picture throughout almost its entire range, and if the picture is strong, it may hold throughout its entire range.

When the picture has been locked into horizontal synchronization by adjusting this screw, you may find that a dark vertical bar about one-half inch wide appears in the picture area, as in the test pattern at R on page 45. When this occurs, the Phase Adjusting control must be turned until this blanking bar moves off the right-hand edge of the picture. This phase adjustment is underneath the chassis and is on the opposite end of the transformer on which the Frequency Adjustment control is located. This set is unique in that there are plates in the bottom of the cabinet that can be removed to permit access to the underside of the set without taking it from the cabinet. This access to the bottom is necessary because of the peculiar way in which the picture tube is mounted—it is supported by both the cabinet and the set. Hence, when the set is removed from the cabinet, there is no very convenient way of supporting the tube. (In the next workbook, we will tell you how to make a support so that you can work on this set out of its cabinet.)

By removing the bottom plate that is nearest the rear center of the set, it is possible to reach the Phase Adjusting control. As mentioned before, this control is adjusted until the vertical blanking bar disappears off the right-hand edge of the picture. It is possible to hit an unfavorable condition in the adjustment of this control where ripples appear in the picture. The screw should be turned clockwise away from this unstable position. With the screw in the proper position, it usually extends beyond the bushing about one-half inch. You will probably have to have someone else watch the picture while you make the adjustment because of the position of this control. Fortunately, this is an adjustment that rarely needs to be made.

The size of the picture is adjusted by the height and width controls. The height control is on the rear apron of the set chassis, and the width control is within the high-voltage compartment at the right of the chassis. It is reached through a hole in the shield that surrounds this compartment, and can be adjusted with an insulated screwdriver.

The effect of pictures that are too wide, too narrow, too high, or too short is shown in the test patterns L, M, N, and O.

However, a simple adjustment of the height or width control in a set with electromagnetic deflection gets into difficulty because this changes the wave shape of the sweep voltage in such a way that the picture is made non-linear. Vertical non-linearity is shown in the test pattern at S, and horizontal non-linearity is shown at T.

When you attempt to adjust the height of the picture, you in effect change the shape of the sweep voltage by shifting the operating point of the vertical output tube to a different point on its characteristic curve. This could be corrected somewhat by shifting the operating point of the vertical output tube by means of the Vertical Linearity control. This control provides slight variations in the shape of the wave by shifting the operating point to different points along its curve. However, since the slope of the curve varies at these different points, and thus varies the effective gain of the tube, it is apparent that adjustments of the Vertical Linearity control affect the picture height also. Therefore these two controls are interrelated. Make the basic height adjustment by means of the Height control, and then vary the Linearity and Height controls together to get as near a linear picture as possible.

If these controls are in proper position when you start, you can vary one and then the other independently to see their effects, then it would be a good idea to throw them both out and to restore the picture to normal. Practice is highly important in teaching you how to adjust these controls as well as to show you what the picture looks like when they are out of adjustment.

The problem with horizontal deflection is even more complex. There is a Width control to set the width, but the amount of signal fed to the horizontal output tube is adjustable by means of the Horizontal Drive control, and the Horizontal Linearity control tends to straighten out distortion in the picture.

The Drive control determines the voltage on the grid of the output tube and thus affects the point on the trace at which the tube conducts. Clockwise rotation of this control increases the picture width, but at the same time crowds the right side of the picture and stretches the left side. The Width control increases the over-all picture width but tends to cause the right side of the picture to stretch slightly. Thus, it counteracts to a certain extent the effects of the drive control. The Linearity control counteracts the effects of both to a certain extent in that counter-clockwise rotation of the adjustment screw causes the second *quarter* of the picture to stretch and the first quarter to crowd.

Experiment with each of these controls individually to see just what effect it has on the picture. Restore each carefully to its original setting before experimenting with the next one. Finally, to adjust them all to the proper setting, you should turn the Horizontal Drive control clockwise as far as possible without causing crowding of the right side of the picture. This position provides maximum high voltage. Since it affects the high voltage, you probably will notice a change in the brightness of the picture. Next, adjust

the Width control until the picture just fills the mask horizontally. Finally, adjust the Horizontal Linearity control until the test pattern is symmetrical from left to right. A slight readjustment of the Horizontal Drive control may be necessary when the Linearity control is moved. If repeated adjustments of the Drive, Width, and Linearity controls fail to give the proper horizontal linearity, it may be necessary to move the tap on the damping resistor R209, which is in the high-voltage supply in the position indicated in Fig. 24. However, this latter is an exceedingly rare adjustment. Ordinarily, it needs to be made only when the yoke or the horizontal output transformer are changed for different types.

The foregoing completes the adjustment procedure on this set with the exception of the adjustment of the deflection coils, focus coil, and ion trap on the picture tube, and, of course, the alignment of the set. The alignment we shall leave for another text, but the adjustment of the coils and the ion-trap magnet is given in another section of this book.

REMOVING THE PICTURE TUBE

When this set is shipped from the factory, the picture tube is not in it. In addition, whenever the set is to be taken out of the cabinet to be serviced, the picture tube must be removed first. The picture tube must, of course, be put back in the set when the repair has been made and the set is returned to the cabinet. Hence, it is important for you to learn how to put in and take out the picture tube.

The cabinet of the table model is shown in Fig. 18. We shall describe the method of getting the set in and out of this cabinet. However, if you have a console model, there will be some differences in the method, and the manufacturer's manual should be consulted.

The table-model cabinet comes apart in a rather unusual way. The center section of the *top* of the cabinet comes off, then the front panel that has the protective glass and the picture mask will come off the front of the cabinet. Both these panels must be

TO REMOVE CABINET TOP, TAKE OUT THESE SCREWS & SLIDE TOP BACK
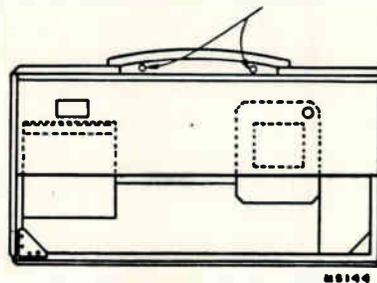
Courtesy RCA

FIG. 25. The screws indicated here must be removed before it is possible to slide the top center portion of the cabinet back and thus release it from the front of the cabinet. When it is released, it will lift off, exposing the picture tube directly underneath it, and much of the set. A great deal of the service work on this set can be carried on through this cabinet opening.
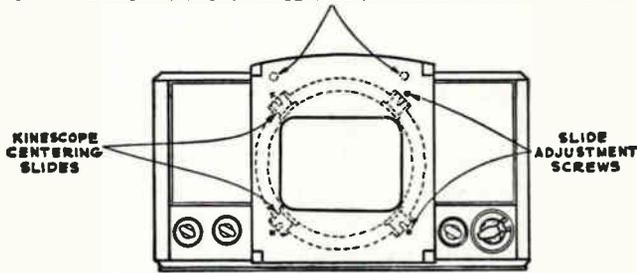
FIG. 26. The front panel is held to a bridge inside of the cabinet by two screws. When these are released, the front panel can be tilted forward and lifted up. When the front panel and mask attached to it have been removed this way, you will then see the face of the picture tube, which is held in position by centering slides. These slides are adjusted as explained in the text to hold the picture tube in place.

removed before the picture tube can be removed or installed.

Since this receiver is quite heavy, it is necessary to support it on a firm work-bench while you are working on it. To take the top section of the cabinet off, turn the receiver around so the back is facing you as in Fig. 25. In the center, under the curved top section, as indicated here, are two metal brackets that have screws passing through them. Removing these screws releases the rear edge of the top center section. This curved top section can then be pulled straight back. Pulling on it carefully releases two metal "fingers" from a slot in the front panel, and the top can be lifted straight up and away from the set. Taking the top off this way discloses much of the interior of the set and all of the coils associated with the picture tube. A great deal of the servicing of this set is done through this opening or by removing the bottom plates from the cabinet, rather than by taking the set out of the cabinet.

To get the picture tube out, it is necessary to remove the front panel also. With the top off, you will find that there is a wooden bridge between the remaining top sections at the front, to which the front panel is fastened by two wood screws. These screws face inward—they are inside the cabinet, and can be reached only by taking the top section off. When these two screws have been removed, the front panel will tilt forward slightly and can be lifted up so that it is released from a groove at the bottom front of the cabinet. When the front panel is taken away, the safety glass and the mask come off with it. The tube face is then completely exposed.

The front end of the picture tube is supported in an opening in the rest of the front of the cabinet by means of four supports that are called centering slides. The positions of these supports are shown in Fig. 26.

If a tube is in the set and is to be removed, be sure the set is not plugged into a power outlet. Next, the protective back should be removed from the cabinet so that it will be easier to unplug the picture-tube socket. Then, the ion-trap magnet (on the neck of the tube just above the base) is slid off the base end of the tube. This ion-trap magnet may be held on by clamps; if so, the thumb nuts are loosened enough to allow the magnet to slide off. The high-voltage connector in the side of the large funnel of the tube is then unplugged. The top two of the centering slides are released by unscrewing the bolts that hold them to the cabinet. Just release them; you do not need to take them out. You should now be able to withdraw the tube by grasping it as shown in Fig. 27. Be sure you wear goggles and gloves, and observe the other safety precautions given earlier in this text.

When the tube has been completely removed, place it face down on some soft material in a place where it will be completely safe—where it cannot fall or be accidentally knocked over by anyone.

REMOVING AND REPLACING THE CHASSIS

Once the picture tube has been removed, it is possible to remove the set chassis. Pull off the knobs that are on the front controls, then remove the five bolts under the cabinet that hold the chassis in place.

When these bolts have been removed, examine the back of the cabinet. On several cabinet models, there is a triangular metal corner brace in the left rear corner of the cabinet. This brace is necessary to keep the cabinet rigid. To get the set out when this brace is in place, slide it over to the right, then rotate the set or swing it around so that the left rear corner comes out first. If you do this properly, this corner of the chassis will clear the brace and the set can be turned partly sideways so that it can be slid out of the cabinet. Don't remove this cabinet corner brace.

To install the set in the cabinet, reverse the fore-
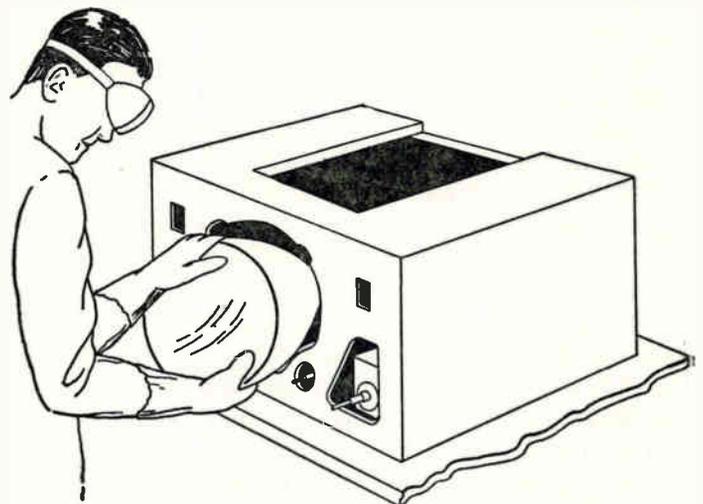
FIG. 27. This shows how to remove the picture tube from the cabinet. It is necessary to take the picture tube out before it will be possible to take the chassis from the cabinet in the RCA series. Protective gloves and goggles should be worn when handling the picture tube.

going processes. Insert the set in the cabinet with the right-hand section first, then swing it around into place so as to clear the corner brace.

With the chassis in place, insert the bolts through the bottom of the cabinet to hold it in position. The knobs can then be put on the control shafts.

REPLACING THE PICTURE TUBE

To install the tube, insert it in the front of the cabinet so that the neck goes through the deflection yoke and the focus coil. Do not put any pressure on the tube neck—support the weight of the tube entirely from the front and slide it into position. If it tends to stick at all, the focus coil and deflection yoke are probably not aligned. In such a case, loosen the adjusting screws that hold the focus coil. These are shown in Fig. 28. Release these wing nuts so that the focus coil can be moved, and thus can be aligned with the deflection yoke. As the tube is put into position, the high-voltage contact that is in a recessed well on the side of the tube must be approximately on top of the tube.

However, you will determine the final position of the tube by means of the ion-trap flags. As you look at the gun structure of the tube, you will see that the second cylinder from the base inside the glass neck is provided with two small metal flags, as shown in Fig. 29A. The picture tube must be installed so that the two flags are in the position shown in this figure, when seen from above. As you put the tube into place,
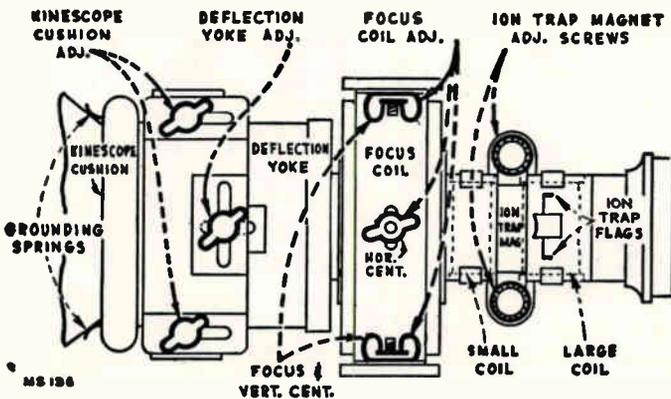
FIG. 28. Here are the adjustments for the deflection yoke, focus coil, and ion trap on the picture tube neck in the RCA series.

the base of the tube should protrude about two inches beyond the focus coil. If the tube sticks or fails to slip into place smoothly, investigate, and remove the cause of the trouble. Do not force the tube.

Slip the ion-trap magnet onto the neck of the tube while you support the weight of the tube with one hand under the front of the face. The ion-trap magnet on the early models was an electromagnet containing two coils. If this is the type you have, place it on the

tube so that the large coil is directly over the ion-trap flags, as shown in Fig. 28. If you have an ion-trap magnet that uses permanent magnets, of the style shown at B in Fig. 29, then it goes on in much the same way, with the larger magnet directly over the ion-trap flags. Connect the tube socket to the base, then push the picture tube into the set until the face of the tube protrudes approximately one-quarter of an inch outside the front of the cabinet.

If you have not moved the two bottom centering
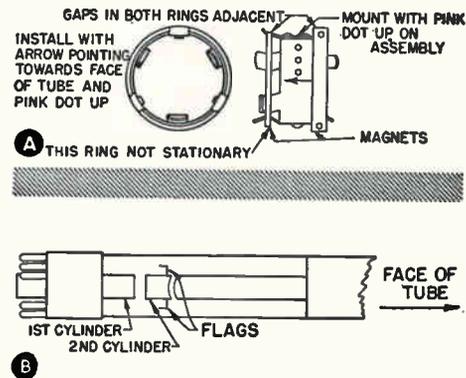
FIG. 29. The ion trap shown above should be centered over the ion-trap flags shown at B. From this position, the ion trap is moved back and forth and rotated for brightest raster, as explained in this text.

slides, you need to move only the top two until the tube face is held securely. Wipe the tube face and the front panel safety glass clean of all dust and finger marks with a soft cloth moistened with "Windex" or a similar glass cleaner.

Re-install the cabinet front. Slip it into the slot at the bottom and then push it back to where you can fasten the two screws to it through the wooden bridge above the two top centering slides. With the front panel in place, slip the picture tube as far forward against this front as possible. Next, slide the picture-tube cushion firmly up against the flare of the tube and tighten the adjustment wing screws. This cushion is in front of the deflection yoke, and its adjusting screws are shown in Fig 28. When the cushion is up tight against the tube, slide the deflection yoke as far forward as possible. Connect the high-voltage lead to the second-anode socket.

You have now installed the tube, and are ready to carry out the adjustments of the focus coil and the ion-trap magnet. You would use the following procedure even if the tube remained in the set and you were merely experimenting with these adjustments. In the latter case, all you would have to do would be to take the top off the cabinet to reach the adjustments shown in Fig. 28.

To make the proper adjustment of the focus coil and ion trap, connect the set to power and connect an antenna. Turn the power switch to the on position,

the Brightness control fully on, and the Picture or Contrast control fully off or counter clockwise as you face the front of the set.

Starting with the ion-trap magnet in the initial position with the large magnet over the ion-trap flags, move the ion trap forward or backward, at the same time rotating it slightly around the neck of the tube, until you see the brightest raster on the screen. Tighten the trap-adjustment thumb screws enough to hold the trap in this position, but leave them still free enough to permit further adjustment of the trap. Reduce the brilliancy by turning the Brightness control down until the raster is just slightly above average brilliancy. Adjust the Focus control on the chassis rear apron until the line structure of the raster is clearly visible. Now readjust the ion trap for maximum raster brilliancy. The final touches on this adjustment should be made with the Brightness control set at the brightest level at which good line focus can be maintained.

It is rather necessary in the initial adjustment of this ion trap to get a raster as quickly as possible to avoid damage to the picture tube. However, once you get a clear raster, you can take your time about getting the adjustment for maximum brilliancy. As a warning—be sure you do not touch the high-voltage lead during any of this process—it is insulated, but if there is any break in the insulation, you can get a shock. Also, you may get a small shock even through the insulation on a lead carrying a voltage of this amount.

To check on the positioning of the focus coil, particularly if it was moved when the tube was inserted, turn the centering controls to their mid positions. These are on the rear apron of the set. Examine the raster. If a corner of the raster is shadowed, it indicates that the electron beam is striking the neck of the tube. Loosen the focus-coil adjustment wing nuts and rotate the coil about its vertical and horizontal axes until the entire raster is visible, is focused, is approximately centered, and has no shadowed corners. Tighten the focus-coil-adjustment wing nuts with the coil in this position.

Now, examine the raster again. If the lines of the raster are not horizontal or squared with the picture mask, rotate the deflection yoke until they are. Tighten the yoke adjustment wing screw.

You should now be able to get maximum focusing by adjusting the focus control on the rear apron of the set. This completes the adjustment of the coils on the tube neck.

In your first attempts at making this adjustment, it is advisable to move only one thing at a time—experiment with the ion trap out of adjustment, then the focus coil, then the deflection yoke. Then, you can try combinations of misadjustments, to see the effect

on the raster. Remember, that in adjusting the ion trap, you should always start from the proper initial position, and then move for maximum brilliancy. This correct initial position must be reached quickly to avoid damage to the picture tube.

Sometimes you can get a better average focus by moving the focus coil back and forth along the neck of the picture tube while adjusting the focus control. The combination of the two adjustments may give a better focusing, but the final adjustment of the focus coil should leave the raster approximately centered.

STUDYING THE SET

Now that you have become reasonably familiar with the adjustments on this set, the next step will be to become familiar with the set itself. In order to carry out the experiments in the next workbook, you will have to have the set outside the cabinet.

Before attempting to open the cabinet and remove the receiver, always remember to unplug the power cord, and to wait several minutes for the filter condensers to discharge. Also, when you have the set out, observe all the safety precautions that were given earlier in this workbook.

The exact procedure used in removing this set from its cabinet has been given in the preceding section. As you will observe, the picture tube must be removed before the set can be removed from the cabinet. However, before doing this, it might be well for you to remove just the top of the cabinet, and to examine the set carefully from this position. Use Fig. 30 to localize sections and parts. (Notice the position of the loudspeaker; in some models it is on the other side of the picture tube.) This examination will give you a good idea of how much servicing can be done without removing the set from the cabinet insofar as replacing tubes, etc. is concerned.

Then, turn the set up on its back, using a soft cloth to protect the cabinet. Don't turn the set completely upside down, just stand it on the back or on one of the sides. In this position, it will be easy to remove the bottom plates from the cabinet and you will find much of the set exposed. Study the set to see just how much of the bottom is reachable this way.

Finally, actually take the set out. To do this, you should first remove the knobs from the front panel. The knobs are held on the shafts by springs, so you can pull them off. Be careful to see that the retaining springs do not leap from the knobs because they are easily lost.

With the knobs off and the set unplugged, you can now remove the top and the front of the cabinet, and take out the picture tube. Follow the instructions given in the preceding sections carefully.

Then, take out the four screws holding the receiver
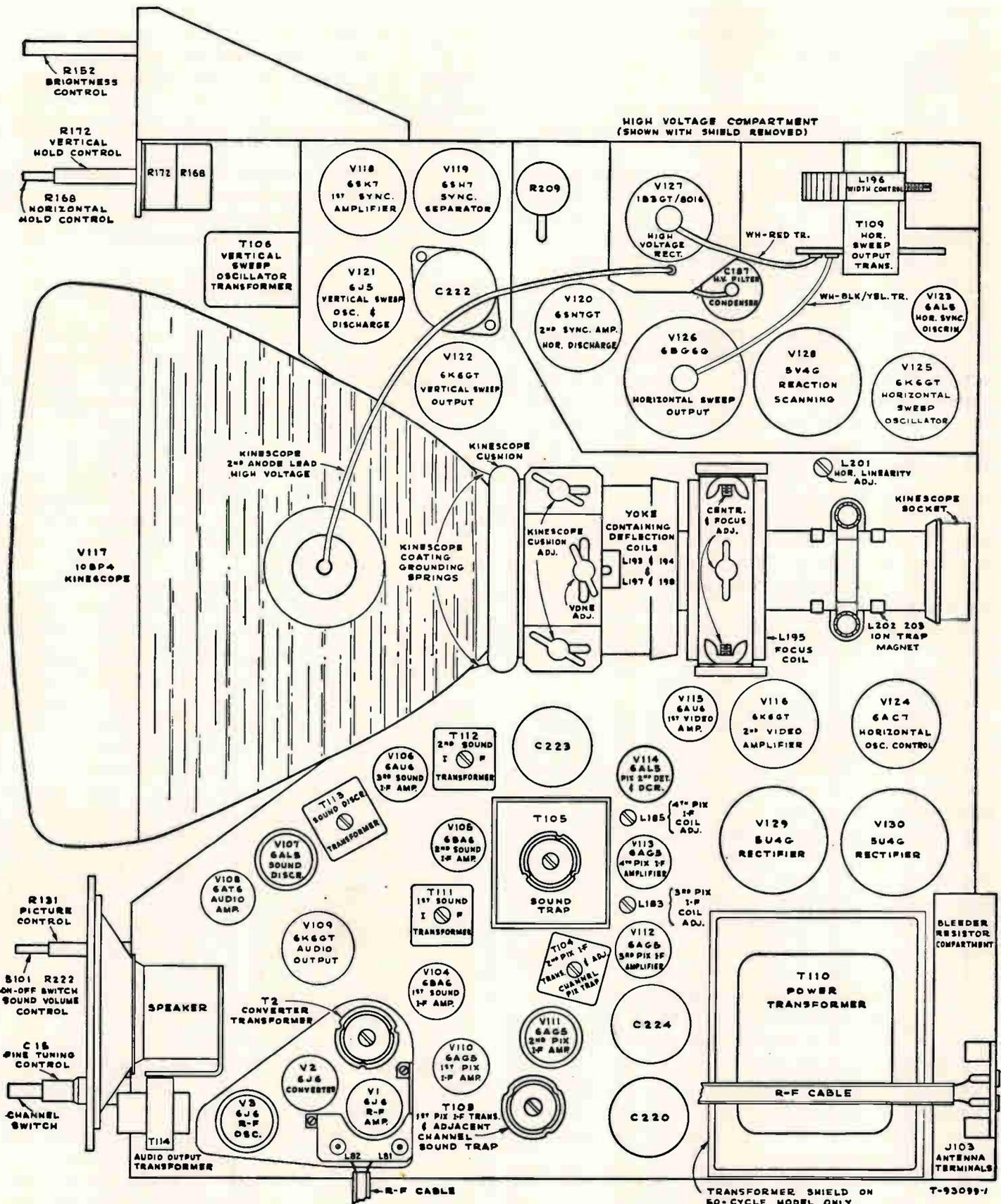
FIG. 30. This is a top view of the RCA series. Learn the locations of the various tubes, and their functions. Notice that the alignment screws are identified here.

in the cabinet. With a table model set, you can do this most easily simply by moving the cabinet to the edge of a table so that one side projects in a way that will permit you to reach two of the screws and remove them. After removing these screws, you can shift the cabinet around until the other side projects so that you can reach the other two screws.

With the screws out, slide the set out as described in a preceding section, so that it will clear the corner cabinet support.

With the set out on the workbench, examine it carefully. Leave the picture tube out. Pay particular attention to the top of the set first, and learn the locations of each tube, using Fig. 30 as your guide. Notice the functions of the tubes, and refer to the large schematic diagram (Fig. C) to study just how the circuits are arranged.

When you stand the set up on the rear apron to examine it underneath, make full use of your schematic and block diagrams, and learn to find your way around in the circuits to the best of your ability. Try picking out parts on the schematic diagram, and then locating these parts from their connections to tube sockets or to other parts you can identify. This will be valuable training for you. You can undoubtedly spend quite a number of evenings examining the set in this way.

It is impractical to have the set out of the cabinet with the picture tube in it and have the set in its normal position because there is nothing to support the weight of the tube. The neck could easily be snapped from the picture tube if you attempted this. In the next workbook, we will show you how to make a support for the tube so that you can experiment with the set.

As a serviceman, you may find sets of this kind for which you do not have supports. In such a case, the only position in which you can have the tube in the set is to stand the set on its rear apron. In this position, you can slide the tube down into the yoke, and allow the weight of the tube to be supported by the brackets holding the deflection coils. This isn't a very desirable method of operating the set. With the set in this position, be sure it is carefully braced so it cannot fall over.

Once you are reasonably adept at locating parts and circuits, you can put the set back in the cabinet and put the picture tube back in, using the procedures described in a preceding section.

This completes your study of the RCA model receivers in this workbook. Now it would be advisable for you at least to read through the other sections of this text to get a comparison of these sets and thus get a general idea of how TV sets differ.

Your next workbook will continue with the Practical Training Plan.
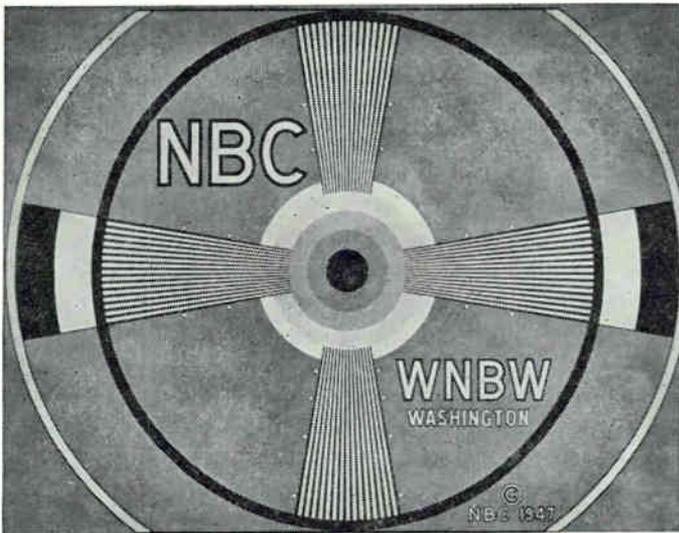
Courtesy NBC

A. This is the standard test pattern as it is broadcast by many stations.

Courtesy RCA

P. Out-of-focus condition.
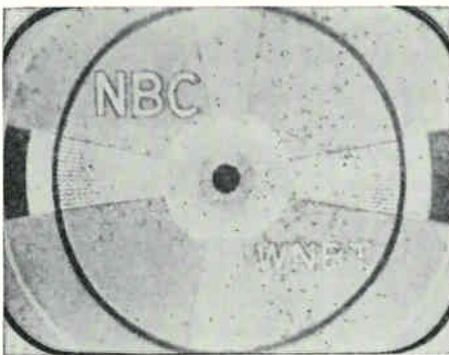
Courtesy RCA

B. A low-contrast, high-brilliancy picture.
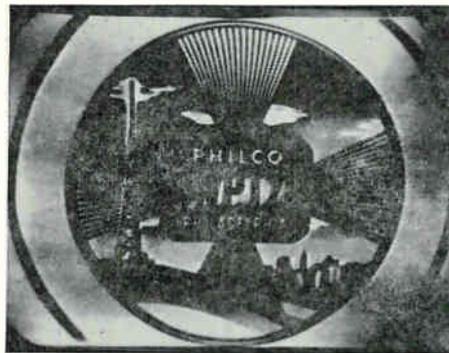
Courtesy Philco

C. A high-contrast, low-brilliancy picture.


NRI TV Lab. Photo

D. Sound bars in picture.

Courtesy Belmont Radio Corp.

E. Horizontal sync far out.
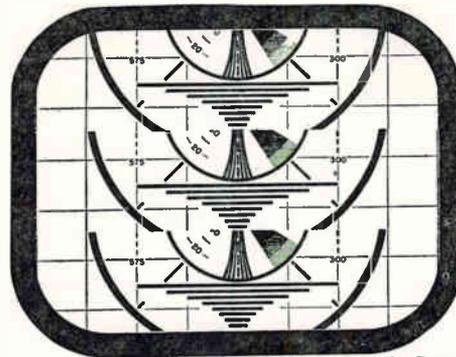
Courtesy Belmont Radio Corp.

F. Vertical sync far out.
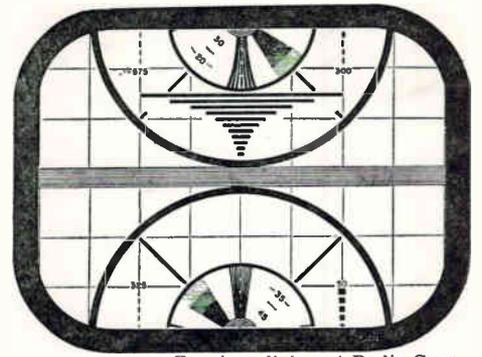
Courtesy Belmont Radio Corp.

G. Vertical sync slightly out.

Courtesy Belmont

H. Picture above center.
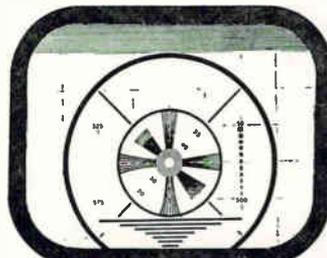
Courtesy Belmont

I. Picture below center.
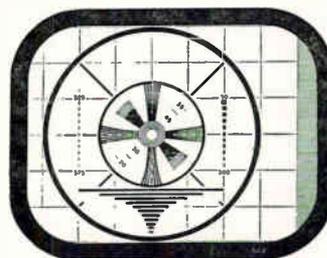
Courtesy Belmont

J. Picture to the left.
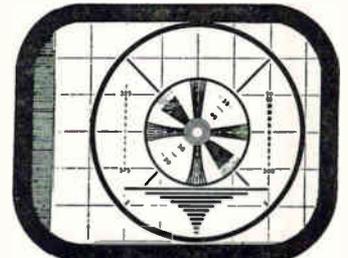
Courtesy Belmont

K. Picture to the right.

44
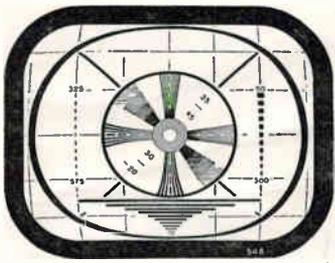
Courtesy Belmont
L. Picture too wide.
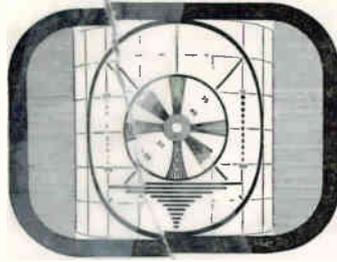
Courtesy Belmont
M. Picture too narrow
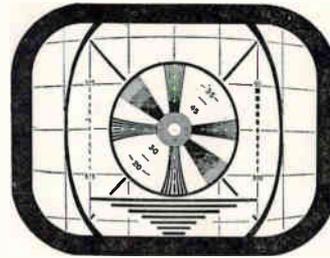
Courtesy Belmont
**N. Picture too high.**
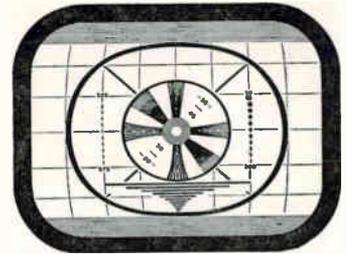

Courtesy Belmont
O. Picture too short.
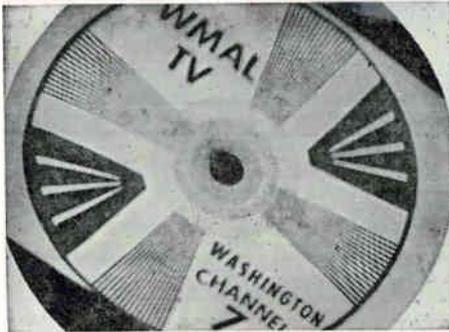
NRI TV Lab. Photo
Q. A tilted picture.
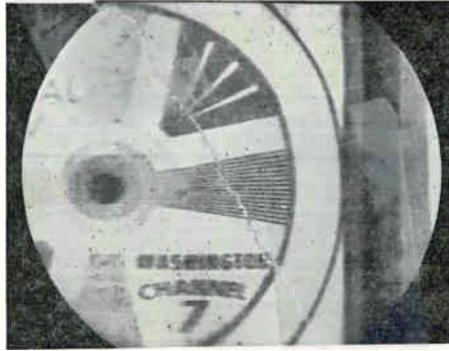
NRI TV Lab. Photo
R. Phase control misadjusted.
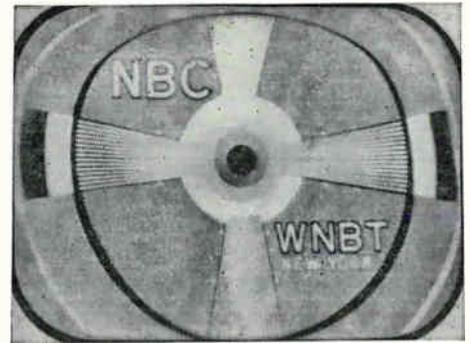
Courtesy RCA
S. Vertical non-linearity.
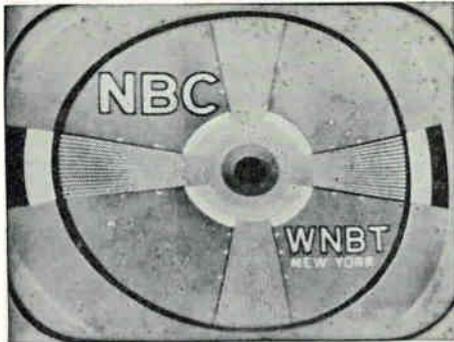
Courtesy RCA
T. Horizontal non-linearity.

Courtesy RCA
U. The lower left corner is shaded because of a misadjustment of the ion trap.