COLOR TV

A NEW WAY TO SERVICE

CARL BABCOKE

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INTRODUCTION

A RE YOU A PROFESSIONAL TV TECHNICIAN who realizes his time is too valuable to waste on nonproductive testing techniques? Then read on, for in this book, there will be *no* 1954 circuits to analyze and *no* transmitter I and Q vectors to confuse you. The troubleshooting methods recommended here are *practical* rather than *theoretical*, for they have been tested and refined in the tempering fires of actual home and shop servicing.

The main emphasis will be on fast (yet accurate) methods of localizing the trouble area; then, further tests pinpoint the defective *part*.

Electronic troubleshooting demands a series of questions and answers, with the purpose behind each question depending on the previous answers. It is quite confusing to list them all because of the multitude of possible variations. "Family tree" charts often clarify this confusion in the shortest time. We'll use such charts where needed. Where an adjustment sequence is given, the *reasons* for doing it that way will be stated so you can judge for yourself and need not follow blindly.

Since this is a book about *color* servicing, chroma symptoms and troubleshooting will be given first attention, with the problems peculiar to the b-w circuits studied later.

No attempt will be made to cover *all* makes and models, or to list *all* typical parts failures. These things have great value in their place, but right now we are concerned with repairing the "tough dogs" and one-time failures that rob of us of time and money. Only thorough and accurate methods will help.

Of course you and I never make stupid mistakes or waste valuable time, so for our horrible example we will invent an imaginary whipping boy. Let's call him Mr. Joseph Q. Bloe, of Bloe's TV Service. Joe is the casual type of technician who turns alignment screws just to see what happens, or he just might replace a flyback when the picture lacks contrast. He is not stupid or completely untrained, just sloppy and haphazard in his methods.

Now let's get started sharpening our troubleshooting skills and changing guesses into certainties.

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A NEW WAY TO SERVICE COLOR TV

Chapter 1

A Philosophy of Servicing Color

IT MAY SEEM STRANGE TO SPEAK OF philosophy in a technical book, yet one of the important requirements for effective troubleshooting is the right state of mind. We, as color TV technicians, will be steady and confident if we apply these three elements to our servicing problems:

The right state of mind.
The ability to reason and plan logically.
Knowledge of electronic circuit functions, and knowledge gained from the chassis under test.

The right state of mind is a composite of several qualities: the desire to do the job right, alertness, perseverance, curiosity, willingness to learn from mistakes, and mild optimism. **The ability to reason** is a talent given us at birth, but it can be cultivated and enriched. **Knowledge** is often easier to acquire than the other two, but it isn't of much use without them. A perfect technician should have the reasoning ability of a medical diagnostician, the watchful eye of a hunting Indian and the knowledge of a graduate electronics engineer! Balanced amounts of these three basics should produce in us a feeling of confidence that a reasonable solution to these color TV problems exists and we will find it!

The three levels of complexity in servicing techniques:
Easy tests, such as tube testing or replacement, visual symptoms from

the face of the picture tube and the use of hearing, smell and touch. **Moderately difficult tests,** such as measuring voltages, making simple adjustments and substituting parts.

Difficult tests, such as scope waveform analysis, checking sweep alignment curves, tests with heat and cold, high or low line voltage, and weak or strong signals.

Here are some hints from my personal Philosophy of Servicing:

1. *Listen* to the customer's description carefully. It may be worthless or valuable, but listen anyway.

2. *Try the easy things first.* Are there any tubes with red plates or unlit heaters? Do any of the parts or tubes run hotter or cooler to the touch than normal? Is there an acrid smell of a burned resistor, a tiny wisp of smoke from an overheated part, or the telltale odor of corona? Can you hear the crackle of the high voltage when it first comes on, or the snapping of an arc? If any of these simple tests show results, they will guide you to the source of trouble faster than a dozen scopes and meters.

3. *Play the percentages.* Each circuit has some parts that are more likely to fail than others because of their nature or the way they are used in the circuit. Check them first.

4. *Use decisive tests.* Whenever possible, use one test to verify the performance of an entire circuit.

5. *Multiply any indefinite tests.* Many tests are only partial ones; checking a coil or capacitor with an ohmmeter, for example. Nail down the diagnosis solidly by using two or three alternate but related tests. Is the picture tube what's causing slow warmup with screen color change? It could be, but it might be a chassis defect, too. Use a CRT checker *plus* chassis-voltage tests to clinch it.

6. *Use standards of comparison,* or guideposts, in judging performance of both b-w and color pictures. For example, use the crosshatch or color-bar patterns to eliminate outside variables such as antenna problems or station troubles.

7. *Buy good service data,* then improve it. No manufacturer or publisher can know what channels you use or their signal strength, so the dc voltages shown on the schematics are usually what would be typical with the set turned to a blank channel and the antenna removed. We are not interested in blank channels, so add in pencil to the diagram the dc and peak-to-peak voltages you measure on your strongest channel (after the set is repaired and working normally). It may not help you on this set, but it could be a goldmine on the next. Especially important are the voltages in the agc, video, first i.f. and sync stages.

8. *Read between the lines* of the service data. If a certain set had design problems, the next similar model may have a circuit improvement you can duplicate with little trouble but with great benefit. Go easy on making changes wholesale; the engineers don't goof that often.

9. *Parts tolerances* may add up wrong occasionally and require a value change. Vertical integrator resistors are a case in point. Vertical sync is the sum of many factors, and the easy way out of a soft hold is often to reduce the value of the integrator resistor. Limit yourself by this rule-of-thumb; never change the part to more than twice or less than one-half the original value. If you need more change than that, you have a faulty part to find, not to cover up with parts changes.

10. *Do what you know how to do* and have the test equipment to do it with. You may not have sweep-alignment equipment, but you *can* check for bad grounds or gassy tubes that temporarily change alignment. If you don't have the equipment to signal trace the i.f.'s, you *can* measure the dc voltages there with your vtvm. How much will a tube amplify without plate voltage?

12. *If you suspect it, check it.* Is the 3.58-MHz oscillator dead or weak? Don't guess, it's too easy to check. You wonder if the color killer is stopping the color; good guess, but disable it and be certain.

13. *Know when and how to experiment.* You should *not* turn i.f. or chroma alignment screws, but you *can* cup a thumb and forefinger around an unshielded coil and notice the effect of this change in alignment. Clip leads are handy and useful for many things, but a 2-foot wire in series with a small-value test capacitor may give you strange and unexpected results. A grid-return point or a cathode can usually be grounded for a short time without ill effects, but don't try this on a heater or B + circuit.

14. *Sleep on the problem, not the job.* Keep alert while you make tests, for some insignificant symptom may be the golden key to the solution. A good technician has been known to give up on a tough one only to find later that the trouble was in something he *thought* he had checked. When nothing seems to work right and your tests are barren, put the job aside for a time and work on something else; you may be repeating a foolish mistake and need a break. Or get a good night's sleep and try it again next morning.

15. *Suspect technician failure,* if all else fails. Of course, *you* would never take a resistor off one terminal and solder it back on a different one by mistake, but Joe Bloe might. And neither you nor I with our 20/20 color vision would ever misread a color code and replace a 470K with a 470. Or would we? Review carefully all changes or previous repairs and check them against the schematic.

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16. *Don't let your test equipment mislead you.* Extension cables on the socket of the picture tube will blur both the color and b-w pictures. A mismatched test-jig yoke may ring or cause insufficient height or width. Analyze all such possible problems before you panic.

17. *Go back to fundamentals.* So the B+ is low. Okay, make a list of the *only* conditions that will cause this—low line voltage, transformer bad, weak rectifier, bad input filter capacitor or too-heavy load current. There just aren't any more, so it *must* be one of them.

18. *Ask for help.* Why waste valuable hours hunting an elusive problem when some friendly technician or distributor service manager may already know the solution? But just in case it is not a well known failure, make a few tests before asking. Even a top tech can't diagnose from thin air and suspicions.

These 18 tips deserve more than the short explanation just given, so watch how they keep turning up in the following chapters.

Chapter 2

What Test Equipment Do You Really Need For Color?

COLOR TV DEMANDS MORE EXACTING performance standards than does b-w, and we would logically expect the test equipment to be extensive and expensive. To a large extent this is not true. A well equipped service truck should already have a stock of tubes, a vtvm, tube and picture-tube testers, hand tools, an assortment of clip leads and a soldering gun. For field color servicing, we need to add only a good dot–crosshatch–color-bar generator, a degaussing coil and a gun-killer switch box.

I believe strongly in the keyed-rainbow type of color generator, rather than the NTSC type, for the keyed-rainbow (called color-bar generator from here on) will tell us more about receiver performance in less time than any other. In a later chapter, I'll analyze receiver performance with crosshatch and color-bar patterns. I think that will convince you of the instrument's accuracy and versatility.

Just any generator will not do all the tests we want to make, however; there are some definite minimum specifications. We need to know over-all performance, including the vitally important tuner and i.f. responses; this means the generator must have rf output on a regular TV channel. Further, this rf carrier should be precisely on the correct frequency. Our technically sloppy friend Joe would probably ask, "What difference does the frequency make as long as I can tune it in with the fine tuning?"
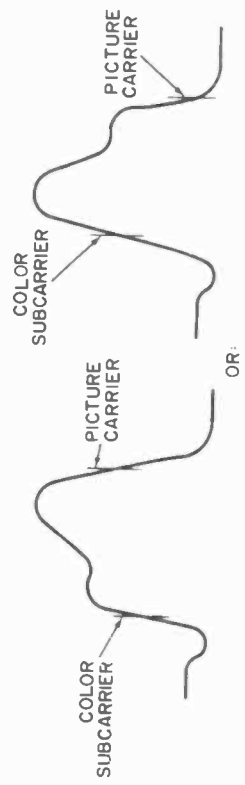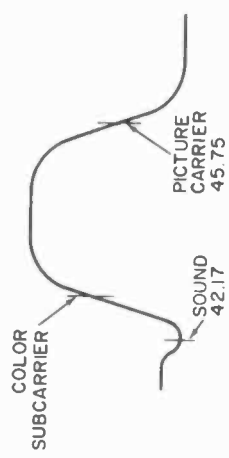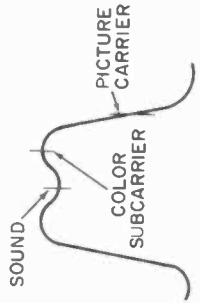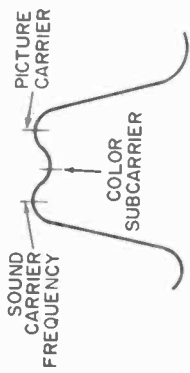
Fig. 201—Curves at left give the same overall alignment curve regardless of fine-tuning adjustment. At right, fine-tuning setting affects overall alignment and can spoil color picture.

Years ago I might have agreed with him, but a strange gremlin crept into the results of my i.f. alignment. At that time I was aligning color sets by inserting the sweep into the antenna terminals and was amazed to find an occasional receiver in which the fine tuning would change the shape of the overall alignment curve radically (as much as a two-to-one tilt). After much futile testing, I finally concluded it had to be in the tuner, so I sent it to a tuner-overhaul station. It worked fine when it came back. Okay, so the set worked now; but what had *caused* the effect? Much later and after inquiries, I found the answer in rf and antenna alignment. Fig. 201 shows how this happens. The carrier frequency of the generator gives us the same wrong results if it is not on the picture-carrier frequency for the generator channel. It will be impossible for us to judge color quality from the bar pattern if the carrier frequency is wrong. This phenomenon also explains the *only* reason we might have perfect color on one channel and very poor on another: The tuner alignment can be right for one channel and terrible for another.

It is also vitally important for the generator to have a 4.5-MHz sound carrier. Without such a carrier, it is impossible to determine the correct fine-tuning point. Color quality varies tremendously with the fine tuning, so tuning must be set correctly every time we judge color. We also need to check for beat patterns, and without the sound carrier there is no 920-kHz beat. This sound carrier does not have to be modulated, but for maximum usefulness, a switch should be provided to kill the sound carrier when necessary. If we are to use this to set 4.5-MHz traps, the frequency should be very accurate, preferably crystal-controlled.

What about separate vertical or horizontal bars for convergence? Years ago I liked this feature, but found it merely makes another non-essential step to slow me down. For example, when we bend a vertical bar, the horizontal bars at the top and bottom also move up and down. It is helpful to see all vertical and horizontal bars at the same time; none of the receiver adjustments are completely independent. We can easily ignore any bars we are not interested in at the moment.

Vertical and horizontal frequencies should be the same as transmitted ones. Many adjustments depend somewhat on frequency. Adjust to the wrong scanning frequencies and get a good convergence job and see how poor it becomes when you tune in a TV station.

A good generator should have:

1. Rf output on channel 3 or 4 (whichever is not used in your area) with accurate frequency.
2. A small, sharp dot pattern.

3. Sharp, narrow crosshatch lines, both vertical and horizontal.
4. Normally sharp color bars; 12 generated, each with 30° phase difference. Two will be in blanking, so only 10 will be seen on the picture tube.
5. An unmodulated 4.5-MHz sound carrier that can be switched off.
6. Horizontal and vertical scanning frequencies the same as the station's.
7. Horizontal and vertical blanking close to that of the station's so you can get an approximate idea of the picture size.
8. The 3.56-MHz color oscillator and 189-kHz oscillator for the vertical bars should be crystal-controlled so we can use the generator to adjust color locking.

Any additional features or functions are fine, but *not essential*.

If you do not own a good generator, check the one you intend to buy very carefully; you may have to live with it for a long time. Don't select one that will barely get you by now. Make sure it will still do the job after your experience broadens and you want more features or better accuracy. Check the specifications from the sales literature. If possible, try it out. Lock a receiver to a station signal, then connect the generator and tune in the receiver with the channel selector and fine tuning only. Did you need to adjust horizontal or vertical hold to make the pattern lock? You shouldn't have to. Does the generator drift so you need to retune in a few minutes? How long does the generator need to become stable from a cold start?

Some technicians prefer to use a station test pattern, rather than a generator, for convergence adjustments. I believe they are misguided in this. Though it will give perfect carrier and scanning frequencies, the station pattern has black lines on a white background, which is just the reverse of what is needed. At high brightness the white parts of a picture tend to bloom or expand. Thus more critical convergence is needed to minimize color fringing. Black is the absence of brightness, and any old sloppy adjustment will look good until the regular program comes on the air. We can't adjust any better than we can see, and a white line on black background lets us see best. Use the station pattern and b-w pictures in extreme emergencies. Don't depend on them for normal convergence.

Why carry a degaussing coil when virtually every set now has automatic degaussing? Have you ever seen automatic degaussing make the purity worse? I have (when there was a defect in it or in the rectifier circuit that feeds it), and external degaussing is a necessary factor to diagnose the problem. Also, there are thousands of sets without the automatic circuit. For those, external degaussing must be used.

Joe Bloe probably would disagree about a gun-killing switch box. "Why waste time hooking up all those wires? I just adjust with all the colors on, or maybe turn down a screen control once in a while." Of course, there are other ways of seeing just one color or more than one at a time, but a good switch box saves much time and trouble and usually allows us to converge better because we can see the pattern better. If
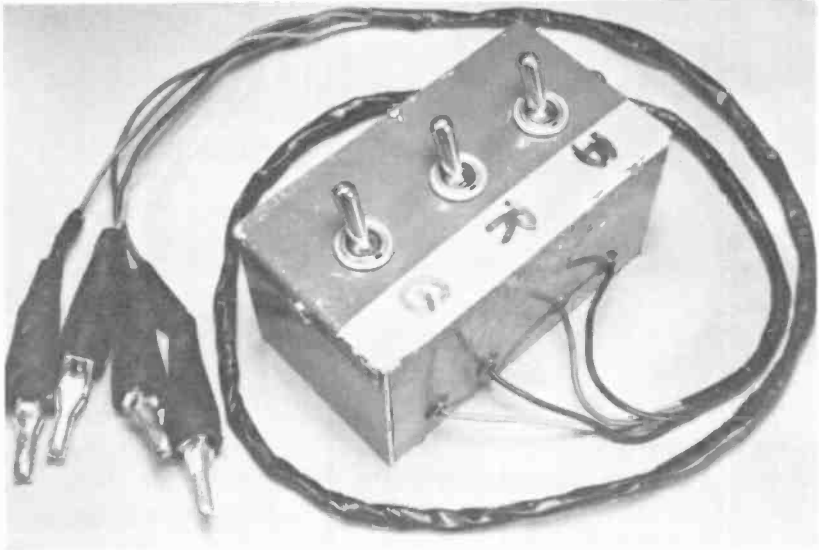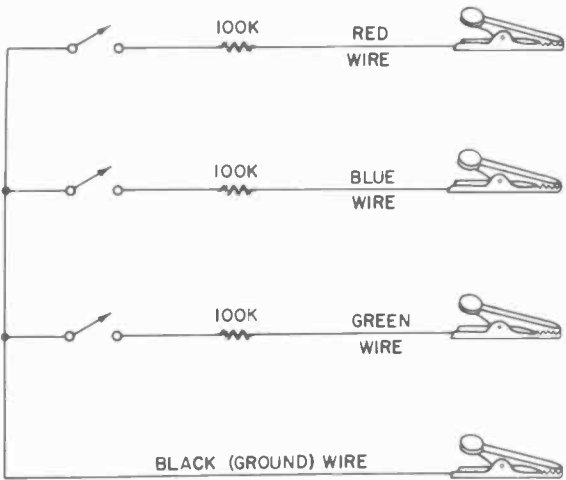
Fig. 202—Circuit diagram and photo of a home-made gun-killing switch box.

price is a factor, build your own. Fig. 202 shows the simple diagram and a picture of a home-made switch box—12 years old and still going strong.
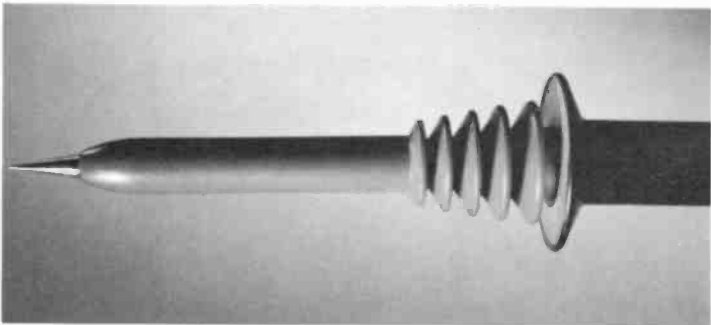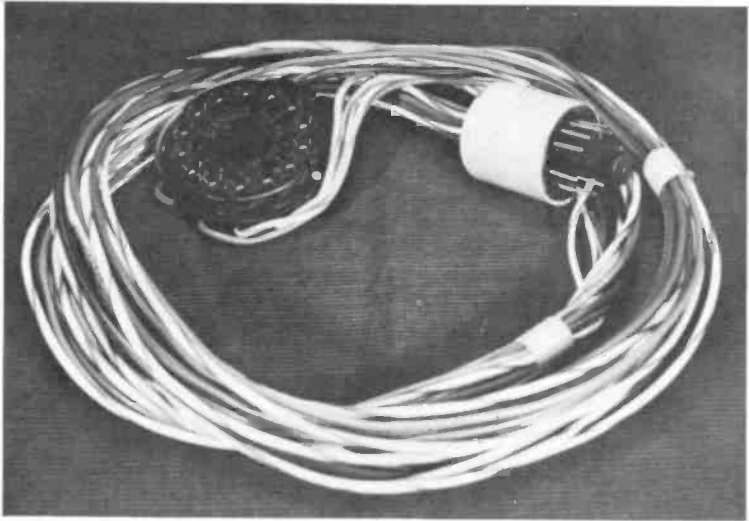
Fig. 203—Extension cables and a high-voltage probe are important accessories.

For effective shop servicing, we might add a wideband scope, a bias box, a color test jig, extension cables (Fig. 203), a high voltage probe, test sockets (Fig. 204—the octal with the resistors is for measuring regulator current), and complete alignment equipment, including the loads and modified probes specified by the manufacturers. Whether or not you service in the home is your own business, but unavoidable shop

repairs should be very few if you follow the troubleshooting rules and tips in the following chapters.
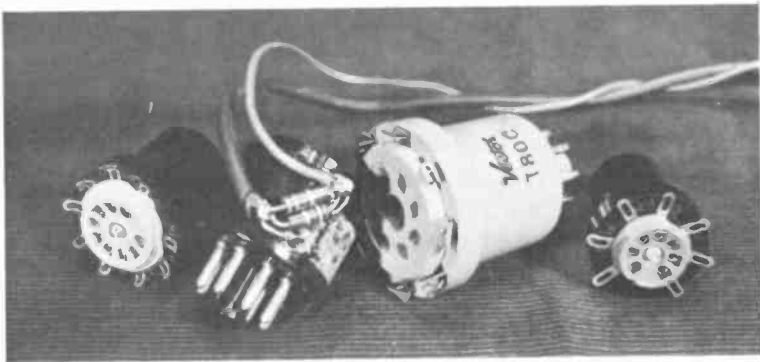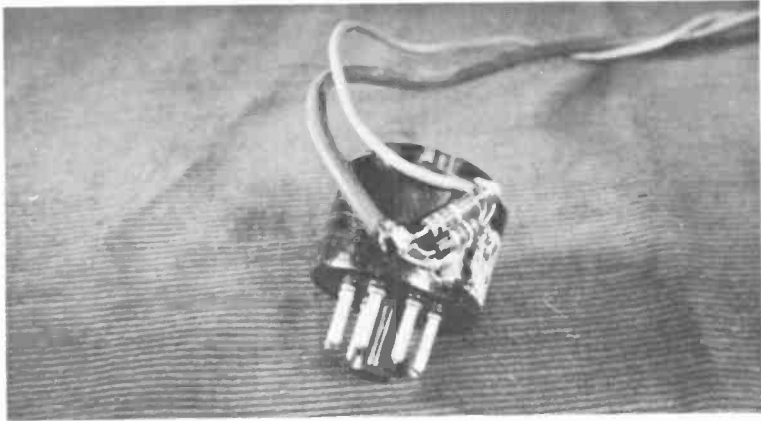
Fig. 204—Test sockets save many times their cost by reducing unproductive time.

Chapter 3

Visual Chroma Analysis: Eyeball Tests

D ID YOU FORGET YOUR COLOR-BAR GENERATOR on a call where the complaint was wrong colors? How can you tell if the tint is wrong or if one of the three colors is missing? Either defect will give false colors.

Don't give up yet. There's still the "poor man's generator": snow and b-w programs. Turn the color control up completely, adjust the color killer to show colored snow, tune in a blank channel and look at the "confetti." Can you see small specks of all three colors scattered at random over the screen? If so, the 3.58-MHz oscillator is running and all the demodulators are putting out a signal. A dead X or $R - Y$ demodulator will eliminate red specks from the snow, and a dead Z or $B - Y$ demodulator will stop the blue specks.

For a test that is similar but much more obvious, tune in a normal b-w program (leaving the color killer turned to give colored snow) and adjust the fine tuning slightly into the sound bars to make colored "flares" around any sharp, narrow vertical lines in the picture. Are there separate red and blue flares which appear magenta when viewed from a distance? If so, the 3.58-MHz oscillator and all the demodulators are working, but we can't be certain the color will lock or what the tint setting will be. Red flares without blue mean the Z or $B - Y$ demodulator is dead, and blue flares without red mean the X or $R - Y$ demodulator is not working. Check the tube or replace it, then inspect all the resistors in the defective demodulator.

The visual symptoms just given will be the same for any make or model, but from here on we must specify sets.

When the 3.58-MHz oscillator is dead, the older RCA sets show only purple wherever *any* color should be in the picture. This is true also of the previous test with the flares; in this case they would be purple, but a purple made up of red and blue together, and not separate red and blue flares one above the other. The color and fine-tuning controls work normally but the tint control has no effect. The color is weaker than it is with the oscillator working. Newer RCA chassis will
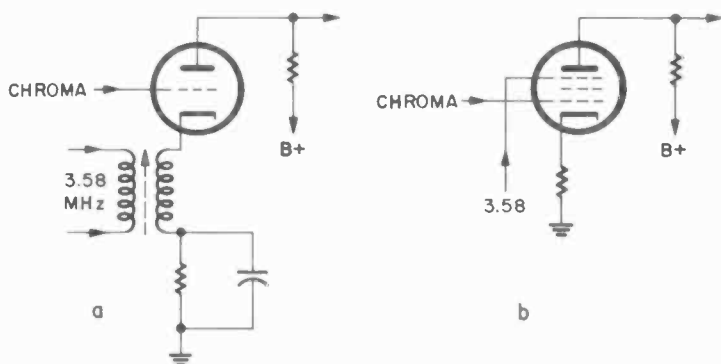
Fig. 301—These two demodulators act in opposite ways when the local 3.58-MHz subcarrier is lost. In the circuit in (a) plate current falls without 3.58, so plate voltage rises. Strong chroma signal lowers plate voltage slightly. Therefore, any chroma voltage creates negative-going output. Both X and Z demods cause less-than-background amounts of blue and red, and (since green is the negative sum of blue and red) a positive amount of green. These are inverted in the − Y amplifiers, so screen shows red and blue bars covering each other to make magenta wherever any color should be. In (b), plate voltage decreases, plate current is greater. Strong chroma increases plate voltage somewhat. Therefore, any chroma voltage creates positive-going output voltage. Both X and Z demods have a positive-going output and produce a negative amount of green. The − Y amplifiers invert these, so the screen shows green wherever any color should be.

show nothing but green under the same condition. Most Motorolas show purple, Admirals green. All Zeniths, G-E's with diode demodulators and RCA CTC19, CTC20 and CTC24 show no color if the 3.58 signal is missing. Remember all this the easy way: *The 3.58-MHz carrier is missing if the screen shows only one color, which is not changed by the tint control.*

Fig. 301 shows why *any* color can be seen when the 3.58 signal

is missing. The demodulators act as if there were a little bit of 3.58-MHz when the color sidebands are present, but they act as if there were none at all when there is no color. Both receiver demodulators have the *same* signal output since they are supplied with the same chroma and no 3.58. The action of the triode vs the pentode demodulators is reverse (triode gives purple and pentode gives green) because of the way they are made nonlinear, *not* because one is pentode and the other triode.

Visual color-bar analysis

How can we know for certain whether a poor color picture is caused by the station, the receiving antenna, the location or the receiver? To know is crucial, for your technical reputation may depend on your answer. If you guess wrong, the customer may find out the truth later on. Or you may waste hours trying to eliminate the trouble from the receiver when its source is really the station or a poor video recording. Luckily, the answer is deceptively simple: Eliminate the station and antenna, then judge the set by itself. The only reasonable way to do that rapidly is to use a color generator as a signal source.

Good color depends on good b-w characteristics, so we must first determine the condition of the tuner, i.f.'s and video stages. The sharpness of a picture depends partly on the receiver's ability to reproduce spikes and square waves with sharp corners but without overshoot or ringing. Poor video high-frequency response blurs right and left sides of the spikes, but the right side much more so. Ringing will make an outline around the picture much like small, sharp ghosts.

The crosshatch generator pattern is ideal for analyzing b-w picture sharpness. Since it has narrow vertical bars and is motionless, we can take our time in examining it. To avoid confusing results, follow these tips:

1. B-w convergence and screen color should be good. Misconvergence drastically degrades visual sharpness.
2. Disconnect the antenna from the set. The antenna may blur the picture or cause a double image.
3. Remove any gun-killing devices and any extensions to the picture tube socket.
4. Don't use excessive brightness, contrast or color.
5. Use the 4.5-MHz sound carrier in the generator. Without it you can't set the fine tuning the same each time.

6. Connect the generator to the antenna terminals. Only an overall test will tell us everything.

Use this sequence of adjustment:

1. Turn set's channel selector to generator channel. Turn color control down.
2. Adjust fine tuning into sound bars, then back just enough to eliminate "rope" pattern.
3. Adjust brightness and contrast until space between bars can be seen but bright bars do not defocus very much.
4. Analyze bars for sharpness, particularly on right side where the black "overshoot" line is. Look for ringing on right side of bars. Fig. 302 shows some possible conditions. Each make and model will respond a little differently to this test because of changes in i.f. and video response, so try this on several individual receivers to establish a standard.
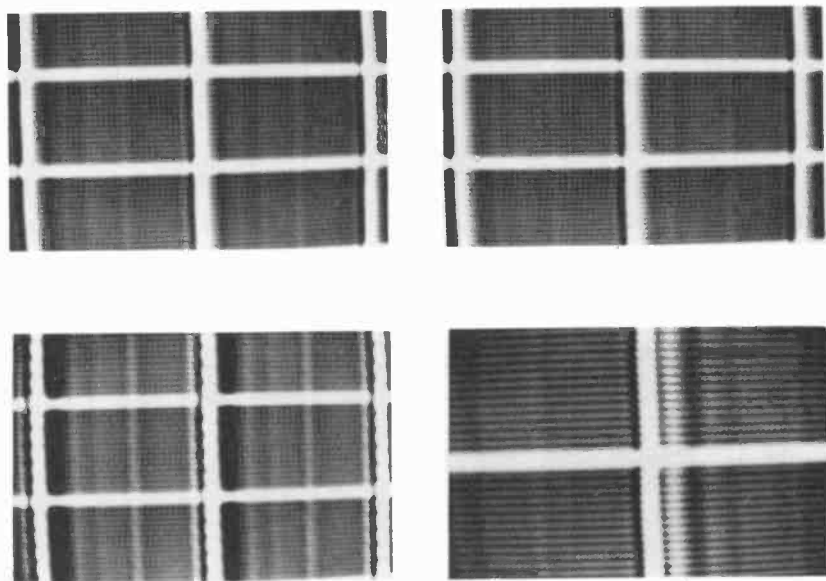
Fig. 302—Sharpness of crosshatch bars is judged mostly by right side of bar. Notice a normal bar is preceded and followed by a black edge. In (a), normal crosshatch sharpness in a particular set; in (b), vertical lines are blurred by incorrect fine-tuning adjustment. (c) shows normal crosshatch with receiver tuned into sound bars, and (d) shows ringing caused by bad i.f. alignment.

This same analysis can be used with b-w receivers, but the bars may show more ringing because of the difference in high-frequency peaking.

Color-bar analysis is similar, with a few additions. The same "tips" apply, but follow this sequence of adjustment:

1. Turn color control up high. Turn generator to "color bars" function.
2. Adjust receiver fine tuning into sound bars, where color will have 920-kHz beat pattern, then back just barely enough to eliminate beat.
3. Adjust color control up or down to give bright colors, but not blooming or defocused. Adjust brightness high enough to show space between bars.
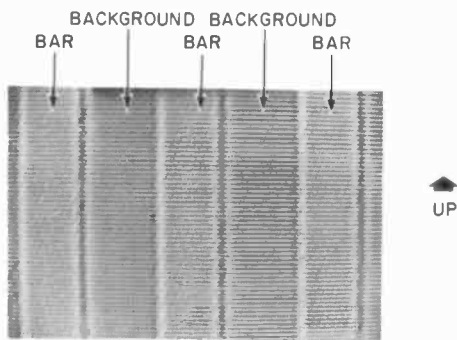
Fig. 303—Color bars should look like this in black-and-white with the color control turned down. Color should be within lines that mark edges of bars when it is turned up. Faint diagonal pattern is from generator—not from beat.
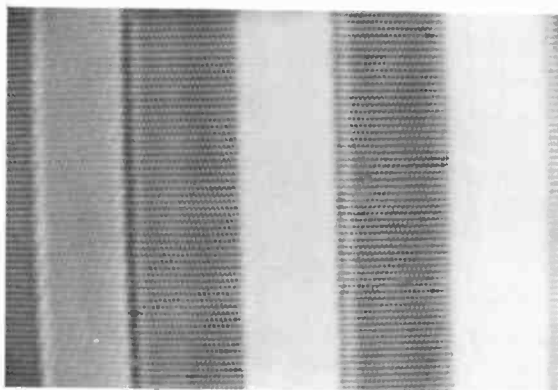
Fig. 304—Edges of color bars should be fairly sharp.

4. Adjust tint control to make third bar from left maximum red.
5. Judge quality of the bars:
    Turn color control down and up again. Are the colors within the faint b-w lines that mark bar location? (Fig. 303).
    Are bars even in coloring across their width?
    Are bars normally sharp? (Fig. 304).
    Is there any 920-kHz beat? There should be none. (Fig. 305).
    Do bars have a vertical edge of another color at right or left? Every set and generator shows some of that; does this set have too much?
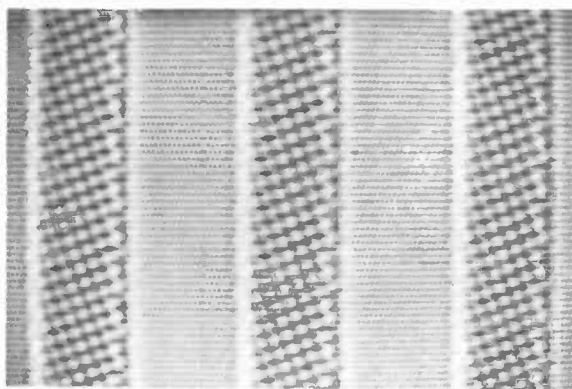
Fig. 305—920-kHz beat makes clothlike pattern in bars.

If the receiver passes these tests, it is certain to have good bandwidth and phase response. Any ghosts, blurs or streaks in the picture must be from outside the receiver.

What do we look for if the receiver flunks the color-bar test? Usually the alignment is bad in the picture i.f.'s even though the b-w picture looks *almost* normal. Increased-value video plate resistors can narrow bandwidth and change the phase of the color signal, and open peaking coils will cause a huge change in picture sharpness. Don't be too quick to rush the set in for a complete alignment until you have checked some condition that may change the alignment curve *temporarily*: gassy i.f. tubes, poor grounds on the i.f. or video board, loose tube shields or an open or short in the shielded i.f. cable from the tuner to the chassis. Look at a vacant channel and estimate if the amount of snow is normal for full i.f. gain. Also notice if the snow is in horizontal streaks—sure sign of near-regeneration (Fig. 306).

Good, sharp bars are not enough. The phases of the three colors

must match the transmitted phases. The tint control changes all three at the same time, so they should all roll right or left together when the tint knob is adjusted. The third bar from the left is usually the red one when the tint control is set according to theory. To allow for differences in the transmitted signal, the tint control should move the bars enough to make the second bar red, or the fourth bar maximum red. Any movement beyond this is okay, but not necessary.
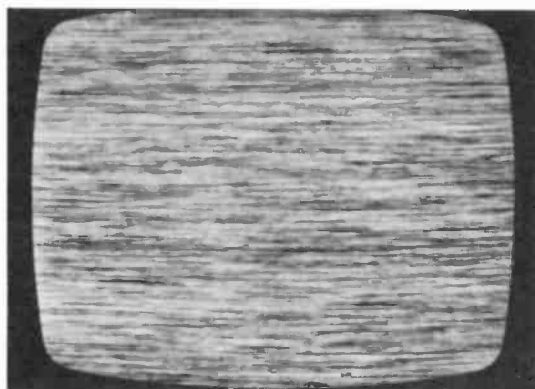
Fig. 306—Snow in horizontal streaks indicates rf or i.f. stages close to oscillation.

Each color has a phase of its own. You can check that by finding which bar is brightest for each color. However, the brightest green bar is not visible because it is generated during the horizontal retrace time. The most accurate method is to check the phase of each color by locating the "crossover" point. This type of color-bar generator is the gated- (or keyed-) rainbow where 3.58-MHz sidebands are transmitted in 12 bursts with equal spaces between the bars and no 3.58-MHz carrier. The spaces between the bars are our zero reference points. The chapter on phase and demodulators proves that any chroma signal 90° away from the phase of the 3.58 applied to that demodulator will give zero output, just as if there were no chroma. Each color will have at least one bar whose brightness (Y) content is the same as the background color (zero) between the bars. That point is called a "crossover." The crossovers can be checked by a scope at the picture tube grids, or visually on the face of the picture tube. See Chapter 5.

The visual test from the screen of the picture tube should be done this way:

1. Disconnect any gun killers or picture-tube socket extensions. (Loss of high frequencies will upset the zero reference.)
2. Turn on red only by turning down the other two screen controls or by using 100K resistors from green and blue grids to ground).
3. With color bars tuned in correctly, adjust for moderate amounts of color, then set tint control so sixth bar is the same color and brightness as the spaces on each side of it. (Mark this bar before killing the other two colors.)
4. Without moving the tint control, notice where the green and blue crossovers are by turning red off and green or blue up.

By the 90° theoretical standard, blue crossovers should be at the third and ninth bars, while green crossover should be at the seventh bar. In the sets now using the 105° difference between demodulators, these bars would be ½ bar to the right.

If the third and ninth blue bars don't reach crossover at the same point on the tint control (for example both might be brighter than background) the frequency response of the $B-Y$ channel or the chroma alignment might be substandard. If this difference is small, ignore it—the picture will not show it. Most of the new receivers have no adjustment for the crossovers; instead, fixed components are used to shift the phase to one of the demodulators. Very poor i.f. or chroma i.f. alignment will also change the exact crossovers, so don't worry about them until after correct alignment is restored.

One more characteristic of the color bars is essential: the amount or amplitude of each color signal fed to the picture-tube grids. Forget about the 59% green, 29% red and 11% blue formula. It is used only at the transmitter. Theoretically, each color should be transmitted at the 100% level and kept that way right up to the picture tube. But to avoid overload, these levels are changed at the transmitter. At the picture tube grids we want 100% blue, 85% red and only 35% green as measured on a calibrated scope. These percentages will vary considerably from set to set and between models.

Hum problems

We all know what hum in the picture i.f.'s or video stages of a b-w receiver looks like. Color receivers can have this same hum pattern. In addition, the hum may be in one color and not the others. Some examples are given on the pages printed in color. The easy way to identify which color has the hum is to look at just one color at a time. A gun-killing switch or screen control adjustment will allow you to do this rapidly.

The most likely origin for hum in one color is in the X or Z demodulators; in that case, the hum will be principally in red or blue respectively. Such hum can be seen with the color control turned down because the $-Y$ amplifiers have good response to 60 Hz. Hum in the cathode of the chroma i.f. stages will eliminate the color (all colors) in a hum-like pattern as shown in Fig. 307, but no hum will be seen with the color control turned down. Hum in the phase detector or reactance stage bends *all* the colors in an S-curve (see Fig. 308). Hum in the $-Y$ amplifier stages (or in the high-level demodulators in some Motorolas and all Zeniths) will show with the color control turned up or down. Heater-to-cathode leakage in one of the guns of the picture tube will cause a slight hum pattern, and may remove the video from one or all
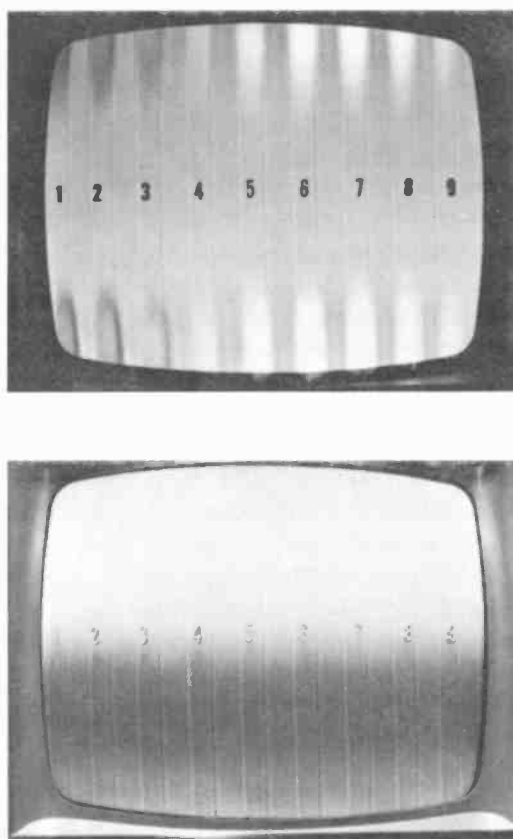
Fig. 307—Hum in chroma i.f. only (upper photo) will modulate color with hum pattern, but no hum will be seen when color control is turned down. Lower photo shows hum in $-Y$ amplifiers—visible even without color.

three colors.

The sources of hum include heater-to-cathode leakage inside a tube, poor grounds in heater and grid or cathode returns, and filter hum.
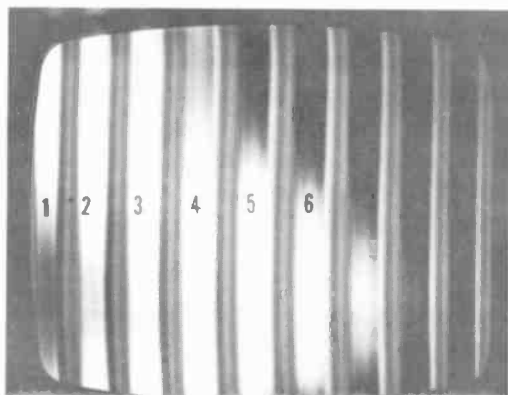
Fig. 308—Hum in reactance stage bends color bars into S-shape.

60-Hz hum will show only one complete cycle of one dark and one light area (unless vertical retrace divides the hum so part is at the top and part at the bottom), while 120-Hz hum will show two such cycles (Fig. 309). When the receiver and program source are operated on a different power frequency or phase, the hum will travel slowly up or down the screen.
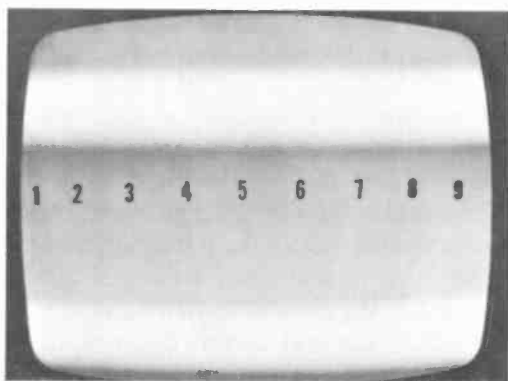
Fig. 309—120-Hz hum from bad B+ filtering shows two light or dark horizontal bands.

Shading problems

Shading is a darkening of one of the four edges of the picture. Darkening at the top or bottom indicates shading from the vertical sweep circuit (Fig. 310), while darkening at right or left means shading from horizontal sweep. Since the shading is caused by the vertical or horizontal, it occurs at the scanning frequency and so it does not move. Practical experience shows no cases of vertical shading (top or bottom) originating in the chroma channel. Vertical sweep sawtooth will give b-w shading if it gets into the B+ circuit. Some rare examples will be given later under general case histories.
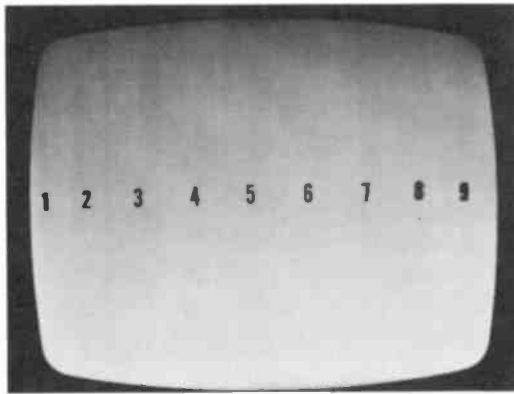
Fig. 310—Vertical-sweep sawtooth getting into video shades top or bottom of raster (usually top), but does not move as hum-modulation does.

Horizontal shading can make the left or right side of the raster darker than the rest of the screen if it affects all three colors the same (Fig. 311), or it can cause a change in screen color at right or left if it affects just one or two colors. Poor frequency response in one of the −Y amplifiers will darken the *left* side of the screen in whichever color is affected. Any condition that broadens the horizontal blanking spike will also darken all three colors the same so there is no change in screen color. A shorter time constant in the grid circuit of one of the −Y amplifiers will darken the right side of the screen in that color. A small amount of B+ leaked into the grid circuit of the blanking amplifier will darken the right side of the screen (all three colors the same). The edge of the dark area moves further to the left as the B+ leakage increases (Fig. 312).

Hum and shading problems are comparatively rare, but refer back to this information if you encounter them.
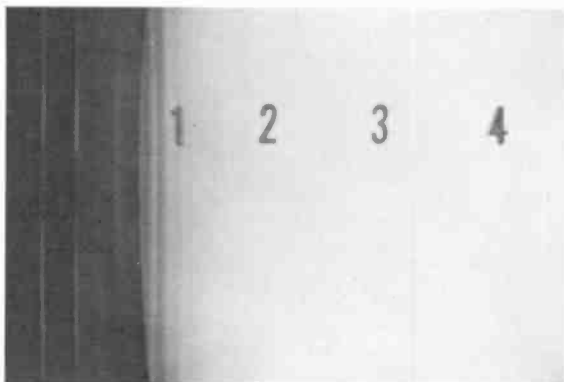
Fig. 311—*Horizontal shading darkens right or left edge, or makes one edge a different color, if shading does not affect all three colors.*
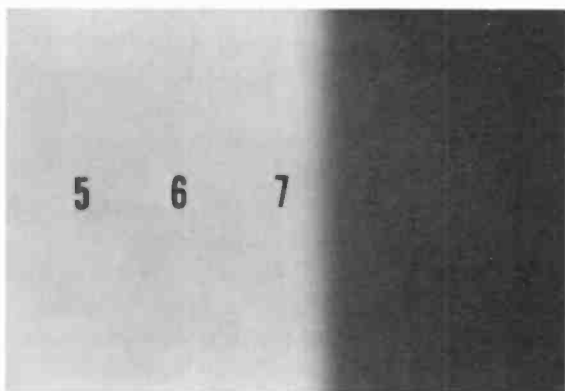
Fig. 312—*Right side of picture blanked out by B+ leaking to horizontal blanker tube grid.*

Chapter 4

What Is Chroma All About?

A COLOR RECEIVER IS JUST A B-W SET (of certain critical specifications) with a color picture tube and a chroma channel added. This chroma channel is the heart of any color receiver, yet its basic functions are simple.

1. The chrominance signal is amplified in a color i.f. circuit whose bandpass is shaped to definite specifications.
2. The 3.58-MHz color carrier, which was removed at the studio, is recreated with the correct frequency, amplitude and phase.
3. The chrominance signal and the 3.58 carrier are combined in the demodulators to produce $R - Y$, $B - Y$ and $G - Y$ signals which drive the red, blue and green picture tube grids.

Each of these fundamental circuits may have many subdivisions and variations according to the exact make and model.

Let's take the chroma circuit of the RCA CTC16X, since it is typical of many modern receivers, and study it in detail. Fig. 401 shows the complete diagram of the chroma i.f. amplifier, sometimes called the chroma bandpass. It's just a simple one-tube tuned-pentode amplifier and should be easy to understand, troubleshoot and repair. Yet, do you recall the day Joe Bloe called you for advice, saying . . . . "I don't have any color at all. Is it the picture i.f.'s or the 3.58 oscillator, or where do I look?" His voice was unusually serious, as though income-
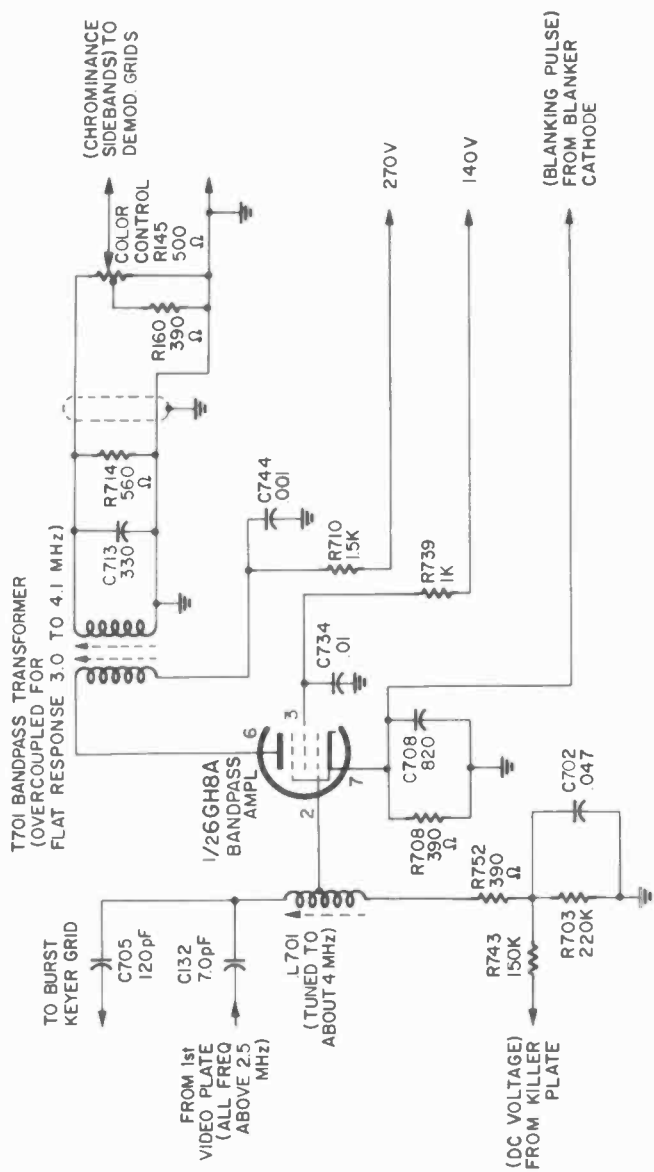
Fig. 401—Chroma bandpass amplifier of RCA CTC16X color chassis.

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tax time or the end of the world was near. You had attended a service meeting the previous night (Joe was too busy making night calls to go), so you quoted from the speaker, "Joe, 90% of all cases of *complete* color loss originate in the chroma i.f., which includes the color killer." After Joe's usual wholesale tube replacement method had failed, and he was driven to call for help, he found a shorted 6GH8 chroma i.f. amplifier had burned open its 1K screen resistor.

Why should we first suspect the chroma i.f. rather than the 3.58 oscillator or the demodulators? In this model, a dead *oscillator* will still permit weak color, but only *green*. So it is easy to check this possibility. There are two *demodulators*, but it would be unusual for both to fail at the same time. The *picture* i.f. may give weak or poor color but will seldom stop *all* color. The *picture tube* cannot fail to give color if b-w is normal.

Play the percentages, in this case, means to check the most likely cause—the color killer—first. The fastest way to test the entire color-killer circuit is to remove all the killer voltage at the point it is applied to the bandpass amplifier. Ground the rear end of R703 (220K) as shown in Fig. 402. Now you should see "confetti," normal color, or the stripes of out-of-lock color, if the killer had been biasing the bandpass tube to cutoff. Check the killer and killer-detector voltages carefully if

Fig. 402—Remember this test point at R703.

this test restored the bandpass gain. If it did not restore the gain, inspect the bandpass circuit for unlit heaters, burned resistors, damage to the board, or damage to the unshielded takeoff coil. If none of these tests proves anything, move to the second level of tests: voltage and resistance.

Fig. 403 shows the 6GH8 voltages we should expect under four pos-

sible conditions: normal color program, normal color bars, out-of-lock color program or bars, and normal b-w program. The color killer biases the 6GH8 to cutoff during b-w or out-of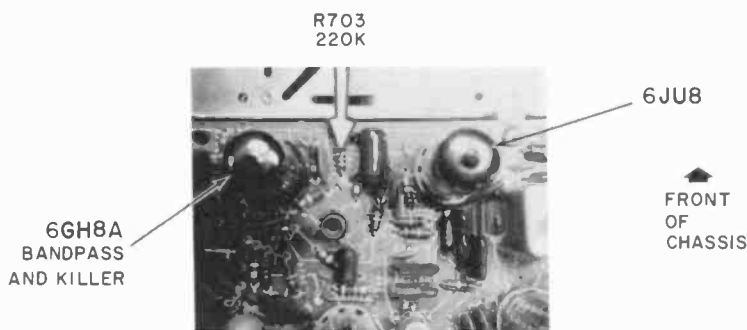-lock color programs, and this changes only the cathode and grid voltages of the 6GH8. The cathode voltage when the tube is cut off is from the horizontal-blanker cathode current. Blanking is applied here to prevent any burst from entering the chroma channel. Excessive blanker current could raise the 6GH8 cathode voltage enough to kill its gain, but the primary symptoms would then be wrong brightness because of a loss of blanking. An open in the 390-ohm cathode resistor would stop all color, but would also remove all horizontal blanking so the screen would be very dark.

	Normal color program	Normal color-bar generator	Color bars out of lock	B-W program	No signal
Grid voltage (at R703)	0	-3	-7.5	-7.9	-9.4
Cathode voltage pin 7	5.4	4.5	3.3	3.1	2.65
Screen voltage pin 3	142	142	142	142	142
Plate voltage pin 6	257	257	257	257	257

Fig. 403—6GH8-A chroma bandpass amplifier voltages.

If any of the 6GH8 voltages are abnormal, check the components in that part of the circuit with your ohmmeter, including coil continuity. Here are two tips to improve the accuracy of ohmmeter readings:

1. Remove the tube from its socket before checking the grid resistance, or allow enough time for the cathode to cool completely. Otherwise, grid conduction may give a false low reading to ground if the positive ohmmeter prod goes to the grid.
2. To reduce the possibility of opens in sockets or board wiring, measure the resistance from connecting points of the circuit rather than across the suspected part itself. For example: In Fig. 401, measure from the grid pin of a test socket inserted in the 6GH8 socket to ground. If the reading is about 220K, you have proved the continuity of the socket, L701, R752 and R703 in one easy test. An ohmmeter test is the best one to use on a grid return

suspected of being open, for the open allows the grid to float and acquire a negative charge which may bias it to cutoff. But a voltmeter will not measure this voltage, for the moment you touch a probe to the floating grid, the voltage goes to zero.

Insufficient screen voltage could be caused by excessive screen current or leakage to C734, which by the time of the test could have burned R739. Low plate voltage could be caused by an open in the primary winding of T701, excessive plate current, a leaky C744, or an increase in the value of R710. We do not usually suspect the 140- or 270-volt supplies, for any large change would give very obvious symptoms in the b-w picture.

What would our friend Joe do if he saw the heater of the 6GH8 light up and then die out? Chances are he would replace the tube, write up the ticket and leave. And he'd probably have a callback the next day! What did Joe do wrong? He didn't cross-check to see whether the *tube* was bad or the filament wiring was intermittent.

In addition to the usual tube-tester check, he could have waited until the tube died out (or rocked the tube in its socket), then used a clip lead to short pin 5 of the 6GH8 to ground. If the tube lights only when this pin is externally grounded, the bottom socket connection or the etched wiring from pin 5 to ground is open. A similar test can be made for the hot side of the heater on pin 4, except it should be jumped to the 6.3-volt supply or to pin 6 of the 12BY7 tube. These tests can be made without pulling the chassis, for the sockets have holes in the top above the pins large enough for a sharp wire or prod to be inserted. A 9-pin test socket could be used to make certain the open is not in the socket itself. Warning: Be careful about grounding the hot side of the 6.3-volt wiring. One good spark and the etched wiring will vaporize like a fuse element. Then you'll *certainly* have an open circuit!

Or, Joe could have used the ac scale of his vtvm to find this open. If both heater pins have 6.3 volts on them, the ground side is open; but if neither has voltage, the open is in the hot side of the heater supply.

You can use a magnifier and a flashlight to locate opens in the wiring. A small hairline crack is all it takes, if the crack goes completely through the etched wire. Solder bus wire over the crack to strengthen it, otherwise it may crack later in the same place. Sweating all the joints in the near vicinity is not recommended except as a last resort. In a noncritical circuit, such as the heater circuit, a piece of insulated wire can be run between any two points where there's an open.

The recreation of the 3.58 subcarrier is done in four stages in the CTC16X. The first stage is the *burst amplifier*, sometimes called *burst*

keyer. Its input comes from the top of L701 through C705, a coupling capacitor to block the killer voltage (Fig. 404). This capacitor also delays the arrival of the keying pulse to the keyer grid so the burst and pulse get there at the same time. As shown in Fig. 404, the input signal consists of any video frequency above about 2.5 MHz, this includes the burst. To separate this burst from the other signals, the tube is biased with a large cathode resistor so it is actually cut off until the positive-going spike cancels the cathode bias by making the grid about as positive as the cathode. While the horizontal pulse is there, the grid bias is
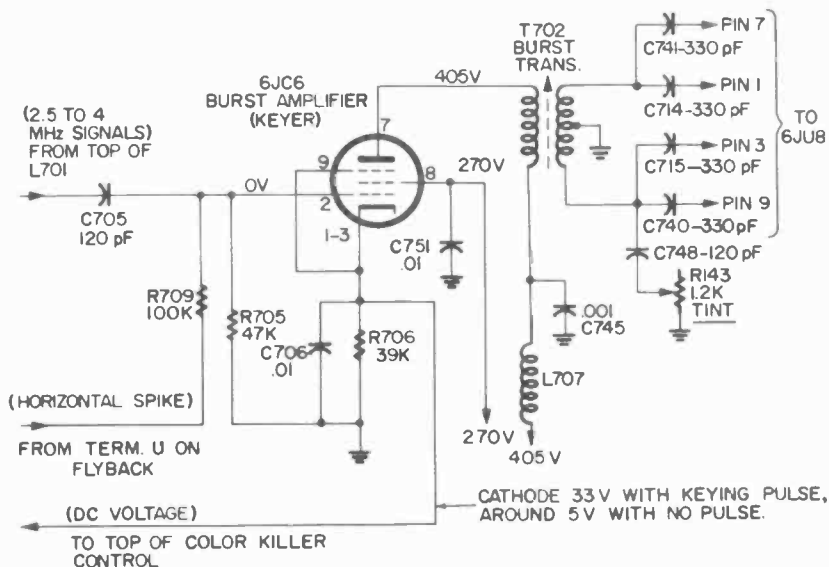
Fig. 404—Burst keyer (amplifier) of RCA CTC16X chassis.

near zero so the tube draws normal current while it amplifies. Fig. 405 shows how the tube amplifies the burst and nothing else. (Of course, it will also amplify snow or high video frequencies when there is no burst received.)

Remember these tips when you troubleshoot the burst-keyer stage:

1. The grid should measure 0 volts dc at all times.
2. The cathode voltage stays the same whether or not there is any burst.
3. The amplitude of the horizontal keying pulse determines the cathode voltage; the more pulse, the higher the cathode voltage. A typical reading is 33 volts with normal pulse and 5 volts with none.

Dc voltages are the first thing to test when burst is lost. An open in L707 or in the primary of T702 will eliminate all plate voltage. A friendly warning: L707 is quite near TP703 (which we ground during 3.58 oscillator adjustments), and should you ground L707 by accident, there will be 400 volts of fireworks, and the coil will probably be burned open. In such an emergency, a 1K resistor can replace the choke.

Part of the cathode voltage is applied to the color-killer grid by way of the color-killer control, so any large change in cathode voltage will also change the killer action. Higher cathode voltage will tend to kill the color, while lower voltage will give colored confetti on b-w programs.

Fig. 405—*Burst amplifier amplifies only when positive-going spike appears at its grid.*

The burst transformer (T702) is tuned to resonance at 3.58 MHz by C748 in series with the tint control. Varying the tint control changes the phase of the burst; the phase of the burst (through the phase detector and reactance tube) sets the phase of the 3.58 oscillator to deter-
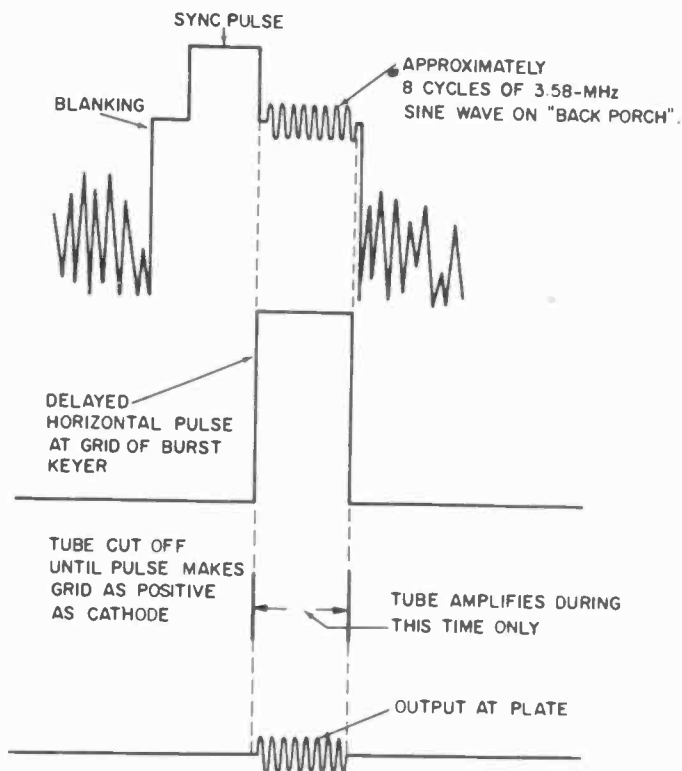
mine the picture tint. There is one small drawback in this use of a resistor in series with a tuning capacitor: the ac voltage in the tuned circuit changes considerably with the resistor adjustment (perhaps 25% total change). The minimum voltage occurs just about where we want the control set for best tint. This, plus variation in burst from the station makes it impossible to give exact figures for the amount of burst to expect. We will give some approximate voltages later on under troubleshooting. Also all color may be lost at the correct tint point if the color killer is set too low.

The burst transformer has a center-tapped secondary giving two outputs of 180° phase difference to supply two similar, but not identical, phase detectors. One detector corrects the 3.58 frequency and one controls the color killer. We'll talk about the color-killer detector later. Fig. 406 shows how the burst from T702 is coupled through 330-pF capacitors to the 6JU8 plate (pin 1) and cathode (pin 3). These two points are prime test points, so remember them. The 3.58 signal from the oscillator is fed to the other plate and cathode at pin 2. The instantaneous voltage across each diode is determined by the burst and 3.58 voltages, and the phase between them. When the 3.58 oscillator is locked correctly, the 3.58 will add partially to both diodes in the same direction, giving a negative voltage at pin 1 equal to the positive voltage at pin 3. Should the oscillator drift and change phase, the 3.58 at pin 2 will add more to one diode and less to the other, producing unequal
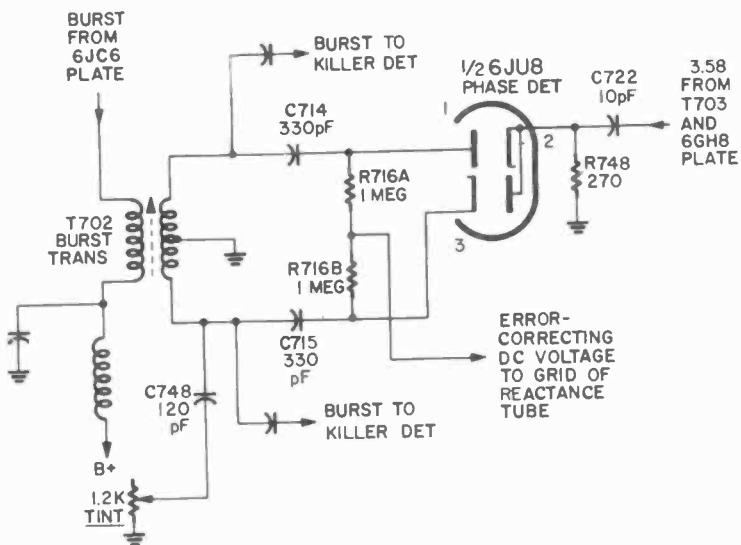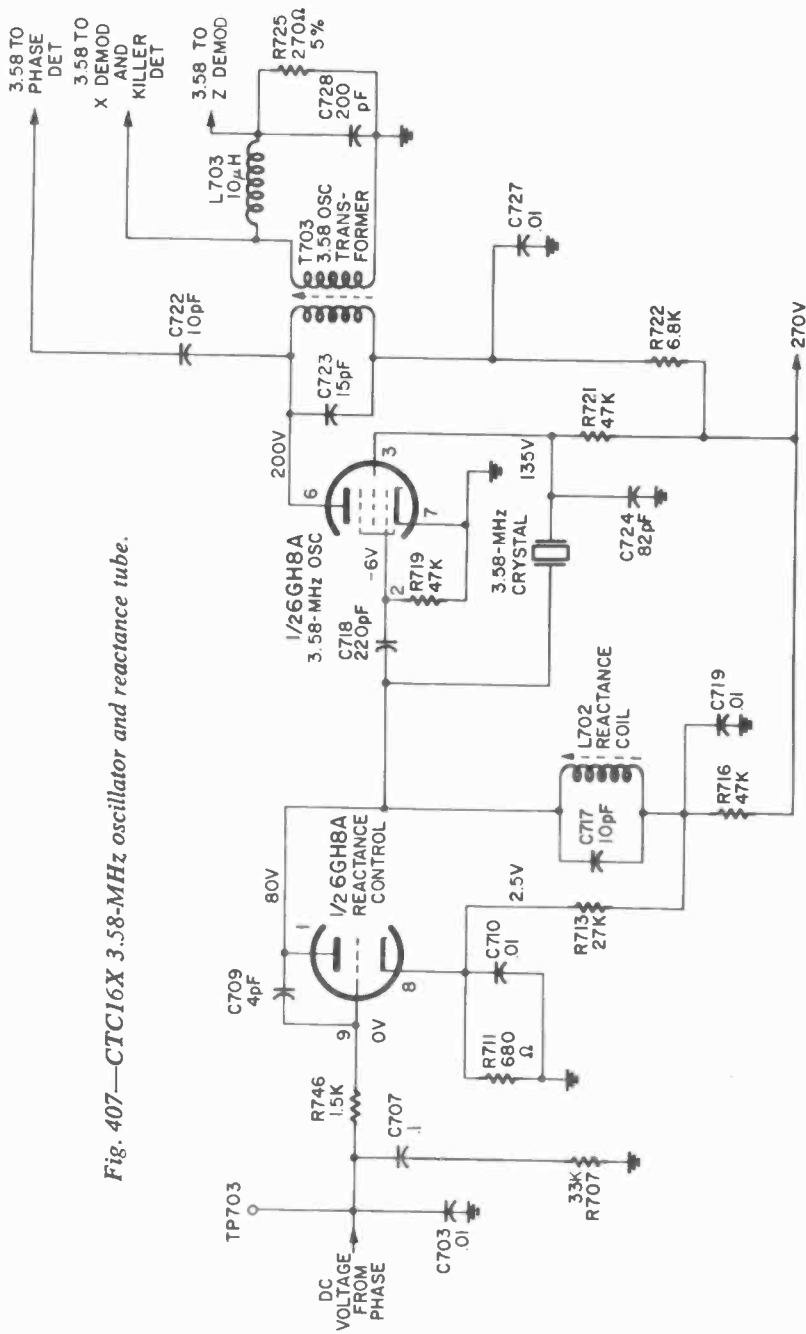

Fig. 406—3.58-MHz phase detector circuit in RCA CTC16X.

Fig. 407—CTC16X 3.58-MHz oscillator and reactance tube.

voltages at pins 1 and 3. These voltages are combined in the two matched 1-meg resistors, and the resulting small positive or negative voltage is fed to the grid of the reactance tube, which forces the oscillator back into phase.

This error-correcting dc voltage from the phase detector is smoothed by the anti-hunt circuit (C703, C707 and R707 in Fig. 407) and fed to the grid of the 6GH8 triode section, used as a reactance tube. A tube can function as a variable capacitor if the normal Miller effect is increased with a grid-to-plate capacitor (C709) and a grid resistor (R746), and if the gain of the tube is varied by changing the grid bias. The reactance coil (L702) has the only adjustment we can make to the frequency, so we ground TP703 to make the grid voltage zero to eliminate all automatic locking, then adjust the coil so the oscillator is the same frequency as the chroma signal. After we remove the ground, the burst through the phase detector and reactance stage will control the oscillator frequency enough to give strong, stable locking.

The 3.58-MHz oscillator is actually a triode type, because the 6GH8 screen grid acts as an anode. The signal is electron-coupled inside the tube with the amplified signal appearing at the plate. T703, the plate transformer, has little effect on frequency, a noticeable effect on phase and tint, and a large effect on the amplitude of 3.58. Surprisingly, the color locking will be loose if the transformer is misadjusted enough to weaken the output voltage by 50% or more. The phase detector *must have both* normal burst and 3.58 signal to give good color lock; loss of either will destroy locking.

The 3.58 plate transformer is the distribution point for four different voltages of three different phases. From the primary comes the sample of 3.58 to be compared with the burst in the phase detector. The secondary supplies 3.58 for the killer detector and the X demodulator. From this same point is taken the 3.58 for the Z demodulator after the phase is delayed 90° by L703, R725 and C728. This phase is not adjustable, but is determined by the parts tolerance. R725 can be changed to make small corrections to the phase, if needed.

The chrominance sidebands have been amplified and their bandwidth limited for normal specifications up to the color-saturation control. The 3.58 carrier, of the correct phase, amplitude and locking, has been generated. The next step is to combine these sidebands with the missing carrier to recreate the station's $R - Y$ and $B - Y$ signals. This is done in two nearly identical demodulators. In this chassis they are called X and Z demodulators just to have a convenient label; but it is important for us to remember that X is *almost* $R - Y$ and Z is *almost* $B - Y$. Fig. 408 gives the schematic of the two demodulators plus the three $-$ Y amplifiers.
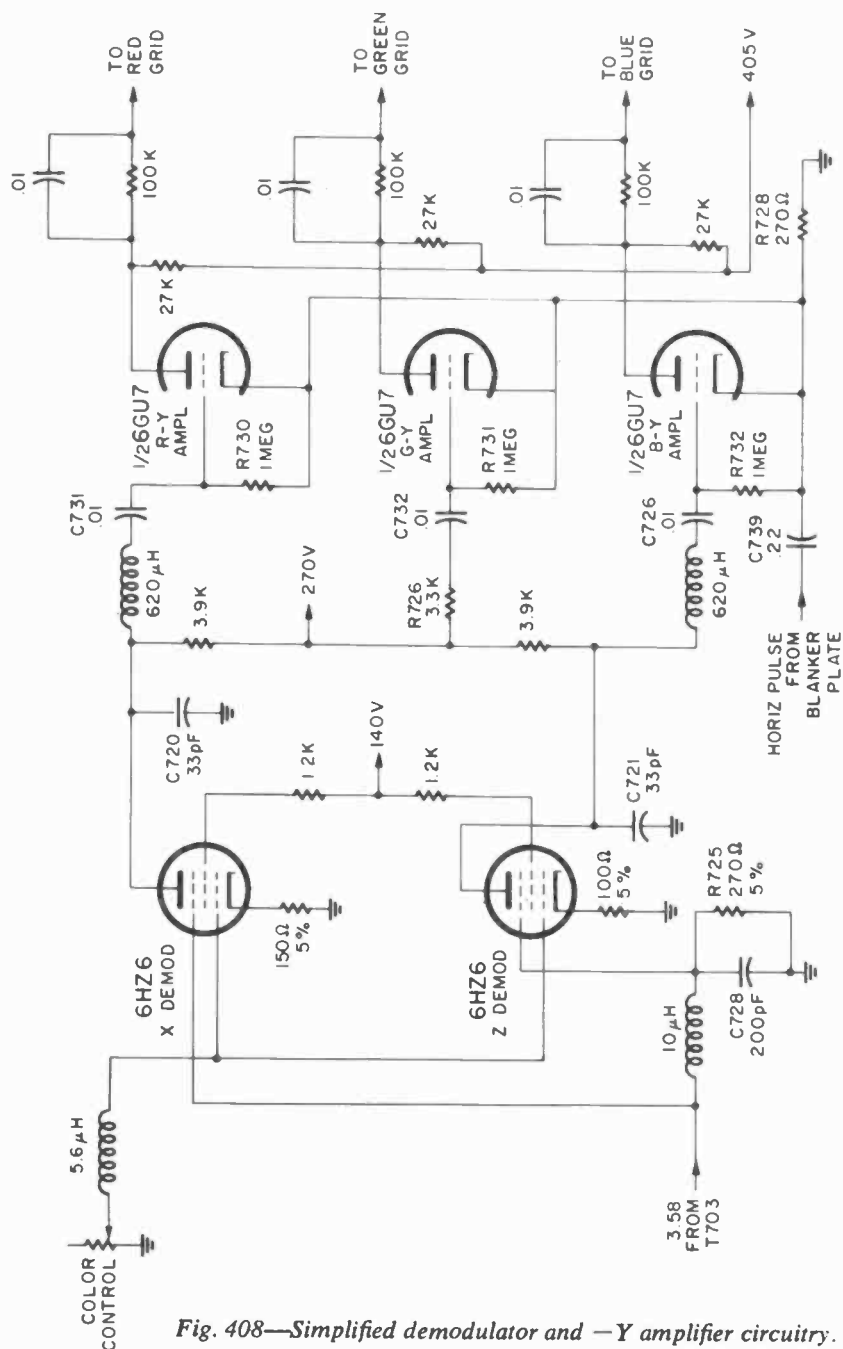
Fig. 408—Simplified demodulator and —Y amplifier circuitry.

Demodulators are important and interesting, so we'll talk about them in detail later. For now, let's just say the chrominance sidebands are fed to both control grids in parallel, while the 3.58 (of two different phases) is fed to the suppressors. The chrominance signal is taken from the plate, filtered to remove the 3.58 and any frequencies above 0.5 MHz and sent on to the $-Y$ amplifiers. To derive $G - Y$ from the other two, we must take certain percentages of $R - Y$ and $B - Y$, invert the phase of this addition and amplify it. The $R - Y$ and $B - Y$ are amplified first, then combined in a common cathode circuit to make $G - Y$, which is amplified (without phase reversal). The phase of the $R - Y$ plus $B - Y$ is inverted instead of the $G - Y$, as you can see in Fig. 409. The combination of these signals into the common cathode gives cross-mixing to change X and Z into $R - Y$ and $B - Y$ respectively. A small amount of negative feedback from plate to grid of the $-Y$ amplifiers completes the mixing and extends the high-frequency response.

Horizontal blanking is inserted into this same common cathode circuit, not only to blank out the picture tube during horizontal retrace, but also to reset the bias on the $-Y$ amplifiers during each horizontal cycle. This gives an action that is similar to a small amount of dc restoration, and permits the stages to act as if they were direct coupled. A tube operates on *any* grid-to-cathode voltage, so a signal can be ap-

Fig. 409—How G $-$ Y is made from X and Z signals.

plied to either element. In this case, the blanking pulse is applied to the cathode with enough voltage to cause grid current—the same act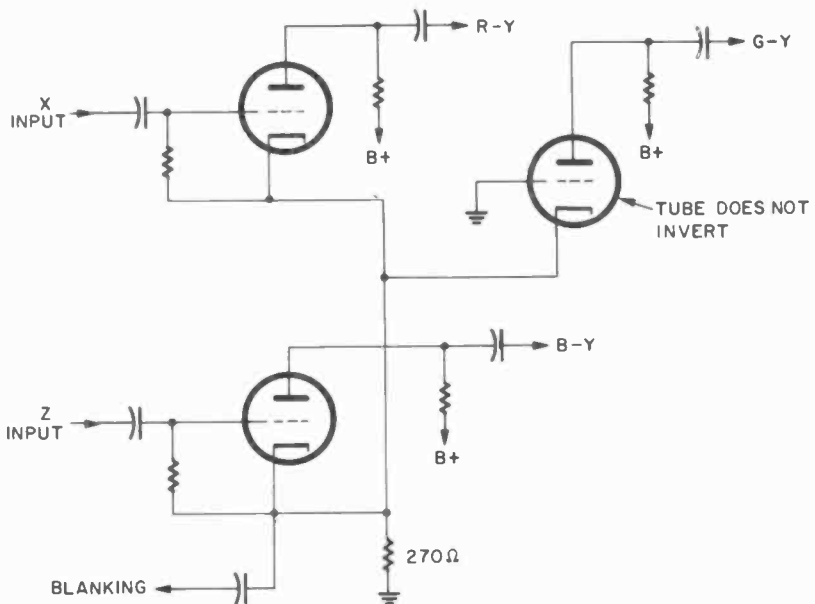ion as in a diode rectifier. The polarities are such that the grid measures negative to the cathode. Between horizontal cycles some of the voltage leaks through the 1-meg grid resistors back to the cathodes, but not enough to shade the brightness on the screen (normally). Note for troubleshooting purposes that the grid bias depends on the amount of blanking pulse, as well as on the conditions and values of the .01-μF coupling capacitor, the 1-meg grid resistor, and the tube. The tube bias changes the plate voltage, which is direct-coupled to the picture tube grids. The picture tube grid voltage is one of the factors governing brightness. Just remember these two rules:

1. An increase in blanking pulse to all three $-$Y amplifiers gives a higher tube bias, raises the plate voltage (and also the picture tube grid voltage) and makes all three colors brighter, thus making the whole screen brighter.
2. A change in blanking to *one* $-$Y amplifier only (bad grid resistor, capacitor or tube) changes the voltage on *one* picture tube grid to make the screen color different.

These rules are true for color *and* b-w reception.

The chart in Fig. 410 gives typical voltages to be expected when we deliberately change the amount of blanking to set the brightness level

CTC15, —16 or —17 Chassis

CRT Bias Switch Position →	Top	Middle	Bottom
Blanker grid voltage 6GU7 pin 2	—86	—82	—75
Blanker plate voltage 6GU7 pin 1	120	150	190
Pulse at blanker plate	11 p–p	13 p–p	15 p–p
Blanker plate resistor	47K	33K	22K
Grid to cathode of R—Y 6GU7 pin 2	—5.8	—6.9	—8.2
Grid to cathode of B—Y 6GU7 pin 7	—5.9	—7.0	—8.4
Grid to cathode of G—Y 6GU7 pin 7	—5.7	—6.9	—8.3
CRT red grid	155	170	190
CRT blue grid	153	169	185
CRT green grid	154	170	190

Fig. 410—Blanker voltage readings.

with the KINE BIAS switch. Use it as a guide to help you through the maze of voltage combinations possible with this system.

The horizontal-blanking circuit, shown in Fig. 411, is a simple one when everything works as planned, but it can lead to some most bizarre symptoms with certain parts failures. A strong horizontal pulse is supplied to the grid through the 150-pF capacitor and 68K resistor. Grid rectification causes the grid to measure around −85 volts dc, and the huge grid spike produces a smaller (but limited or clipped) plate spike of opposite polarity. A smaller spike created in the cathode circuit goes to the bandpass amplifier cathode to blank it. The plate spike is the one fed to the −Y amplifier cathodes, and is adjustable via the KINE BIAS switch, which changes the blanker plate voltage and thus the pulse amplitude.
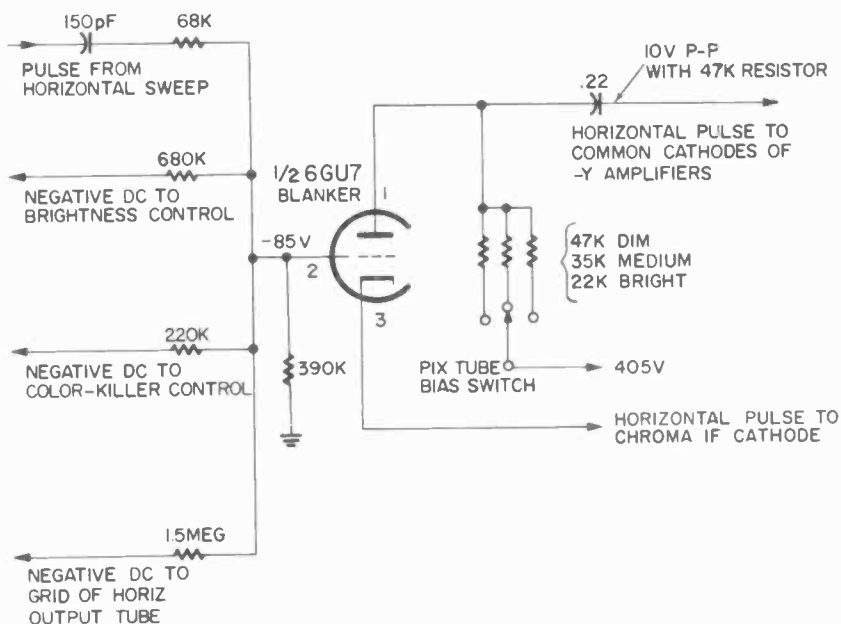
Fig. 411—Horizontal blanking circuit.

In addition to the two blanking pulses, this circuit supplies three others with dc from the grid circuit. (It happens to be a convenient point for obtaining negative dc.) Negative voltage is supplied to the brightness control and to the color-killer-threshold control. Therefore, any large change in the blanker grid voltage will change their range. The brightness control gives the most obvious symptom, for a more negative blanker grid makes the picture darker; less negative, picture brighter. The voltage fed to the grid of the horizontal output tube

prevents too large an increase in the high voltage if the high-voltage regulator becomes inoperative. In such a case, the horizontal pulse at the blanker grid increases, raising the negative voltage, which increases the bias on the horizontal output tube and lowers the pulse voltage in the flyback transformer. We will come back to this, for many mysterious cases of loss of picture width can come from defects here.

To sum up this mighty midget: horizontal blanking defects can cause brightness, color-killer, width, and shading problems. Would you imagine that complete loss of grid rectification (bad tube, perhaps) in the blanker could cause the brightness control to become completely inoperative? The loss of negative voltage to the brightness control makes the picture too bright while the loss of pulse to the $-Y$ amplifiers makes the screen too dark. These two effects cancel each other, so we see a picture of moderate but uncontrollable brightness.

Fig. 412—Color killer and detector schematic.
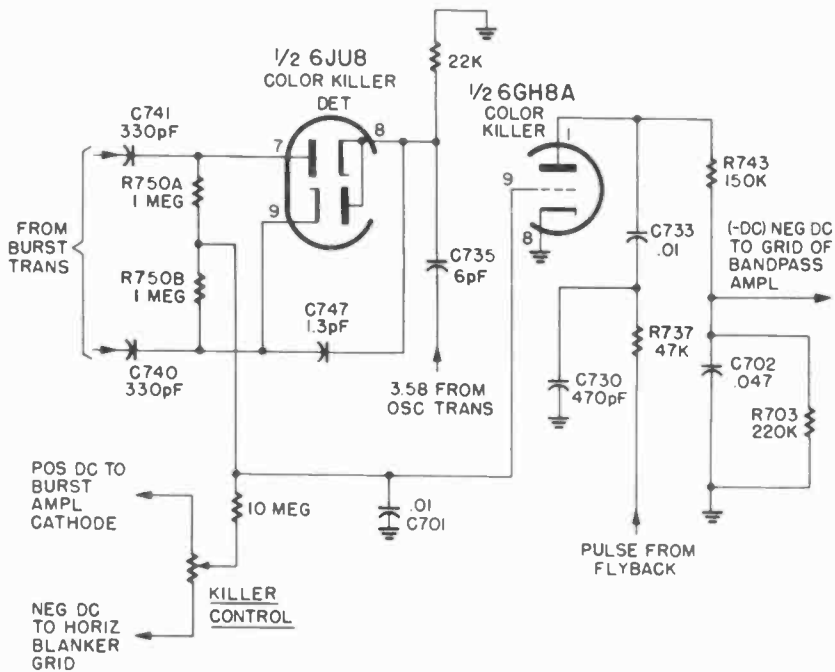
We skipped over one circuit because it is only a refinement not necessary to basic operation. Fig. 412 gives the complete circuit of the color killer and its phase detector. This phase detector is similar to the one used to lock the color, but here the phase of the 3.58 from the os-

cillator is different, making the negative voltage at pin 7 larger than the positive voltage at pin 9, when the color is locked *properly*. The voltage between the two matched 1-meg resistors is around -3 volts and is fed to the grid of the killer tube along with a voltage from the killer control, which sets the operating point of the tube. The killer tube is a grid-controlled rectifier with a horizontal pulse on the plate. When the grid bias is around zero, the plate rectifies the pulse, producing negative voltage that is filtered and applied to the bandpass amplifier grid to bias it to cutoff, thus killing the color. When the grid bias is negative, there is no plate rectification, no dc is produced and the bandpass amplifier amplifies normally. To adjust it, tune in a blank channel and (with the color control turned fairly high) adjust the killer control until the confetti is just barely eliminated. Check performance on a color show to make certain the killer will let color through when it should.

The most important thing to remember about the killer circuit is that many things other than the condition of parts will affect killer action. For example, strong burst is necessary, or the difference in the dc voltage at pins 7 and 9 will not be large enough to bias off the killer tube. Consequently, the killer will rectify and bias the bandpass tube for no color. Insufficient 3.58 from the oscillator will do the same thing. If the color is out of lock, the output of the killer phase detector will be zero and kill the color.

Chapter 5

Don't Be Afraid of Phase, Vectors and Demodulators

M ANY GOOD TECHNICIANS RUN FROM ANY mention of phase or vectors as though they were plagues. I must confess, I avoided the whole subject for many years because I believed I could do a good job of servicing without it, and thought it too complicated for me to understand. Color TV servicing proved to me it was very necessary, for in some circuits of a color receiver a change in phase brings a change in the tint of the visible color. Fortunately, the basic concepts of phase are easy to understand if we leave out the advanced mathematics and take the explanation in small steps.

In physics, "phase" is the relative position of a wave or an object compared to a reference point at a specified time. In Fig. 501, the racing car on a circular track has phase compared to any designated position on the track. If the starting point was east or 0°, the racer is shown at the 90° position. Halfway around the track would be 180° and on around to the starting point would be 360° (or 0° again).

In electronics, phase is the position of a waveform compared to a reference (another waveform) at a certain time. Let's take the circular path of the racer in Fig. 501 and plot an electrical waveform with the degrees of rotation spaced equally along the horizontal line of the graph and the distance north or south from the starting point along the verti-

cal line of the graph. For convenience, we will plot every 30° (see Fig. 502) and place a dot on the graph. When the dots are connected, the waveform we call a *sine wave* is formed. The custom of assigning de-
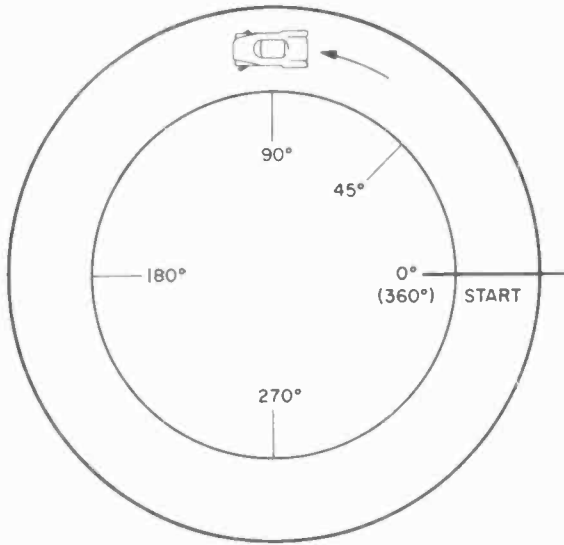
Fig. 501—Position of racer is "phase" when compared to racer's starting point.

grees to various locations on the sine wave originated this way. In a way this is artificial, for an actual sine wave is born and dies every cycle; it cannot be tranquilized and made to lie still while we mark neat lines on it. Still, visualizing degrees on a sine wave is of enormous importance for it permits precise mathematical calculations.
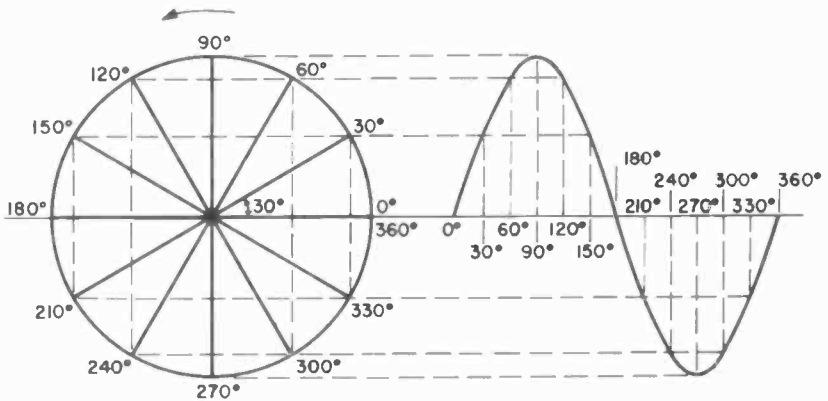
Fig. 502—How a sine wave is obtained graphically from a rotating vector.

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Back to our mechanical analogy: *two* racing cars on the circular track can have a phase relationship to *each other* in addition to the phase of each compared to the starting point, as shown in Fig. 503. Let's say they're traveling at the same rate of speed with B starting first. If so, the 90° relationship will remain constant so long as they continue to run. This is a neat analogy to two sine waves of the same frequency (rate) but 90° apart in phase. Or it could be the same sine-wave signal split into two paths of 90° phase difference. If we plot the rotating vectors (as in Fig. 502) for the two racers, the result is two sine waves of 90° phase difference as shown in Fig. 504-a.
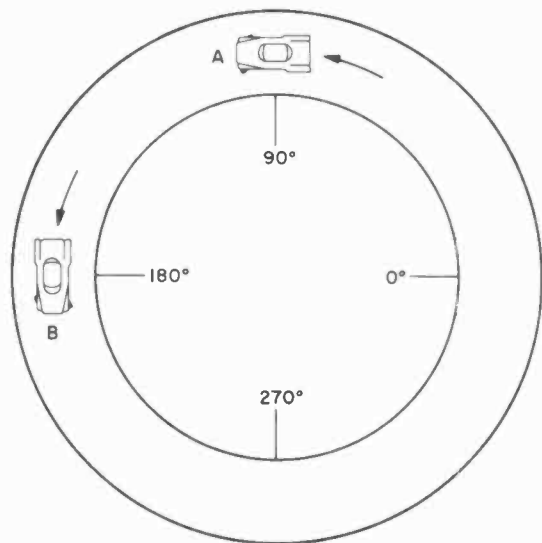
Fig. 503—Two moving objects can have phase relationship to each other.

Should we want to combine the distance and direction of the *two* racers compared to the starting point, it would be virtually impossible from Fig. 503. But the same information transferred to the form of Fig. 504-a makes it easy to add (with a ruler) the heights of the two waves at the degrees markings and derive a composite waveform as shown in Fig. 504-b. If we measure carefully, we will find the new waveform to be a sine wave of 1.4 times the amplitude (or voltage) of either original sine wave, and its phase will be 45° from both, or exactly midway between the originals.

Let's leave the mechanical concepts and concentrate on sine waves,

since they are the basic building blocks of electrical waves. Suppose we want to connect two sources of same-phase sine waves in series—what voltage will we get? Fig. 505 shows this to be simple addition whether the voltages are equal or not. Opposite-phase sine waves will show
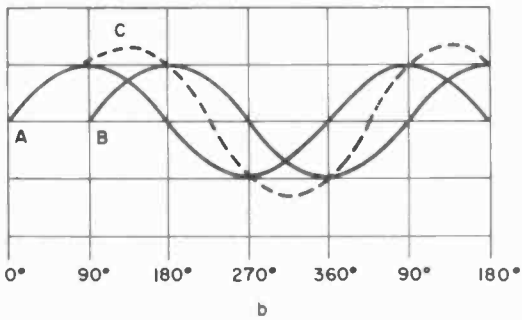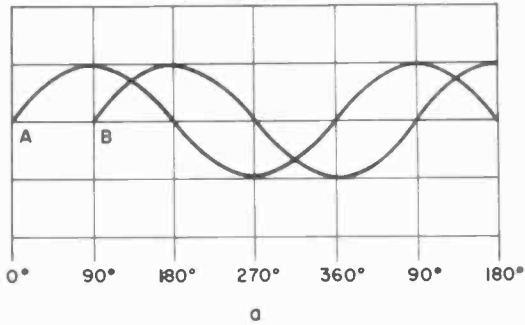
Fig. 504—Plotting racers 90° apart (a) gives these sine waves of 90° phase difference. Adding waves (b) gives new sine wave.
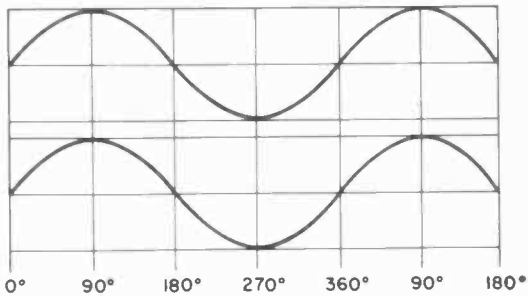
Fig. 505—Sine waves of same phase (0° difference) add completely. If each is 10 volts, sum is 20. If one is 10 and the other 6, sum is 16 volts.

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simple subtraction regardless of voltage ratio, as shown by Fig. 506, but the remaining waveform left from the subtraction of unequal out-of-phase voltages will have the phase of the greater voltage.

So far, so good. But if we attempt to graph waves of only a few degrees difference, for example, the difficulties will be large and the accuracy questionable. There is a better way based on straight lines instead of a circle. Fig. 507 shows the problem of where you are if you
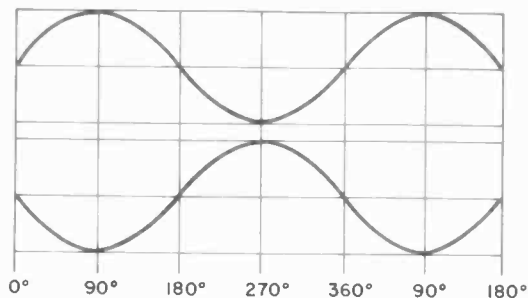
Fig. 506—Sine waves of opposite phase (180° apart) subtract. If voltages are equal, sum is zero. If upper wave is 10 volts and lower 7, sum is 3 volts at 0° phase. If upper wave is 4 volts and lower 9, sum is 5 volts at 90° phase.
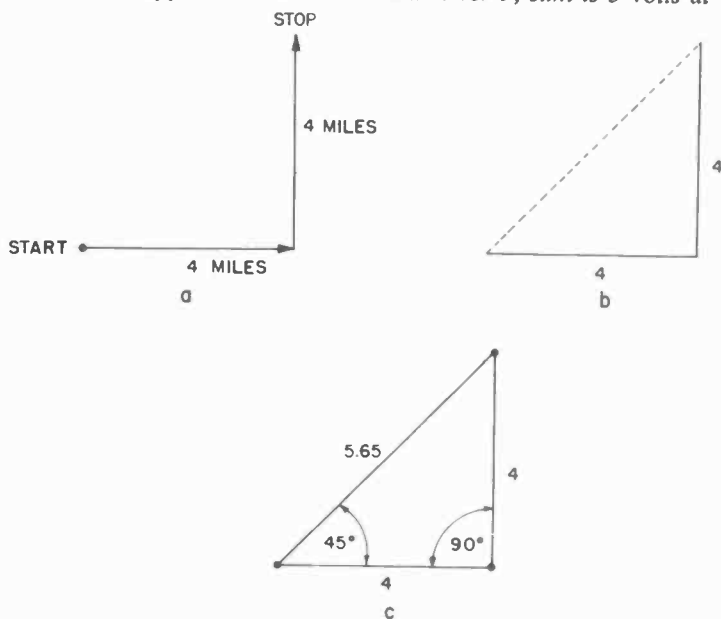
Fig. 507—Problem: drive 4 miles east, then 4 miles north. Where are you from your starting point (a)? One answer (b): draw accurately to scale and measure; should be about 5.6 miles. Better answer (c): use trigonometry to calculate hypotenuse of a right triangle.

drive 4 miles east, then 4 miles north. Of course, you can obtain an approximate answer by drawing an accurate graph, but you will have a more accurate and much faster answer if you solve the problem by geometry. In similar fashion, we can plot the resultant voltage and phase formed by adding two 90° signals by using *vector* diagrams.

Look at the vectors in Fig. 508. The addition of in-phase voltages is given in Fig. 508-a; this gives the same answer as Fig. 505. Subtraction of out-of-phase voltages is shown in Fig. 508-b, with the same answer as in Fig. 506. The addition of 90° voltages is given in Fig. 508-c and shows the same answer as Fig. 504. These three examples should prove the validity of the vector diagram, and the accuracy and speed vectors offer. The principle illustrated in Fig. 508-c is used at the TV broadcasting station to create the chroma signal.
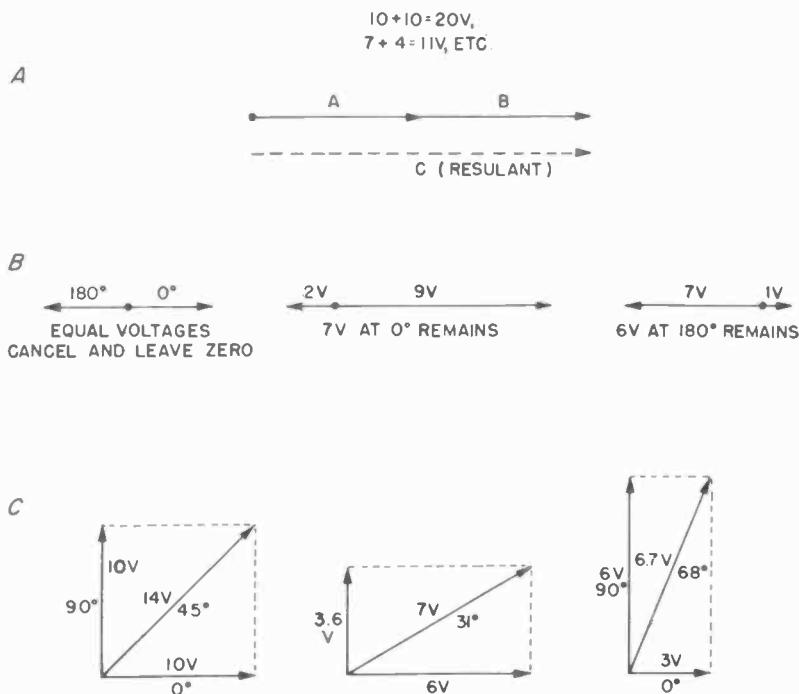
Fig. 508—*Vector diagram of addition of two in-phase sine waves (a). Addition of two out-of-phase sine waves (b). In effect, they subtract. 90° voltages (c) add partially.*

Another kind of vector diagram is necessary to show phases other than 90°. Fig. 509 shows how a parallelogram can be drawn from the two
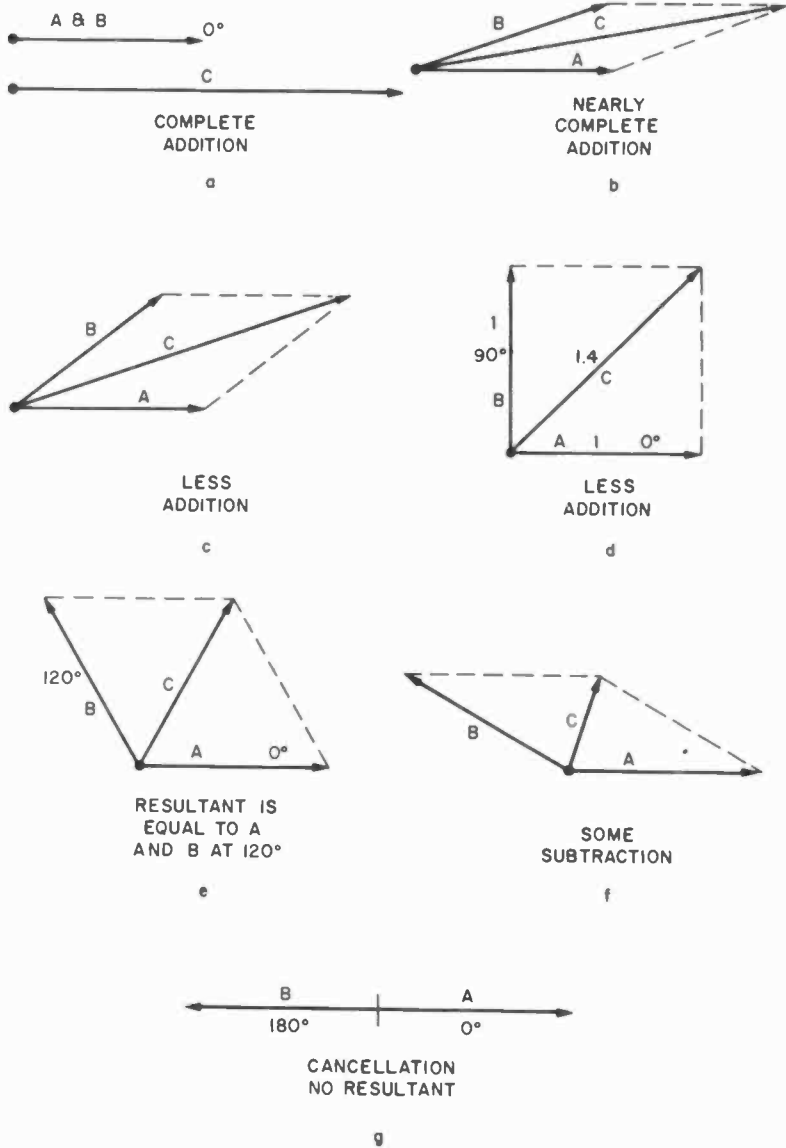
Fig. 509—Use parallelogram solution for phase differences other than 90°

INPUT

OUTPUTS ARE 180°
OUT OF PHASE

a

INPUT — LEADING PHASE (90°MAX)

INPUT — LEADING PHASE (90°MAX)

INPUT — LAGGING PHASE (90°MAX)

INPUT — LAGGING PHASE (90° MAX)

INPUT — LAGGING PHASE (180°MAX)

INPUT — LEADING PHASE (180°MAX)
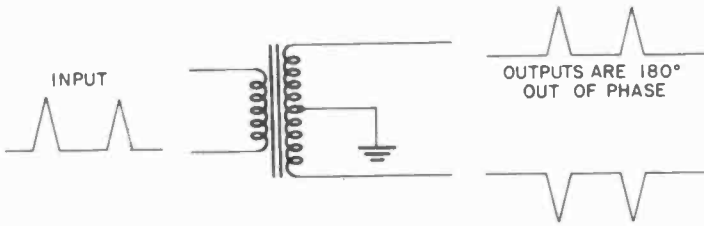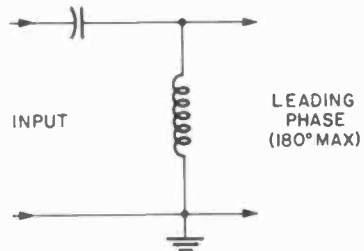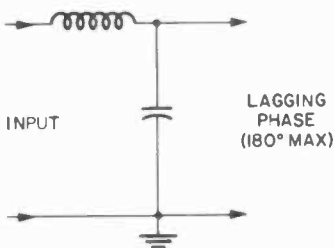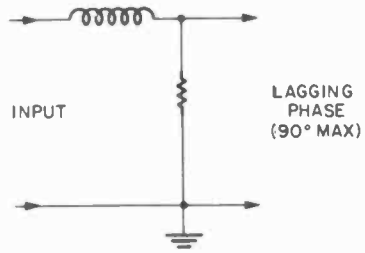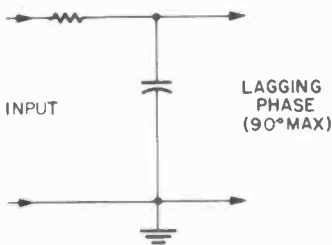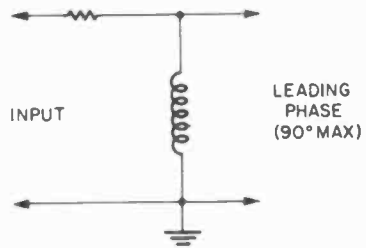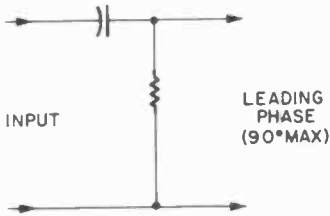
b

*Fig. 510—Transformers (a) give 180° voltages. Capacitors and inductors (b)
shift phase.*

known signals. The diagonal then represents the resultant voltage and phase. Have you noticed, in vector diagrams, that the voltage (or amplitude) is indicated by the length of the lines and the phase by the number of degrees? One rather strange conclusion comes from a study of Fig. 509: Two equal voltages separated by any phase from 1° to 119° add partially, with the greatest addition near 1° and the least near 119°. Voltages of 0° add completely and voltages of 120° produce a resultant equal to the original voltages. From 121° to 179° the voltages subtract, and at 180° there is complete cancellation. (This was a surprise to me, for I had expected 90° to be the midpoint between addition and subtraction.)

Now that we understand how to add and subtract voltages of different phases, let's find out how these phase angles are created in practice. Transformers give fixed amounts of phase shift, such as 90° and 180°, as shown in Fig. 510-a. For the in-between values, capacitors or inductances are used. Each single capacitor or inductance can shift phase a maximum of 90°, but remember this is a maximum; depending on the rest of the circuit, the phase shift *may* be virtually unmeasurable. Resistors alone do not shift phase, but may be used in RC and RL filters, which do (Fig. 510-b). Capacitors and inductors can be used together for greater phase shifts.

Fig. 511 shows how phase shifts in two branches (one producing a
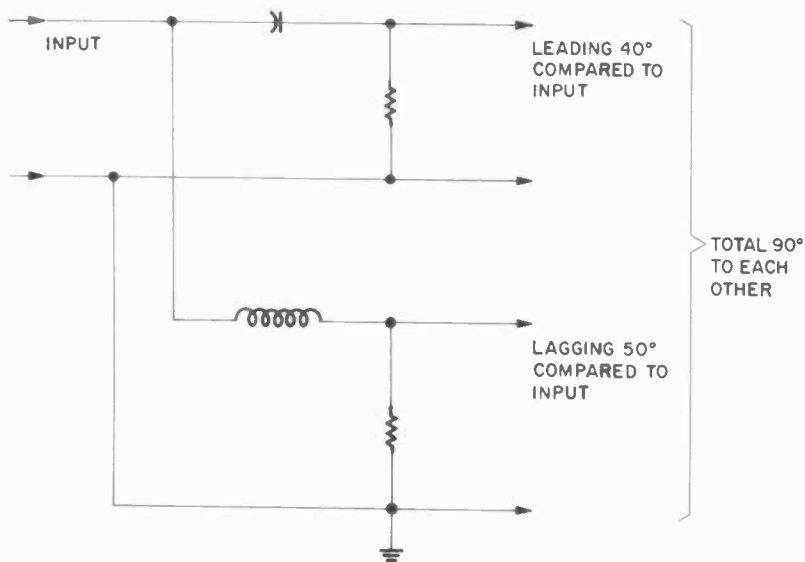
Fig. 511—Different phase shifts in two branches off same circuit add here to give 90° phase between output voltages.

leading voltage and the other a lagging voltage compared to the common input) can add. These phase shifts are caused by the frequency responses of the RC and RL filters used. Fig. 512 shows the frequency response curve of a simple low-pass filter. Notice the *more* attenuation, the *more* phase shift, up to the theoretical 90° maximum. Or to say it another way, phase shift changes with frequency in a simple fixed filter.
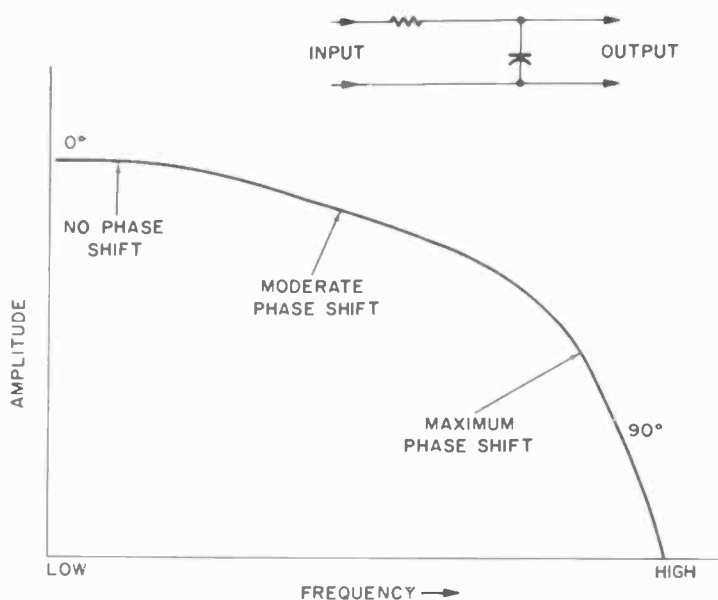
Fig. 512—Frequency discrimination causes phase shift.

In TV, phase shifts can be either desirable or detrimental. For example, high-frequency attenuation, with its inevitable phase shift, will blur the b-w picture. The effect on the color picture is even worse; the colors may be blurred, wrong or moved to one side out of register with the b-w picture—all of these because of phase shift in the wrong circuit, or because of the wrong amount of phase shift.

Now let's talk about circuits where phase shift is absolutely essential —the color demodulators. Two signals come into each demodulator; the chrominance sidebands and a sample of the re-created 3.58 carrier, at a specific phase. The chrominance signal in the receiver is a 3.58-MHz sine wave which changes phase and amplitude according to the tints and color saturation being transmitted at that time. There are usually two demodulators, with a 90° difference in the phase of the 3.58 fed to them. Each demodulator must respond to the signal intended for
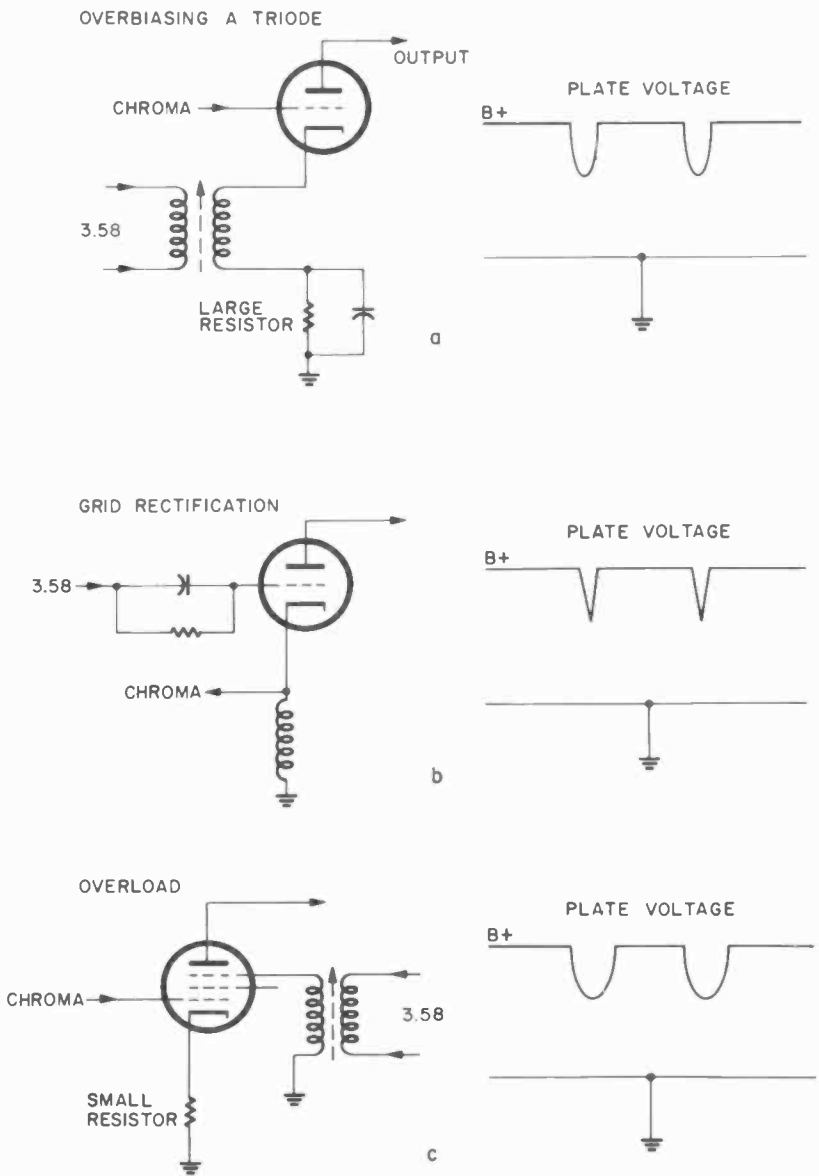
Fig. 513—Three ways to make demodulator a nonlinear amplifier of 3.58-MHz subcarrier.

it and ignore the signal meant for the other, for both signals were combined into one at the transmitter. From the demodulators come the $R - Y$ and $B - Y$ signals, with green derived from them.

A color demodulator must have several characteristics to fulfill these conditions. It must be very nonlinear to the 3.58 carrier, but not to the chrominance signal. To do this, the 3.58 voltage must be large and the chroma signal much smaller; the ratio should be between 5:1 and 10:1.

The chroma and 3.58 signals must be fed into separate elements of the demodulator tube to avoid mixing the two 3.58 signals of different phase. Any two elements can be used, but most late-model tube demodulators use grid and suppressor, or cathode and grid.

Fig. 513 shows three methods of making the demodulator nonlinear to the 3.58. In the first example, the tube has such a high cathode bias that it is cut off for all except the tips of the 3.58 sine wave. In the second example, grid rectification of the 3.58 is used. The grid functions exactly as a diode plate would in a shunt peak-reading rectifier; in addition the negative dc grid voltage prevents plate current except on the tips of the sine wave. Plain overload is used in the third case; it is necessary for the grid, suppressor and cathode returns to have low resistance to prevent grid rectification. The type of tube used has a very sharp-cutoff suppressor characteristic, so the negative-going side of the sine wave keeps plate current from flowing over much of each 3.58 cycle.

Regardless of which demodulator type is used, the action is the same when the chrominance sine wave reaches the tube. Since the tube is biased to cutoff most of the time, the *amount* of 3.58 changes the *average* plate current and with it the *average* plate voltage. The chrominance sine wave, coming in by the other element of the tube, either adds or subtracts from the voltage of the 3.58 carrier (Fig. 514). When the two are in phase, they *add*, and the *average* plate voltage is reduced. If the demodulator were connected directly to the picture tube grid without following amplifiers, the color governed by that demodulator would go darker. When they are out of phase, they *subtract*. The higher *average* plate voltage makes that color brighter. A 90° chrominance signal does not change the *average* plate voltage because the signals add half the time and subtract half the time, thus cancelling out.

This fulfills the condition that each demodulator ignore the 90° signal intended for the other. The 3.58 pulses must be filtered out before the demodulator signal reaches the picture tube, otherwise a clothlike beat pattern would be visible at all times, on b-w as well as color. This filtering must not extend down as far as 0.5 MHz or it will blur the color picture.

No chroma signal is transmitted for bright white; that is supplied by
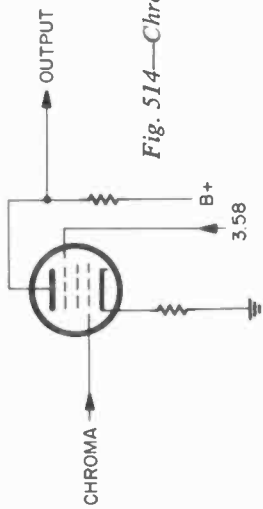
Fig. 514—Chroma signal adds to or subtracts from 3.58-MHz voltage.

STATION R-Y WAVEFORM	A	OV
(R-Y) STATION CHROMA SIDEBANDS	B	OV
RECEIVER 3.58 CARRIER	C	O REF
DEMODULATOR PLATE VOLTAGE	D	(O REF) +200
R-Y RECEIVER CHROMA (AFTER FILTERING OUT 3.58)	E	OV
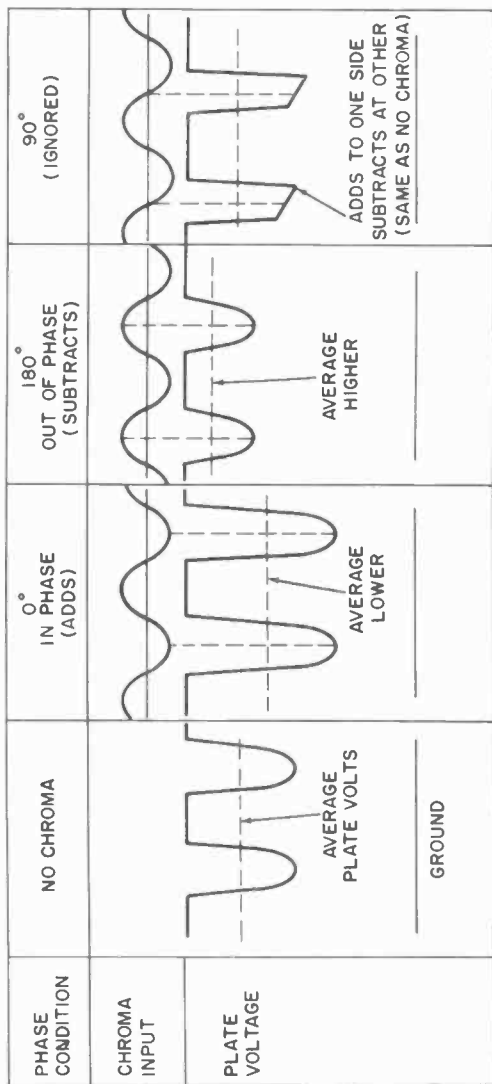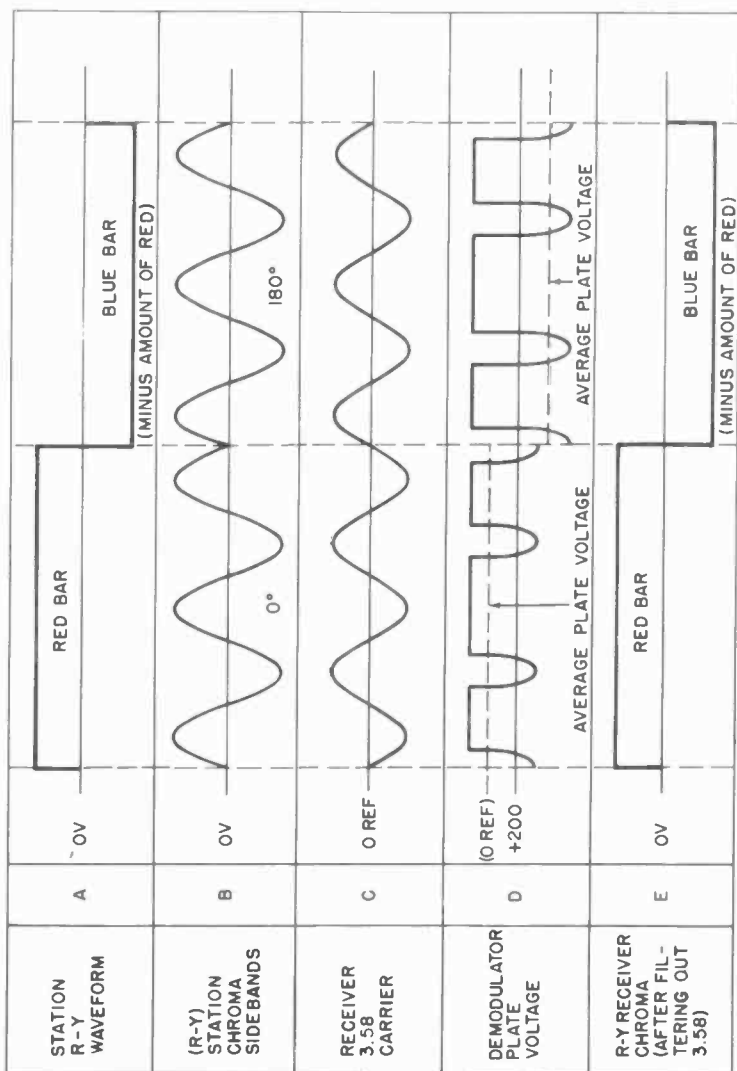
Fig. 515—How R — Y signal at station is changed into chroma sidebands, compared against 3.58 in receiver, and becomes R — Y again in receiver.

the regular b-w video (or Y) signal. For this reason, a demodulator must brighten its color when that color is wanted, but further, must *reduce* that color when a pure color of another tint is required. The black-and-white picture already has red, blue and green combined to make white. If the picture requires a saturated red (red only), the red of the b-w picture must be brightened. At the same time, the blue and green must be turned off completely. This is the reason for the $-Y$ in the terms $R - Y$, $B - Y$ and $G - Y$.

Fig. 515 should make this clearer. Suppose the station's camera is scanning a picture with the left side pure red and the right side pure blue, let's follow only the red signal. Let's say the red camera tube puts out a square wave, shown on line A, with first half above the line where the balanced modulator will put out 3.58 at (say) 0°, and the second half below the line causing the modulator to give out 3.58 at 180°. These phase relationships are shown on line B. These sidebands combined with the 3.58 phase shown on line C raise the average plate voltage to make the picture brighter red during red-bar time. During the blue-bar time, the chroma sine wave adds to the 3.58, lowers the plate voltage and turns off the red picture-tube gun. (We assume for these examples that the demodulator feeds the picture tube directly without an amplifier between.) Blue action is just the same, only reversed.

All tube demodulators work essentially as described, although there is endless variety in the details. Some Motorolas reverse this plan, with the 3.58 on a common grid, and the chroma sidebands split into two channels differing by 90° before being fed to two separate suppressor grids in the same tube. $R - Y$ and $B - Y$ outputs are taken from the two plates, while $G - Y$ is taken from the common screen. More on this later. The Zenith sheet-beam demodulators have four outputs: $R - Y$, $B - Y$, $-(R - Y)$ and $-(B - Y)$. These last two are combined to create $G - Y$. Motorola and Zenith systems are both high-level demodulators (the picture tube is driven directly).

The G-E demodulators using crystal diodes are basically different from the tube circuits just described (Fig. 516). The center-tapped transformer winding supplies two 180° out-of-phase voltages which are coupled through the 36-pF capacitors to the two diodes. The .005-μF coupling capacitor back to the chroma effectively grounds the point between the two diodes, so a negative voltage is developed at the 36-pF-capacitor end of one diode and a positive voltage at the other. (These two should be equal, but if they are not quite, the dc balance pot is adjusted to give zero output to the $-Y$ amplifier. This is to prevent a shift in b-w screen color when the 3.58 is present. There is no color killer or 3.58 oscillator in this circuit; the burst makes a crystal vibrate to creat the 3.58-MHz subcarrier. With no burst there is no 3.58.)

The chroma signal is fed through the .005-μF capacitor to the two diodes where it adds or subtracts from the 3.58 depending on its phase. Assume that at the moment it is phased so that it adds the 3.58 carrier across D1. Then the positive voltage at D1 would increase. This same phase would subtract from the 3.58 at D2 and decrease the negative voltage there. The instantanaeous voltage at the center of the dc balance pot is now slightly positive, making one color brighter. Just the opposite occurs when the chroma phase is backwards; the output voltage is then negative and makes the color darker. This fulfills the requirement for both positive and negative output from any demodulator. A 90° chroma signal will make both voltages increase the same amount so the output is still zero. This satisfies the requirement that each demodulator ignore the signal intended for the other.

In any type of demodulator circuit, the amplitude of the 3.58 carrier is just as important as the amount of the chrominance sidebands in determining the brightness of the color. Weak 3.58 can cause weak color.

A most peculiar condition can occur when there is no 3.58 at all. Many demodulators will (on a very strong chroma signal) create a single false color that will appear wherever *any* tint should be. The reason is shown in Fig. 517. The pentode type of demodulator will show only green, while sets with the triode type will show only purple when there is no 3.58. The reason for this is not "pentode vs. triode," but in the difference in the methods of achieving nonlinearity in the two types. The pentode will have less plate voltage than normal when the 3.58 is missing. A strong chroma signal will bring it part way back, so there is a higher plate voltage with chroma. Both X and Z demodulators will produce the *same* positive-going output, which is inverted in the $-Y$
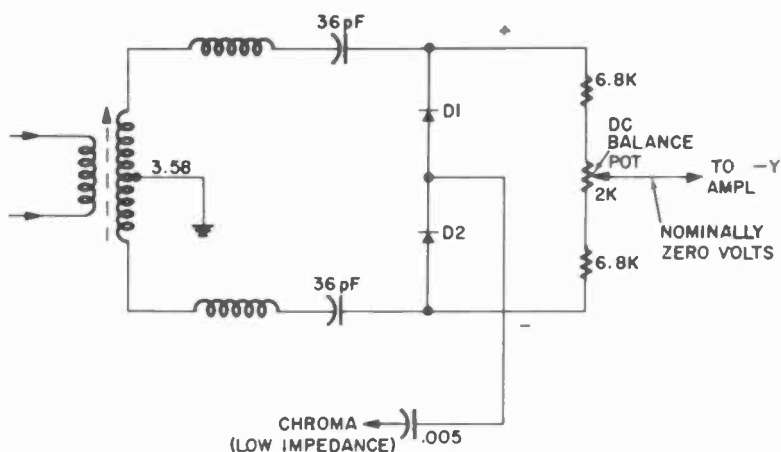
Fig. 516—G-E sets use two diodes as demodulator.

amplifiers. At the picture tube, this gives negative-going red and blue and positive-going green (for green is always backwards from the sum of red and blue); the screen will then show only green wherever there should be any color at all. The triode action is just exactly the reverse, so those models will have only purple on the screen—or positive amounts of red and blue and a negative amount of green.

Zenith sets with sheet-beam demodulators, G-E's with crystal diodes and RCA's CTC19, CTC20 and CTC24 show *no* color when the 3.58 is dead. Here is the easy way to remember the rule: *if there is only green or magenta (purple in the picture, and the fine-tuning and color controls work normally, but the tint control does nothing, the 3.58-MHz oscillator is dead.*

It is usually easy to troubleshoot demodulators from the symptoms on the screen plus voltage and resistance analysis. For the occasional tough case, a scope will help by showing the waveform actually in the circuit.
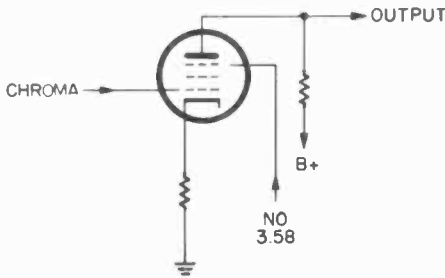
LOSS OF 3.58
LOWERS PLATE VOLTAGE.
EXCESSIVE CHROMA CAN
RAISE IT BY OVERLOAD.
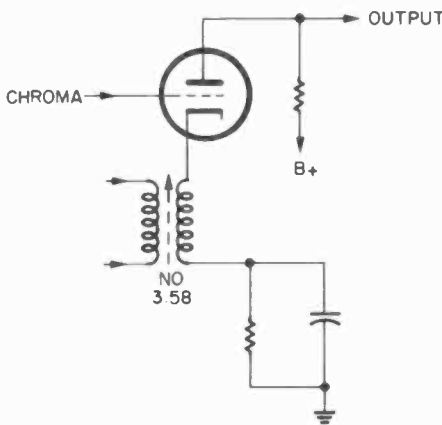
LOSS OF 3.58 RAISES
PLATE VOLTAGE. EXCESSIVE
CHROMA INCREASES PLATE
CURRENT AND LOWERS PLATE
VOLTAGE.

Fig. 517—How loss of 3.58 can cause one color only, from chroma overload.

Chapter 6

Specific Chroma Troubleshooting

T HE ONE-WORD ANSWER TO OUR search for color-receiver malfunc-
tions is: *knowledge!* This knowledge starts with our understand-
ing of the circuits and their functions, continues with information we re-
ceive from the customers and from visual symptoms on the screen, and
concludes with the results from the various tests we make on the ma-
chine. The longer I analyze color troubles, the more convinced I am of
the value of related tests for finding the exact trouble spot. The most val-
uable advice I can give you is: test, test and *test!*

We need to know the normal voltages and waveforms in the chroma
channel if we're to recognize the abnormal ones. The signal source for
waveform analysis is a *keyed-rainbow generator.* The receiver must be
correctly tuned to it, as described under color-bar analysis, and the pat-
terns should be viewed on a good service-type scope. (For color, the
scopes vertical amplifier should be fairly flat out to 4 MHz). We will
analyze first the RCA CTC16X chassis, then other brands and models
to make the methods universal. The whole circuit is given in Fig. 601
so we can locate the points we are viewing on the scope.

The video detector waveform (Fig. 602) shows one large spike (for
horizontal sync and blanking) and 11 smaller envelopes of keyed
3.56-MHz signals which will eventually become color bars on the screen.
Twelve bars are generated, but one is lost in the sync spike. Fig. 603
shows the overpeaked spike and asymmetrical 3.56 envelopes resulting
from a wrong fine-tuning adjustment (too near the sound bars). The
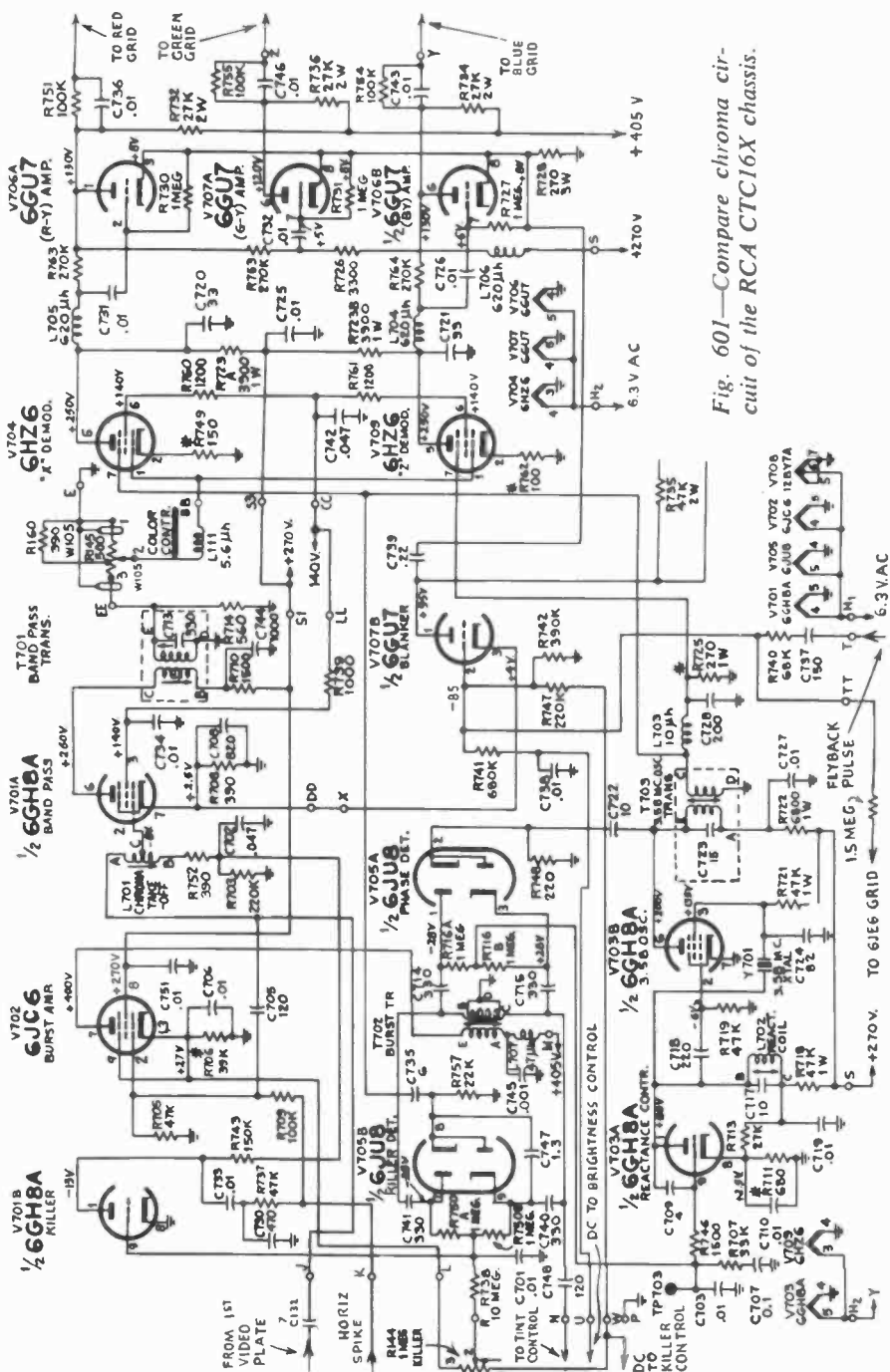
Fig. 601—Compare chroma circuit of the RCA CTC16X chassis.

waveform at the chroma takeoff point (plate of the first video amplifier) is shown in Fig. 604; but on the other side of the 7-pF coupling capacitor (C132), the sync spike is removed by the tuned takeoff coil. Only the 11 envelopes of 3.56 remain; see Fig. 605. The first envelope is amplified by the *burst keyer* and locks the color oscillator. This *burst* occurs during horizontal retrace time and does not form a color bar, so it is removed from the chroma i.f. by the horizontal blanker pulse at the cathode (Fig. 606) to prevent interference in the demodulators. Fig. 607 shows the signal at the chroma i.f. plate, or at the input to the color control. This "hot" lug of the color control is one of our most important test points, so notice carefully the voltage on it. From the color control, the chroma sidebands go to the demodulators, so let's take a sidewise step and follow the burst through the color-locking and 3.58-oscillator circuits before looking at the demodulators.

The waveform at the grid of the 6JC6 burst amplifier (V702) (Fig. 608) shows the same 11 envelopes of 3.56, but the first one is on top of a large horizontal spike. The burst amplifier (actually a keyer tube) amplifies *only* during the time the tip of the spike is at the grid, so the burst from the generator or station *must* be on top of the spike. If the generated burst should be on the side of the spike, the burst in the set will be weak or missing. The horizontal spike would be to blame, then, for the burst can't be changed enough in phase. The spike is normally delayed by R709 and C705, so any change in the tolerance of these parts, or a horizontal oscillator that fires at the wrong time, will eliminate the burst. The plate waveform (Fig. 609) should be a strong single burst and nothing else; the same waveform is also applied to the phase and killer detectors from T702's secondary.

The 3.58 from the oscillator is supposed to be a pure sine wave, and gives us very little to see. It is difficult to lock on a service scope, so to measure the p–p voltage, or to look for erratic output or hum modulation, we usually set the scope sweep for vertical or horizontal sweep frequencies. See Fig. 610.

The waveforms at the X and Z demodulator plates (before the 3.58 is filtered out) are shown in Fig. 611. The 3.58 "grass" makes the scope picture hard to interpret, so we usually look at the $R - Y$ and $B - Y$ grids, as shown in Fig. 612.

The red, blue and green picture-tube grids are *the* most important test points of all, for from them we can learn the signal voltage (amplitude), and tint or phase (crossovers) of the three colors. The voltage and waveform of the horizontal blanking spike can be seen also; we can even tell if the color is out of lock (Fig. 613). Only blurred bars or beat patterns can't be seen here. If a receiver passes these voltage and

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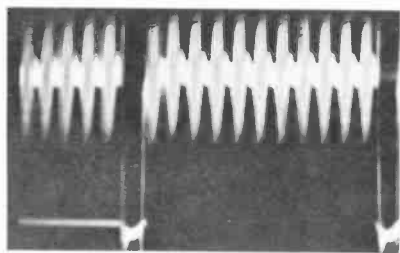
Fig. 602—Video detector waveform.
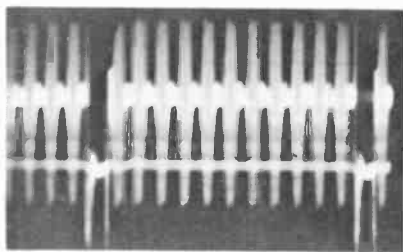
Fig. 603—Lopsided detector waveform with fine tuning adjusted into sound bars.
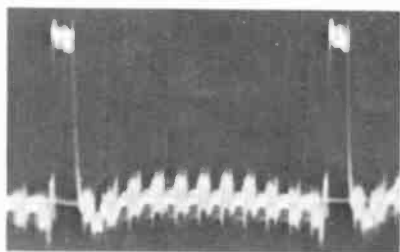
Fig. 604—Waveform at first video-amplifier plate.
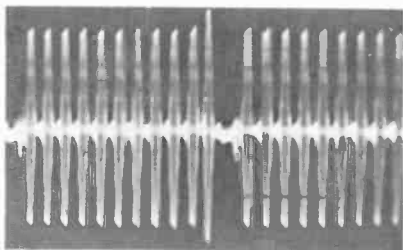
Fig. 605—Waveform at top of takeoff coil. Eleven bars are visible.
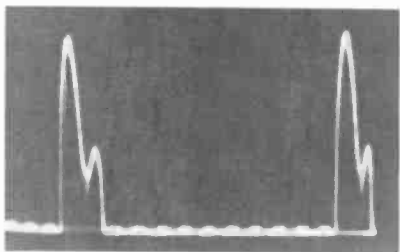
Fig. 606—Horizontal blanking at bandpass-amplifier cathode.
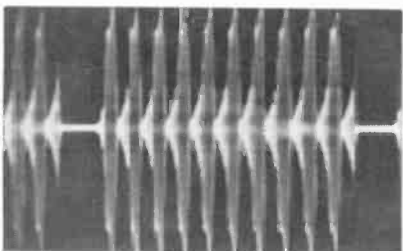
Fig. 607—Waveform at bandpass-amplifier plate. Now there are 10 bars, the number seen on screen.
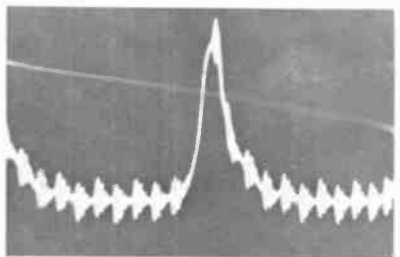
Fig. 608—Waveform at burst-keyer grid. 3.58-MHz envelope on top of horizontal spike will be used for burst.
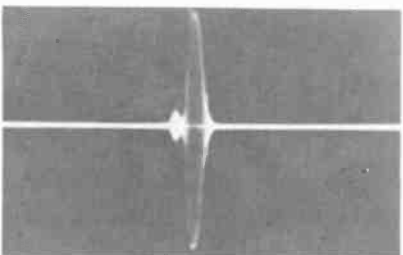
Fig. 609—Waveform at burst-keyer plate.

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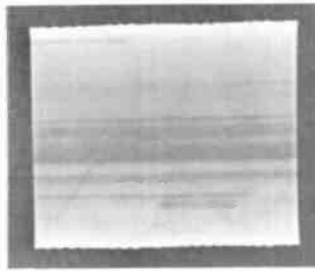
Fig. 610—Waveform of 3.58-MHz oscillator signal with scope sweep set for 7,875 kHz.
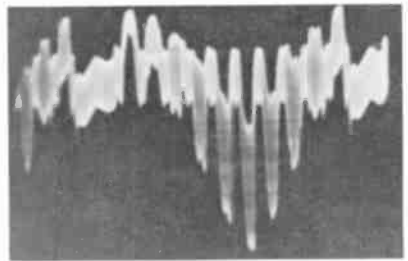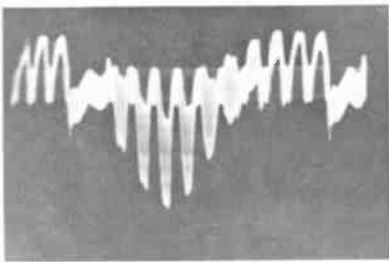
Fig. 611—Waveforms at plate of X demodulator (left) and Z demodulator.
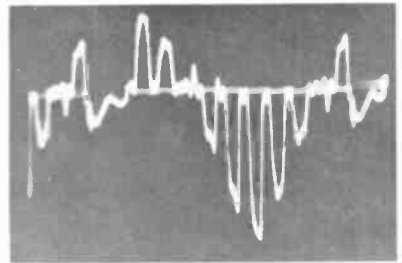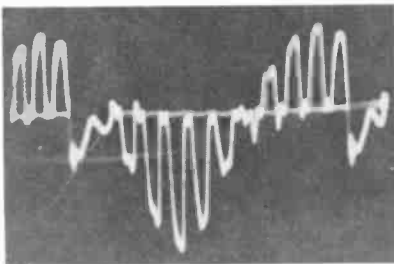
Fig. 612—Waveform at $R - Y$ (left) and $B - Y$ amplifier grids.
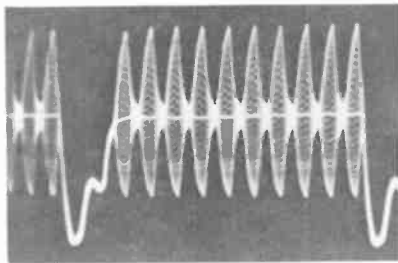
Fig. 613—Waveform at red picture-tube grid with color out of lock.

waveform tests and the visual tests for good color bars, it is certain to show good color on any station.

Fig. 614 matches the scope waveforms with the color bars on the screen to show crossovers and maximum and minimum bars.

Is a scope the only answer?

Suppose you're on a callback, or a warranty job—or for any other reason you want to check out a chroma circuit accurately in someone's home—how much can you do with only a vtvm and a color-bar generator? It may surprise you, but the answer is: almost everything you can do in the shop with a scope. Don't believe it? Okay, read on.

Let's do some tests to find out how much of the chroma circuit we can measure accurately without loading or changing signal voltages. Even dc vtvm probes, with the traditional 1-meg resistor in the tip, have too much capacitance for many of the points we want to check. The remedy is simple: Fasten a 1-meg carbon resistor directly onto the

FIRST BAR
LEFT SIDE OF
PIX

3rd BAR
BRIGHTEST RED

6th IS AT
CROSSOVER
(SAME AS
BACKGROUND)

BACKGROUND SPACE
BETWEEN BARS IS
DEMODULATOR
REFERENCE VOLTAGE
FOR NO COLOR

HORIZ BLANKING
PULSE DURING
RETRACE TIME

10th BAR RIGHT SIDE
OF PIX

HORIZ BLANKING
PULSE

9th BAR

a

BACKGROUND BETWEEN BARS   3rd AT CROSSOVER   6th BAR BRIGHTEST BLUE   9th AT CROSSOVER

b

Ist BAR AT CROSSOVER   BACKGROUND BETWEEN BARS   7th BAR AT CROSSOVER   10th BAR BRIGHTEST GREEN

c

Fig. 614—Comparison of red bars—page 70 (a) blue bars (b) and green bars (c) to waveform on scope connected to corresponding picture-tube grid.

tip (Fig. 615). Secure it with plastic tape and clip the other end fairly short to make it a probe tip. The only capacitance we add to the circuit now is the small capacitance of the resistor itself. The resistor will lower the readings, so just change the probe to the AC/OHMS position to restore the calibration. Are we just splitting hairs, or does this really help? The original probe applied to the burst amplifier plate (pin 7) reduced the burst from 125 volts to 107. The modified probe changed the voltage by only 2 volts. The original probe on pin 6 (plate) of the 3.58 oscillator reduced the output by about 30%, but the probe with the external resistor changed it only about 5%.
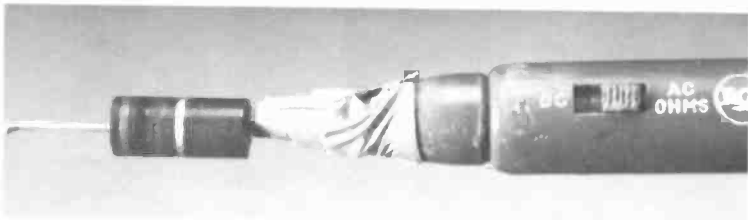
Fig. 615—*Add 1-megohm resistor to tip of vtvm probe to reduce capacitance loading when you measure dc volts in chroma channel.*

The next probe modification is more drastic, for it involves using a *scope* probe on the vtvm for really low capacitance. The circuits of the scope and vtvm are not at all similar, so it is not likely the normal 10-to-1 ratio of normal-to-low capacitance readings will be obtained. With the probe in the direct position, we would use the probe on OHMS or AC (high probe capacitance). For dc we add the external 1-meg resistor, or for ac, where low probe capacitance is needed, we slide the switch to the LOW CAP or ×10 position and multiply by whatever attenuation there is to get the reading.

To prove this probe-swapping method, I measured most of the signal voltages in a chroma channel using both high- and low-capacitance probes on the meter and checking the readings against a scope with the usual low-capacitance probe. I checked for loading or detuning of the chroma circuit by noting any changes in the color bars on the screen. The chart of Fig. 616 gives the results which show the meter with the low-capacitance probe loaded the circuits down exactly the same way as the scope and its low-capacitance probe. The voltages were fairly close on the scope and meter except for the few points where blanking spikes are found. Even with blanking spikes, we can check a normal receiver and write the measured voltages on the schematic to give us a standard for the next repair on that model.

CIRCUIT POSITION	Vtvm normal probe	Vtvm low-cap probe actual	corrected	Scope low-cap probe
1. Chroma input coil	4.5 much less color changes plate	2.4 more color ph. changes	28.8	26 more color ph. changes
2. Bandpass grid	6.0 less color	1.03 little change	12.36	18 little change
3. Bandpass plate	11 much less color much ph. change	4.8 slightly less color some phase change	19	13 slightly less color some ph. change
4. Top of color control	18.5 slight ph. change	1.6 no change	19	18 no change
5. Plate pin (6) of X demod	18 ph. change	2.2 no change	26.4	26 no change
6. Supp. pin (7) of X demod	21 no change	2.2 no change	26	26 no change
7. Plate pin (6) of Z demod	26 ph. change	3.0 no change	36	38 no change
8. Supp. pin (7) of Z demod	20.5 blue to right	2.6 slight ph. change	29	25 slight ph. change
9. Grid pin (2) R—Y ampl.	17 slight ph. change	1.85 no change	22	21 no change
10. Grid pin (7) B—Y ampl.	24.5 slight ph. change	2.5 no change	30	30 no change
11. Grid pin (7) G—Y ampl.	3.6 no change 200 both	unreadable 22 both	264	5 no change 220 color
12. Plate pin (1) R—Y amp.	blanking & chroma 115 no color blurs picture	11 no col. no change	132	110 blanking no change
13. Plate pin (6) B—Y amp.	220 both 110 no color blurs picture 145 both	24 both 11 no col. no change 14.5 both	288 132 174	260 color 110 blanking no change 75 color
14. Plate pin (6) G—Y amp.	120 no color blurs picture 10.8 both	11 no col. no change 0.9 both	132 10.8	120 blanking no change 6 color
15. —Y amplifiers common cathode	9.8 no color no change	0.85 no col. no change	10.2	9.5 blanking no change
16. Osc. grid pin (2)	12 far off freq.	1.2 slightly off freq.	14	14 slightly off freq.
17. Osc. plate pin (6)	8 no color	5.6 little color	67	50 little color
18. Osc. plate transformer terminal C	21 no change	2.2 no change	26	21 no change

Fig. 616—Comparison chart of peak-to-peak voltages obtained with scope and low-capacitance probe, versus those obtained with vtvm using normal and low-cap probes. Changes in color intensity or phase are noted. Signal source is color-bar generator.

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Perhaps the most surprising fact we can learn by studying the chart is that many voltages can safely be measured with the normal high-capacitance vtvm probe.

Another bonus is the discovery that even those circuits most changed by the probes usually have another branch where probe capacitance is no problem. In general, these points will be lower in impedance. For example, the top of the chroma takeoff coil is very sensitive to probes, but the tap on the same coil supplying the chroma i.f. amplifier grid is affected very slightly. The plate transformer primary of the chroma i.f. stage becomes detuned even by a low-capacitance probe, yet the secondary (connected to the color control) is not changed even by a high-capacitance probe. The 3.58 oscillator grid, plate, and screen were the most affected by probes of any points tested, but the secondary (terminal C) of the oscillator plate transformer is not changed by any of the probes. This method of testing the insensitive points of critical circuits is similar to the suggestion made earlier that we judge the condition of a complete circuit by measuring the output signal or voltage.

Test-point and vtvm methods

Adjustments give valuable troubleshooting information, whether or not the adjustment works normally. In this case, the complete afpc (automatic frequency and phase control) series of adjustments can either eliminate the problem or give us a wealth of data to help us find the defective part. Here is the sequence using color bars (Fig. 617).

1. Ground TP703, and turn the color killer fully counterclockwise.
2. Turn the color control up until color is seen easily. Adjust the reactance coil (L702) until the color bars cross the screen upright and nearly stop.
3. Remove the 6JC6 burst amplifier tube. Connect your vtvm (with the external 1-meg resistor on the end of the probe) to pin 1 of the 6JU8 phase detector.
4. Adjust the oscillator plate transformer (T703) for maximum negative voltage on the meter. Expect -8 to -9 volts.
5. Repeat steps 1 and 2.
6. Remove the TP703 ground and re-install the burst tube.
7. Set the tint control to the middle of its rotation.
8. With the vtvm still attached to 6JU8 pin 1, adjust the burst transformer (T702) for maximum voltage on the meter. Expect -45 to -60.

REACTANCE COIL
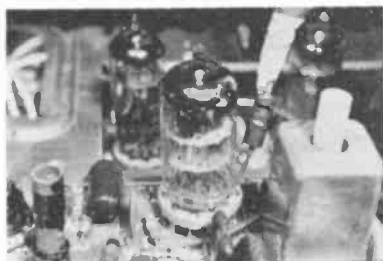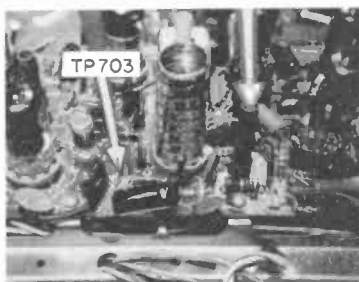
METER CONNECTED
TO PIN I OF THE 6JU8

OSC PLATE TRANS

BURST TRANS
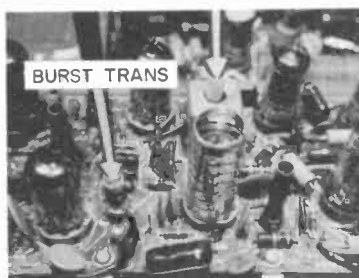
Fig. 617—Complete afpc adjustments for RCA CTC16X. Ground TP703 and adjust reactance coil so bars cross screen upright. Remove 6JC6 burst amplifier (keyer) and connect dc vtvm (15V range) to 6JU8 pin 1. Use external 1-meg resistor on probe. Adjust oscillator plate transformer for maximum reading (−8 to −9 volts). Remove short from TP703 and replace 6JC6. Switch vtvm to −150V range and set tint control to mid-range. Adjust burst transformer for maximum reading (−40 to −60). Remove meter and try locking.

9. Remove the meter and check the range of the tint control; red should move from color bar No. 2 to No. 4 (or more).

10. Try color-locking by reducing the chroma at the generator, or by mistuning the receiver.
11. Turn the set's channel knob to a blank channel and (with color control at maximum) adjust the color-killer control until the confetti *barely* disappears.
12. Tune in a station colorcast and try fine-tuning, color, tint and brightness controls to obtain a good color picture. Change channels and note if the color locks immediately (it should).

What have we accomplished with these adjustments? If all parts, tubes and wiring were normal, we have made the color lock solidly with correct tint. But that's not all. Let's go through that sequence of adjustments again and notice some of the troubleshooting information ready for the taking.

1. Grounding the test point removes all color locking, and puts the reactance tube grid at zero volts. We defeat the color killer to prevent loss of color when the 3.58 oscillator is off frequency. Always do this when testing or setting color locking.
2. We are watching the color bars on the screen, so color must be turned up. The reactance coil is the only adjustment for the 3.58 oscillator frequency. If it does bring the oscillator into frequency, about 95% of the reactance and oscillator parts have been proved good.
3. All burst must be removed before the oscillator transformer adjustment can be set. If the burst tube is part of a dual tube and can't be removed from the socket without stopping some other function, just ground the grid with the shortest possible jumper wire. Pin 1 of the 6JU8 is a very important test point; in this step it is rectifying the 3.58 from the oscillator and thus can show when maximum is obtained.
4. The oscillator plate transformer not only produces maximum 3.58 for the demodulators and phase detectors at resonance, but also changes the phase of the 3.58. Maximum amplitude usually gives correct phase as well. The -8 to -9 volts is average; if it is only -2 or -3 the color locking will be very weak. Strong burst and 3.58 are necessary for strong locking.
5. Steps 1 and 2 should be repeated if the oscillator plate transformer required a lot of adjustment. It has some effect on frequency.
6. The steps above restore the reactance tube grid to the phase detector, and replacing the burst tube should bring back the burst.

If the color goes far out of lock (many color stripes), the phase detector is unbalanced, or voltage is leaking into the reactance grid circuit. Measure the grid voltage, also pins 1 and 3 of the phase detector, to find the source of the wrong voltage. If the color is still not locked after the burst tube is replaced (and the 6JU8 pin 1 is not more than -30 volts), there is no burst.

7. The tint control should give correct tint when approximately centered in its range. This allows some variation to correct poor station tint.

8. Maximum burst and correct burst phase usually occur at the same adjustment point. At any rate, start from the maximum-voltage point. A small readjustment can be made later for correct tint action.

9. The third bar from the left needs to be maximum red (when all the bars are turned on), but the tint control should move the red tint from bar 2 to bar 4 if there is enough range.

10. If all the voltages during the previous adjustments were above the minimums given, the locking should be very good, but check it anyway to be sure it doesn't go into stripes when the program changes.

11. The color-killer adjustment (except killer control) are made automatically by the phase-detector adjustments. But the adjustments may have changed the amount of burst and therefore the amount of control the killer detector has over the killer. The color killer should be the last thing adjusted.

12. Even if these generator checks seemed normal, color should be checked on a colorcast. The antenna or lead-in might weaken the color. The generator burst is wider (more cycles) than the station burst, and horizontal-oscillator phasing can be more critical for burst keying on the station.

The simplified locking adjustment for in-the-home work would include only steps 1 and 2, then remove ground from TP703, then steps 9, 10, 11 and 12. But we would miss the dc voltages that tell us so much about the amount of burst and 3.58.

A wrong voltage or a wrong reaction to an adjustment calls for more testing to find the reason for it. In this particular locking circuit, we should start at the oscillator and work backward for the most accurate results. What value has good burst if the oscillator is completely off frequency? Joe Bloe hasn't learned that yet, but whether it is vertical, horizontal or color locking, we must know whether the heart of the problem

is wrong oscillator *frequency* or weak sync *locking* on sync pulses or burst. That's easy to find out in the CTC16X chroma circuit, for grounding the test point TP703 eliminates *all* sync and frequency-correcting signals. The oscillator *must* be made to run at the right frequency before any other testing can be done. Suppose the screen shows about 12 diagonal rainbows; the oscillator is way off frequency. The tunable transformer in the plate circuit just cannot change the frequency that much, so we go on to the screen resistor and capacitor, the grid resistor and coupling capacitor, then to the components in the reactance stage.

It is hard to imagine any defect here that could not be found easily by voltage and resistance analysis, except for open capacitors, and those can be substituted. Joe would probably suspect the 3.58 crystal first, but actually this should be one of the last things to check. What is the forward-to-back ratio of this 3.58 crystal? Watch out! The crystal is made of pure quartz, so it checks open in both directions. The only true test is in an actual oscillating circuit, so replacement gives the only real answer. *Caution:* there is no universal 3.58 crystal; one intended for a different model may not work at all in your set, or may be far off frequency.

Did the number of diagonal stripes change when you adjusted the reactance coil? It should have, even if the frequency is far out. If the number did not change, the reactance coil may be open. A shorted 10-pF capacitor across the coil would kill the oscillator, not change the frequency.

Suppose the oscillator adjusted to frequency with the test point shorted to ground, but slanted into 15 lines when the ground was removed. Obviously, the voltage at TP703 is no longer zero. The polarity and amount of voltage at the test point may tell us a lot, so let's check it. Assume it measures −40 volts. Pin 1 of the 6JU8 is 40 volts more negative than pin 3, and about the only way this can happen (since there is no other way to get that much negative voltage at the test point) is for pin 3 to have insufficient positive voltage. The diode from pin 3 to pin 2 could be open, or the 330-pF coupling capacitor to pin 3 might be open, or that half of the burst transformer might be open. If the voltage at the test point had been *plus* 40, the defect would be the same, only you'd suspect the components connected to pin 1.

But suppose the test point voltage was 9 volts, what then? This is much too high to be normal correcting voltage, for it runs from about −3 to +3 before the color falls out of sync. Measure the dc voltages at pins 1 and 3 and see if the difference between them is greater than the voltage at the test point. If it is, the trouble is in the diodes at pins 1 and 3, or in the components connected to them. But if the test point

voltage is higher than the difference between pins 1 and 3, the voltage is leaking in somewhere else, possibly through a leaky 4-pF C709 (from grid to plate of the reactance tube) or a gassy 6GH8A reactance tube. Yes, test point TP703 is much more than just a point to ground when adjusting frequency!

Where would the trouble be if pin 1 measured -50, pin 3 $+50$ and the test point zero, but there was absolutely no locking? If the reactance tube were open or otherwise inoperative, TP703 would vary 4 or 5 volts as the colors drifted across the screen. That is not true here, so the most likely defect would be no 3.58 at pin 2 of the 6JU8. To verify that, we remove the 6JC6 burst keyer and measure the voltages at pins 1 and 3 on the 6JU8 again. Instead of the normal -8 or -9, we find zero. That proves the absence of 3.58 at pin 2. Just three things can cause the 3.58 to drop out (besides a solder splatter or other accident): C722 might be open, or R748 shorted (not likely!), or the tube has a cathode-to-heater short. Just remember, normal 3.58 must be here to be compared with burst, or the locking will be almost nil.

But what if there were no color locking when we ungrounded TP703, yet pin 1 was -8.5 and pin 3 was $+8.5$? That would indicate no burst getting to these pins. First, check 6JC6 plate and screen voltages. The screen voltage comes directly from the 270-volt line, so it is not likely we have lost this voltage. Zero plate voltage could be caused by an open in L707 or in the primary of T702. If these are normal, what is the cathode voltage? Plus 46 means normal tube current with normal horizontal pulse on the grid, $+6$ means normal tube current but *no* horizontal pulse at the grid. Usually a pulse at the grid means the burst is there also, for there is only one more component to block it: the 120-pF coupling capacitor. The burst must be on the other side of the capacitor, for we have color. But the phases of the burst and pulse might be wrong because of a defect in horizontal-oscillator phasing or a wrong value of C705 or R709. The ac scale of your vtvm will identify all these voltages except the burst at the grid of the burst-keyer tube.

To review: The major test points in the burst-oscillator circuits are:

1. Pin 1 (and/or pin 3) of the 6JU8 phase detector. Zero volts means no burst and no 3.58 or no rectification in the diode. Up to -15 means there is no burst, but harmonics of the video are present. Up to -29 means off-channel snow, but over -40 means burst is present.
2. TP703, for locking adjustments, can also be used to analyze the phase-detector voltages fed to the reactance stage.
3. The secondary of the oscillator transformer is connected to the

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suppressor of the X demodulator, and the impedance is low enough for us to check the voltage with the normal ac vtvm probe. Normal signal is around 20 volts p–p, and shows the oscillator is running.

There are two major test points in the chroma i.f. channel:

1. Fig. 618 is a repeat of the picture from Chapter 3 showing R703, the 220K resistor which is the most convenient access to the killer voltage applied to the grid of the 6GH8 chroma i.f. tube.
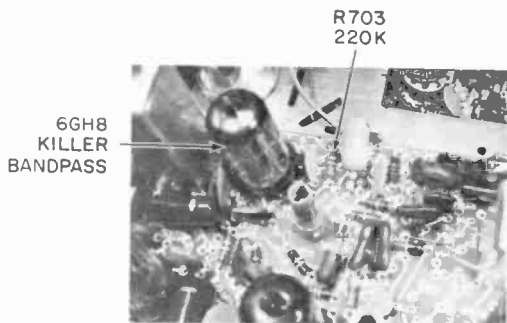
Fig. 618—Use R703 as test point for killer voltage.

This point can be grounded to eliminate any possible killer voltage, or the voltage may be measured. Check this circuit *first* in cases of complete loss of color.

2. The top of the color control is a low-impedance point where we can check the amount of chroma signal available to the demodulators. The normal ac probe of a peak-to-peak-reading vtvm will
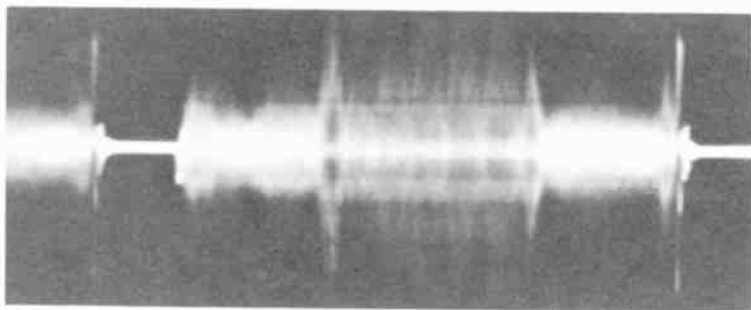
Fig. 619—Chroma waveform at color control during colorcast. Voltage varies with picture; bright colors reach about 6V p–p.

give us an accurate reading without loading. Any p–p voltage above 12 on color *bars* should give bright, saturated colors on a color-TV *program*. Fig. 619 shows the scope waveform at one instant during a colorcast. The voltage and waveshape vary constantly, so we don't use a station signal as much as we use color bars. But on a colorcast any voltage over 6 (p–p) represents extremely bright colors.

Have you noticed we have two branches of the chroma channel from a common source (the takeoff coil)? The first is the chroma i.f., and the second is the burst channel. The burst and chrominance sidebands are the *same* frequency, although they are present at different times. Therefore, strong burst means a strong chroma signal at the takeoff coil; and a strong chroma signal means a strong burst is present at the takeoff coil. One channel can thus be used to judge the other, even though they are not identical and don't do the same things.

Each of the following observations has some exceptions, but they are certainly accurate enough for our "play the percentages" advice.

1. Weak color usually originates in the chroma i.f. or the picture i.f. alignment. (Weak 3.58 can cause weak color, but very rarely.)
2. Bad color locking or wrong phase of all colors is caused by the burst/oscillator channel.
3. Blurred colors (all of them) are usually caused by chroma i.f. or picture i.f. misalignment.
4. Wrong phase, amplitude or sharpness of *one* color is usually caused by a defect in the demodulators or −Y amplifiers .

Chroma troubleshooting with trouble-seeking charts will be discussed in the next chapter.

Motorola chroma circuitry

Other makes and models also have test points where measurements can be made without loading the circuit under test. Fig. 620 shows the chroma i.f. of the Motorola TS918 with the major test points marked. The primary of T104 (the takeoff transformer) is loaded with a resistor to reduce the gain at its resonant point of 3 MHz, while the secondary is unloaded for high gain and sharp tuning at 4 MHz, which gives extra gain to offset the falling response curve of the picture i.f.'s. A meter or scope probe touched to the secondary would cause serious detuning, so the signal should be checked at the primary.

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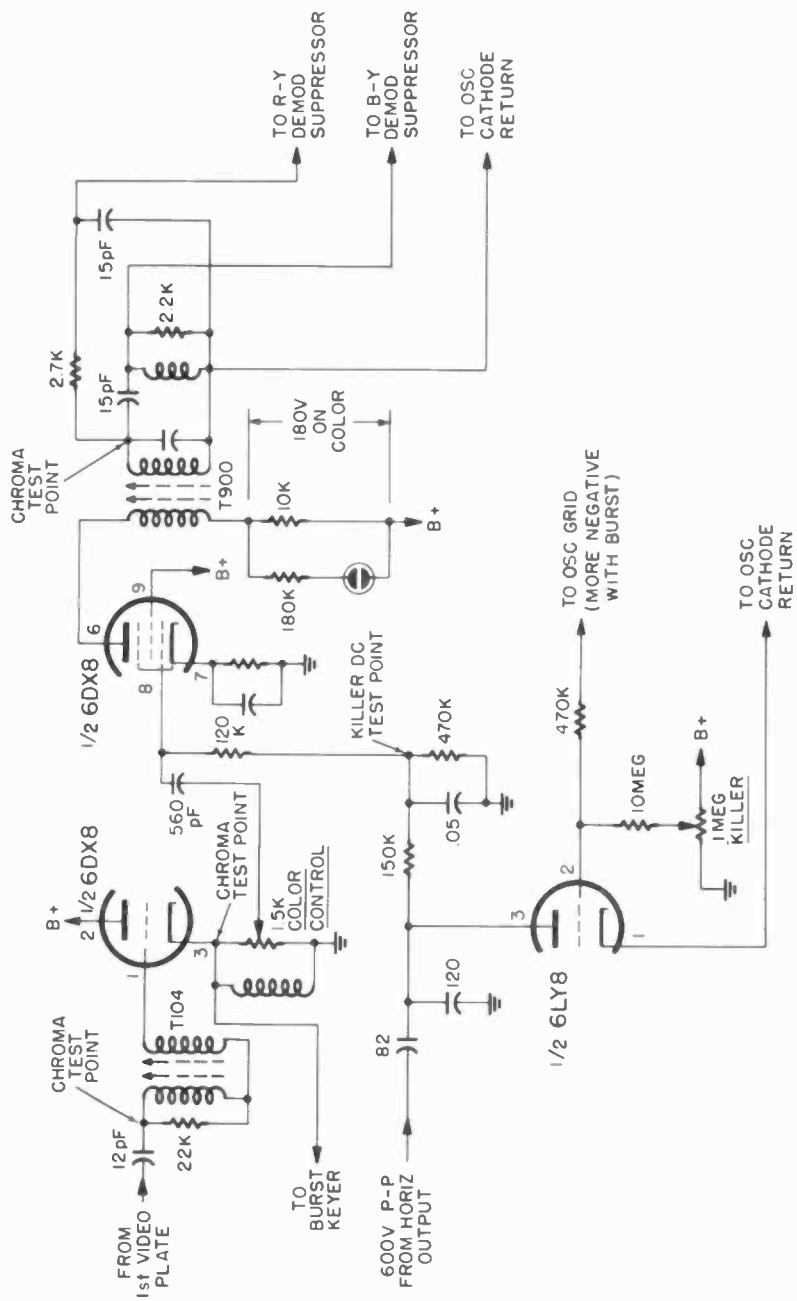
Fig. 620—Simplified schematic of Motorola TS918 chroma i.f.

The first chroma i.f. tube is a cathode follower which changes impedance but gives no gain. The cathode has very low impedance and is ideal for looking at or measuring the chroma signal. It is also the takeoff point for the burst. The color-killer dc is fed to the second chroma i.f. grid, so the test point for measuring or disabling the killer voltage is the ungrounded end of the .05-μF capacitor. The primary of T900 is another spot to avoid (impedance too high), but the secondary and the demodulator suppressor grids are fine points to measure. The secondary should check about 40 V p-p, 6LE8 suppressor pin 7 ($B-Y$) about 20 volts and pin 2, the $R-Y$ suppressor, about 14 volts. The picture tube grids should show the same waveforms as the ones given before, except there will be no horizontal-blanking pulse (blanking is done at the CRT screens). The demodulator diagram is given in Fig. 621; we'll refer to it later.
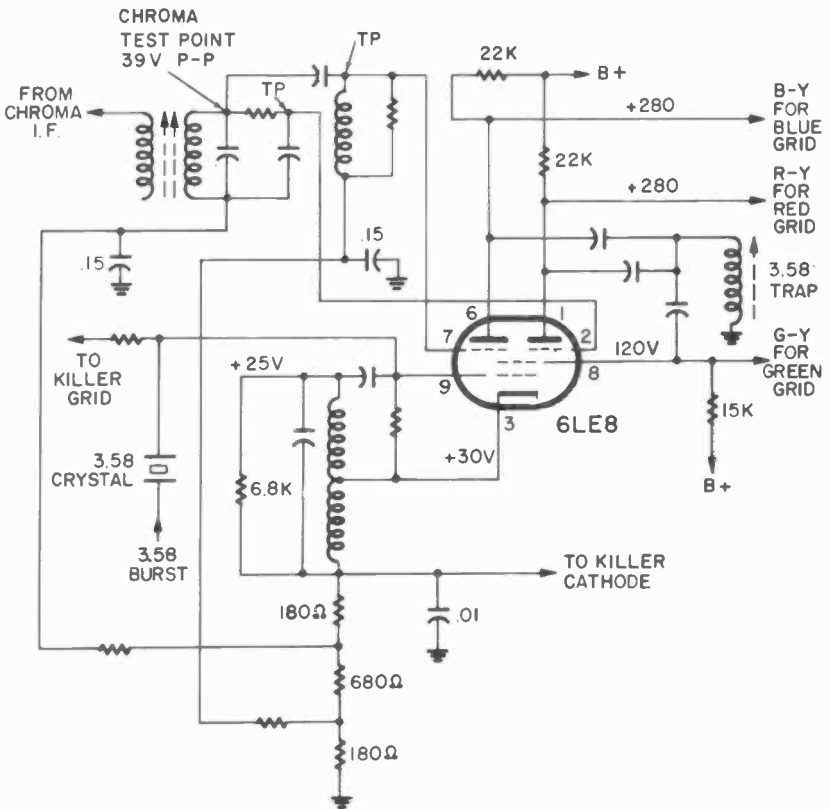
Fig. 621—Motorola TS918 demodulator/oscillator.

Fig. 622 shows the burst stages. Both are keyed and both are amplifiers. The entire chroma i.f. signal is fed to the cathode of the triode burst keyer, while the grid has a large positive-going pulse applied to it. The pulse is delayed and reduced by the 33K resistor and the 680-pF capacitor in the grid circuit. The grid draws current on the tips of the spikes and develops a negative voltage large enough to cut off the tube when there is no spike at the grid. The tube draws plate current and amplifies only when the spike is maximum and the burst appears at the cathode. The burst is amplified and other frequencies are eliminated.
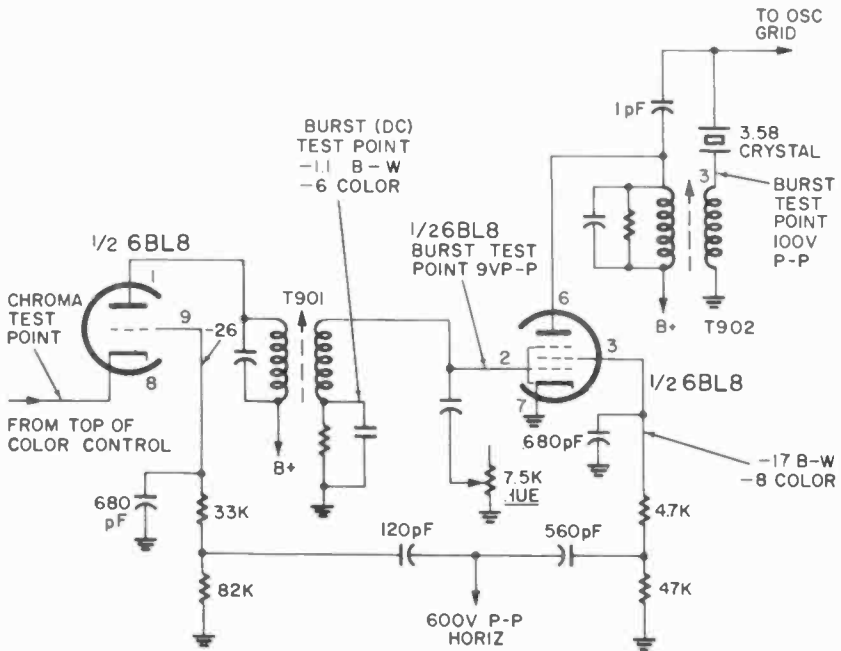
Fig. 622—Motorola TS918 burst keyers (simplified).

The primary of T901 is high-impedance, so the secondary should be used for measurements. This is most conveniently located at the grid (pin 2) of the 6BL8. T902 is not quite so critical, but it is better to attach the meter or probe to the secondary. The dc voltage at the bottom of T901 secondary is also an indication of the amplitude of the burst at the grid since it runs about −1 on b-w and near −6 on color with burst. The pentode half of the 6BL8 is also keyed, by a horizontal pulse at the screen. Again, the pulse is delayed by the 4.7K resistor and the 680-pF capacitor at the screen grid. The screen is negative, so the

tube does not amplify until the positive pulse is fed to the screen and the burst is fed to the grid.

No phase detectors are used here. Instead, the burst (of large amplitude) is channeled through a 3.58 crystal used as an extremely high-Q mechanical filter to make certain *only* 3.58 goes through. The grid and cathode of the 6LE8 demodulator function as a 3.58-MHz electron-coupled oscillator of low stability. The huge burst is fed to this oscillator's grid, forcing it to lock in with the exact frequency and phase of the burst. The phase of the burst is adjusted in the second burst grid circuit to allow for station or receiver-alignment phase differences.

The 6LE8 is used as the 3.58 oscillator, $R-Y$ demodulator, $B-Y$ demodulator and mixer for the derived $G-Y$ signal (Fig. 621). It has two plates, two suppressor grids, but one common control grid, screen grid and cathode. Most receivers shift the phase of the 3.58 applied to one of the demodulators by 90° and feed the same chroma to both. Here the grid and cathode are used as the 3.58 oscillator, and there is no way to split its phase. Instead, the *chroma* signal is split by phase-shift network into two voltages differing by 90°. These two voltages are fed to the two suppressors. The principle of demodulation is still the same. The output from the 6LE8 is sufficient to drive the picture tube grids directly, so it is called *high-level demodulation*.

Fig. 623—"Screen-wire" pattern caused by not trapping or filtering out 3.58-MHz signal from demodulator circuitry.

To understand how $G-Y$ can be taken from an unbypassed screen resistor in this circuit, we must go back to a peculiar tube characteristic. Suppose we have wired a pentode tube in the conventional way. If we vary the negative voltage on the control grid, we find both screen and plate currents decrease with more negative grid bias. But if we keep the grid voltage fixed and increase the negative voltage on the suppressor, a strange thing happens: The screen current increases while the plate

current decreases. In the 6LE8 demodulator, the chroma signal is applied to each suppressor, so in addition to the normal demodulated signals at the plates, a signal made up of some of the output of each plate—but of opposite polarity—is manufactured in the common screen circuit. Remember, to derive $G - Y$ we add some $R - Y$ and $B - Y$ together and invert them. That is the exact action of the screen circuit.

The pulses of 3.58 from the demodulation are removed by traps at the two plates and the screen. Separate capacitors and one common variable coil are used as a multiple trap. Fig. 623 shows the "screenwire" pattern we would see if the 3.58 were not trapped or filtered out.

G-E chroma troubleshooting

The older G-E circuits resembled certain RCA models, but starting with the 1966 CB chassis, the HB Portacolor, and continuing with the 1967 KC chassis, there is no similarity to any other make or model. The heart of the chroma channel is the diode demodulator circuit described in the demodulator chapter, but the rest of the circuit is just as distinctive. There is no color killer, for little color snow can be seen during b-w reception. No phase detectors or 3.58 oscillator are used; the 3.58 carrier is generated by shock-exciting a 3.58 filter crystal with a large burst. The Q of the crystal is so high that it rings (continues to vibrate) until the next envelope of burst arrives to excite it again. Some variation in amplitude must be expected because the ringing will decrease slightly between bursts and because of station fading, so a limiting amplifier is used to increase the burst amplitude before it is applied to the demodulators. Note this important point: *When there is no burst, no 3.58 carrier is applied to the demodulators.*

The simplified chroma schematic of the HB Portacolor chassis (portable 11-inch) is given in Fig. 624. The chroma takeoff transformer is in the cathode circuit of the only video amplifier. The chroma i.f. is a single pentode without blanking or color-killer connections. The grid is medium-impedance, so we can check the chroma there with a low-capacitance probe. The next signal test point is the top of the color control, where we can use the normal vtvm probe for the ac measurement.

From the top of the color control the chroma, including burst, is fed to the cathode of the burst keyer. The burst keyer has a positive-going horizontal pulse applied to the grid to make it a peak rectifier that produces about -120 volts at the grid. As in all burst keyers, the amplitude and delayed phase of this pulse are important. The negative voltage can be used as an indication of those. During conduction at
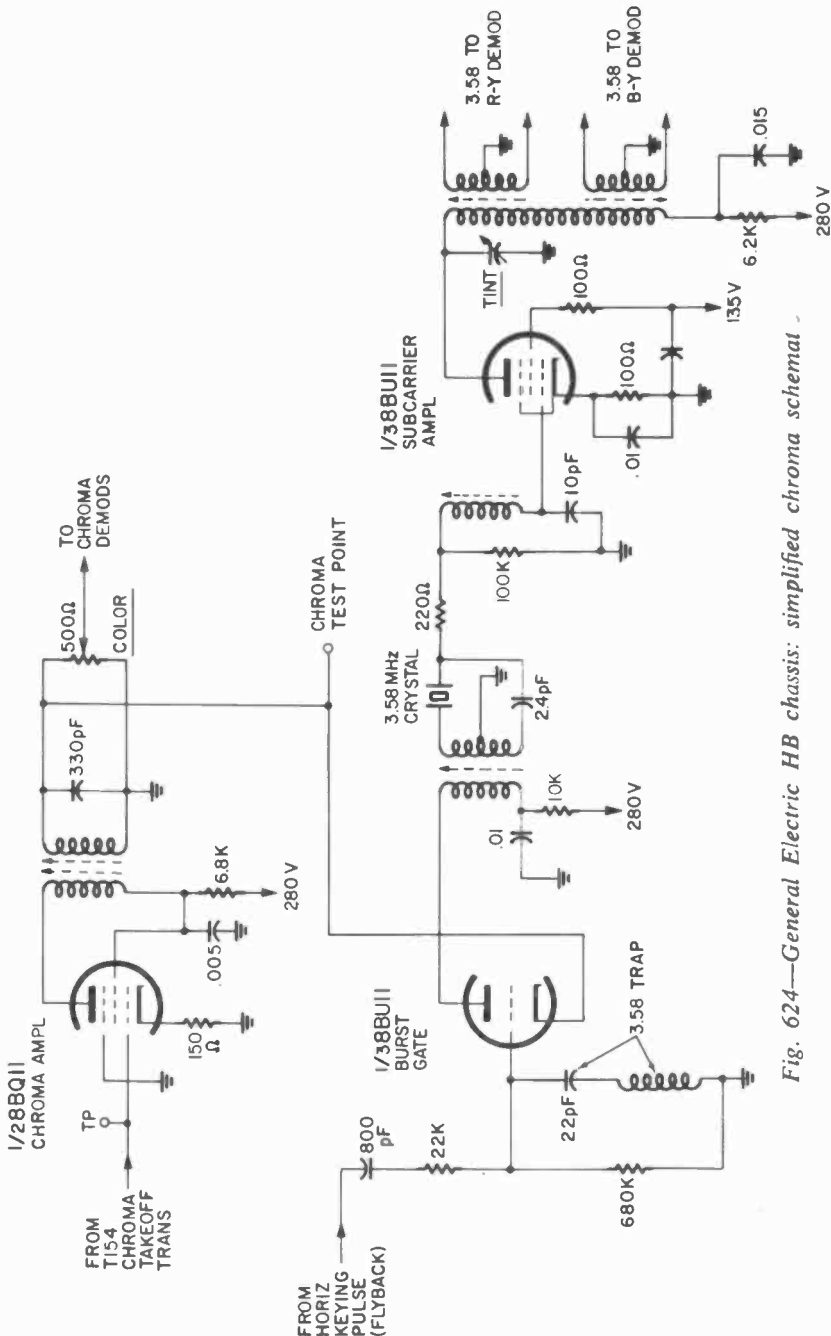
Fig. 624—General Electric HB chassis: simplified chroma schematic

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the tip of the horizontal pulse, the tube is a grounded-grid amplifier with the signal applied to the cathode and leaving by the plate. The grid can't be entirely grounded because a pulse has to get in there, so a 3.58 series-resonant trap is used from grid to ground to short out any chroma or burst. During burst alignment, this trap is tuned for *minimum* burst to the demodulators, while the other burst transformers are tuned for maximum. The keyer plate is high-impedance so it is better to check for burst farther along. A dc vtvm with the external 1-meg resistor can be used to measure the dc at pin 8 of the 8BU11. The more negative the grid, the more burst there is, since this tube uses grid limiting. T503 is tuned by a variable capacitor, which is the tint control—it changes the phase of the 3.58 carrier. The secondaries supply the 180° out-of-phase signals for the demodulators.

Fig. 625 shows one demodulator circuit. The point between D1 and D2 is grounded to the 3.58 carrier by the large coupling capacitor going back to the low-impedance chroma control. The two diodes form (for the 3.58) two peak-reading rectifiers of opposite polarity, so their combination at the grid of the −Y amplifier will give zero voltage. The
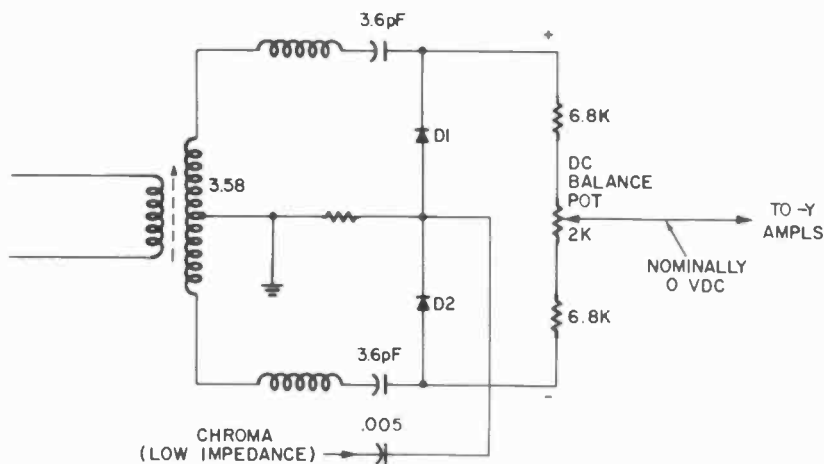
Fig. 625—Demodulator of G-E chassis (simplified).

chroma signal enters between the two diodes, just the reverse of the 3.58, and also gives a positive and a negative output. Either the 3.58 carrier or the chroma signal, if present alone, will make two equal but opposite voltages which cancel out to zero. Only both together, of different phase, will unbalance the rectifiers to produce a negative or positive output to the following amplifier. There is only one problem here: the positive and negative voltages must cancel out perfectly when

the 3.58 carrier is present. Any slight voltage difference is amplified by the $-Y$ amplifier and changes the screen color of the raster. This is the sole purpose of the balancing pot: to prevent a change in b-w screen color when the 3.58 burst is received from the station. The chroma signal is too small to make a noticeable change when there is no burst. The pot can be balanced in either of two ways. First way:

1. Connect a vtvm on a low dc range between the center lug of the balance control and the point between the two diodes.
2. Tune in a colorcast or your color-bar pattern. *Turn the receiver color control completely down.* (This is important.)
3. Adjust the balance control for zero on the meter.
4. Move the meter to the next demodulator, and repeat the adjustment for each demodulator.
5. Remove the meter and try the set.

The other way is the "eyeball" or visual method:

1. Tune in a colorcast with color control up, then turn the color control down.
2. Vary the fine tuning from a badly smeared picture to sound bars and notice if there is any change in screen color. There should be none if all the demodulators are balanced correctly.
3. Any change in screen color indicates need for balancing. Use the screen color with the fine tuning set for a smeared picture as your standard. What color is prominent in the raster with the fine tuning set correctly, just short of sound bars? Suppose it is blue: The $B-Y$ demodulator needs balancing. If red, then the $R-Y$ demodulator.
4. Adjust the balance controls until the screen color does not shift with fine tuning. *Be certain the program is in color.* B-w can't be used for this test.

Zenith chroma troubleshooting

The Zenith circuits are built around the "sheet beam" demodulator tubes. The rest of the circuitry is essentially conventional. Fig. 626 shows the chroma i.f. and killer diagrams. The chroma signal is taken from the video detector after the 4.5 trap instead of from the video amplifier as usual. The first i.f. grid circuit is untuned, so it can be used as a meter or scope test point; automatic chroma-gain-control voltage from the killer detector is also inserted here, so this is a dc test point in case of weak color. The chroma i.f. is stagger-tuned. The
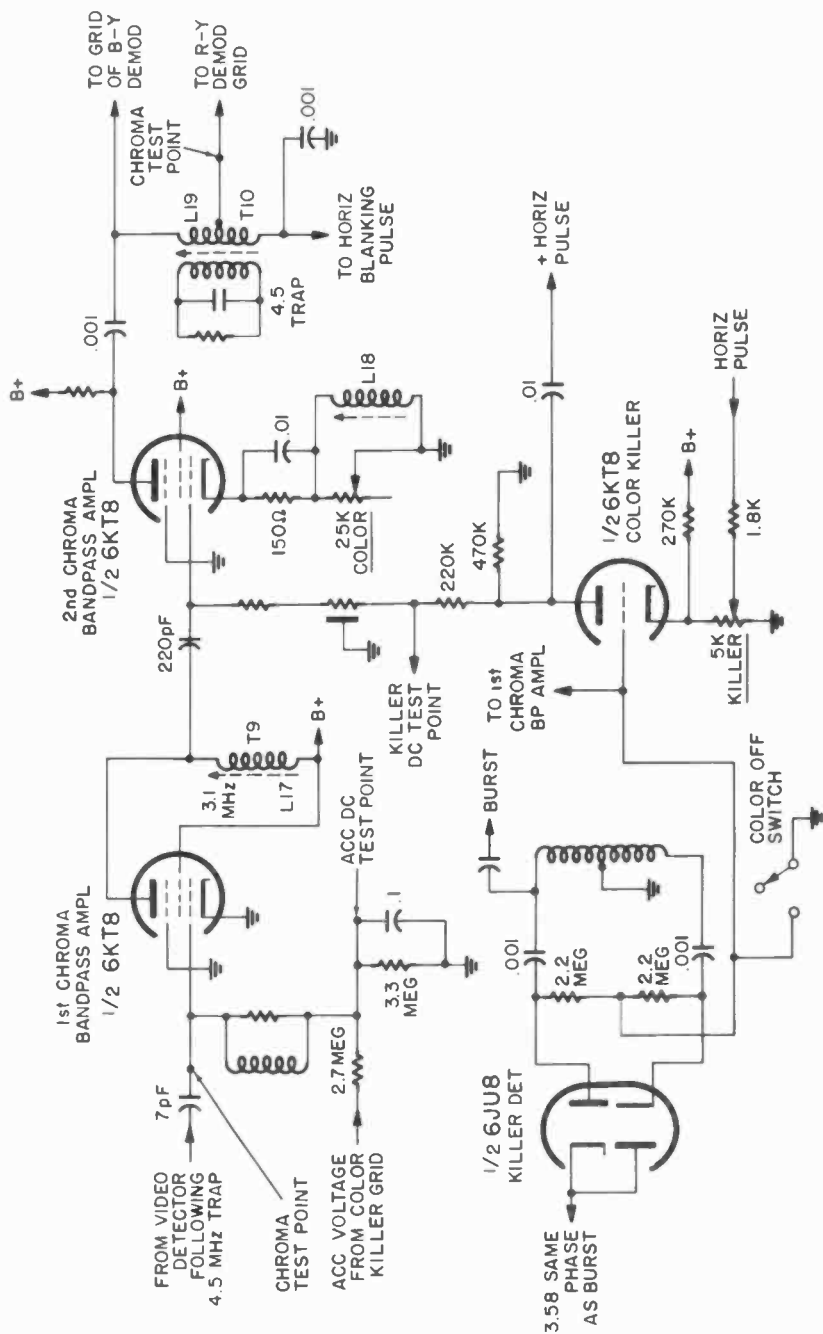
Fig. 626—Chroma i.f. and killer circuitry of Zenith's 25MC30 chassis.

first i.f. plate coil is tuned to about 3.1 MHz and the second to about 4.1 with a 4.5 trap built in. The plate of the first i.f. is fairly high-impedance, but can be used for a test point if necessary. It is capacitance-coupled to the grid of the second i.f. where the dc killer voltage is fed; this dc voltage can be measured at the grid with the external 1-meg resistor, or at the printed component A3 with a normal dc probe.

The color control is a degenerative type in the cathode circuit of the second i.f., so it is not used as a test point. Coil L18, across the control, is used to adjust for minimum color when the color control is turned completely down, and should eliminate color completely. T10, the plate transformer for the second i.f., has two windings. The tapped one allows full chroma to the B − Y demodulator and partial chroma voltage to the R − Y demodulator. The other winding is a 4.5 trap; there is only one core, used to adjust for minimum 4.5. This adjustment also automatically gives maximum response at 4.1 for correct i.f. alignment. Horizontal blanking from the cathode of the horizontal discharge tube is fed to the cold end of T10, so horizontal-blanking pulses will appear at all three picture-tube grids.
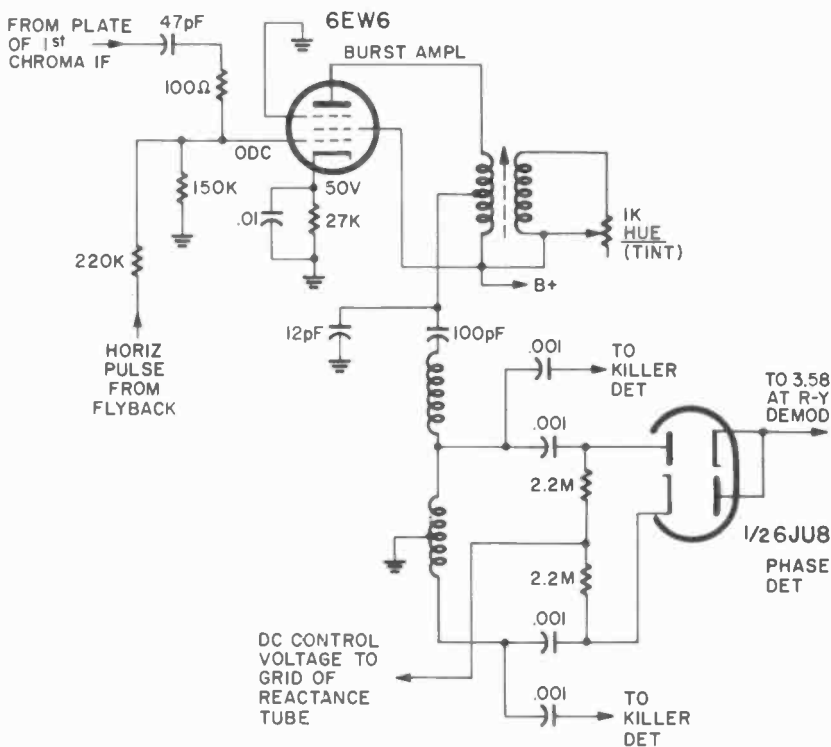
Fig. 627—Burst keyer in Zenith 25MC30.

Fig. 627 is the burst-keyer diagram. Chroma signals, including burst, are taken from the plate circuit of the first chroma i.f. A large positive-going pulse is applied to the grid to overcome (during pulse time) the cutoff bias from the cathode circuit. If the cathode voltage should measure less than 10 volts, it could mean loss of pulse at the grid. Burst signal is tuned in the plate transformer, with the hue (or tint) control in a loading circuit across a secondary winding. The burst is not taken from this transformer directly to the detectors, but is capacitance-coupled to a separate center-tapped coil (without an adjustable core) for phase inversion for the detectors. The reactance and 3.58-oscillator circuits are similar in general actions to the RCA's previously described. The only adjustment is the reactance coil in the plate circuit of the reactance tube. Because of the high 3.58 voltages necessary in the demodulators, there is no low-impedance test point in the output of the oscillator, but pins 1 and 2 of the $B-Y$ demodulator should be less sensitive to detuning by a low-capacitance probe than the others.

The demodulators are high-level type and feed the picture-tube grids with no further amplification. Consequently the signal voltages are higher than in other demodulators. The tubes are of special design, usually called "sheet beam" for the effect of the beam-forming elements. The demodulation action is the same as in the pentode type previously described, but the distinctive circuit difference is the *four* demodulators (Fig. 628). The pin-9 plate of V12 is a true $B-Y$ demodulator. The pin-9 plate of V13 is $R-Y$, while the other two are $-(B-Y)$ and $-(R-Y)$ respectively. Remember, green can be derived from opposite amounts of $R-Y$ and $B-Y$, so here a large amount of $-(R-Y)$ is added to a lesser amount of $-(B-Y)$ to become $G-Y$.

Any major defect in these four demodulators will likely change the dc plate voltages and hence the screen color. A fast check for bad 6JH8 tubes is to cross-switch them and notice any raster-color change. If V12 had an open cathode, for example, the blue grid would be much more positive and the picture would be so blue it would likely bloom out. Red would be changed not at all, and green only slightly since both tubes contribute to the green grid voltage. This same type of reasoning applies to the colors on the screen; one would be radically changed, one would be right, and one would be wrong, if one tube were not demodulating.

RCA Victor chroma troubleshooting

Circuitry typical of RCA chassis CTC12, CTC15, CTC16, CTC16X, CTC17, CTC17X, CTC25, CTC25X and CTC21 has already been
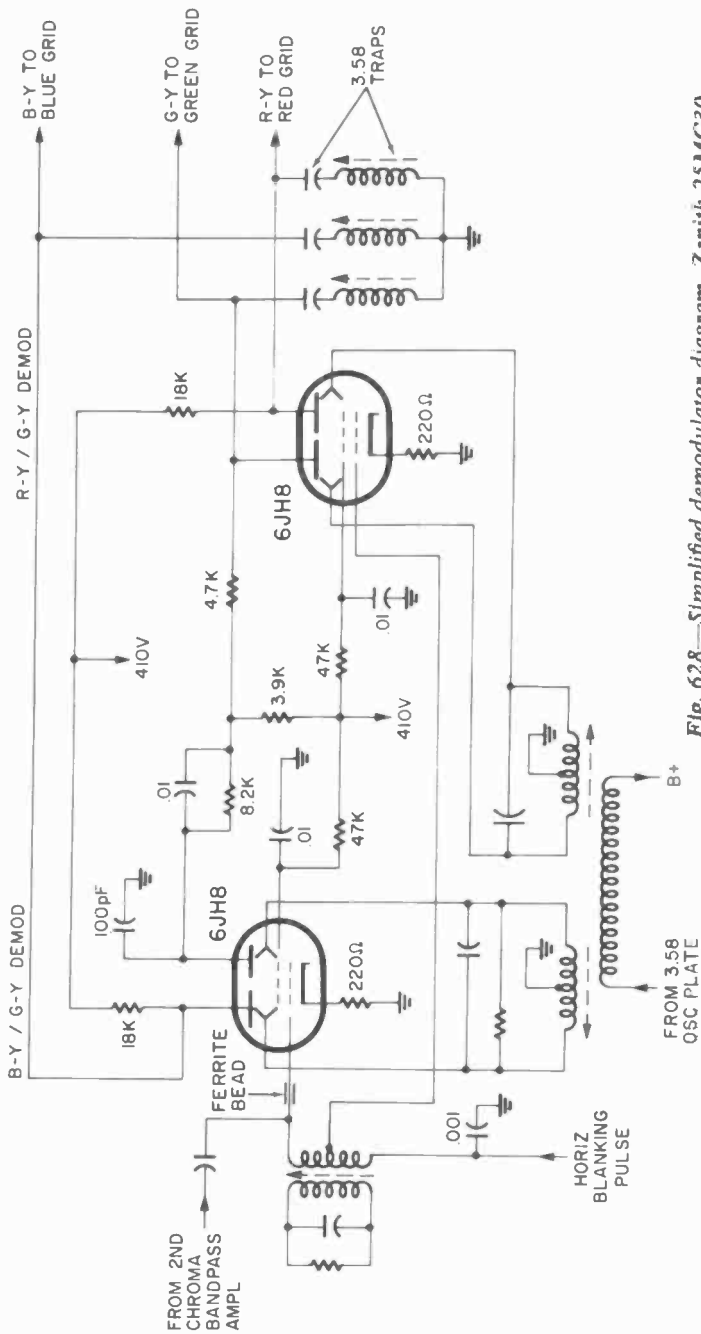
Fig. 628—Simplified demodulator diagram, Zenith 25MC30.

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analyzed under CTC16X. Chroma afpc adjustments are almost identical in all these.

But the CTC19, CTC20 and CTC24 chassis have an entirely different chroma channel. We should go back to the video detector to start our analysis because of the way the separate b-w and chroma amplifiers tie together. Fig. 629 shows this parallel path. The video detector circuit floats partially above ground. At low video frequencies, the detector output is between grid and ground with the triode giving no gain. At high video or chroma frequencies, the low side of the detector goes to the triode cathode through a resonant circuit consisting of the 1.8-μH choke and the 240-pF capacitor; the tube does have gain at those high frequencies. The chroma–sync–agc amplifier (pentode section) receives a part of the low-frequency video through the 10K and 6.8K voltage divider from the detector. The 56-pF capacitor from the triode cathode to the pentode grid boosts even more the high frequencies already boosted by the floating detector input to the triode. Thus the pentode section is a preamp for the main chroma channel.
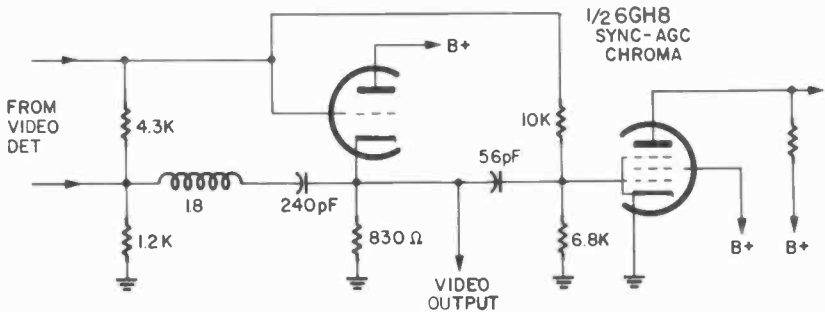
Fig. 629—RCA CTC19: simplified video and chroma amplifiers. Video and agc/sync/chroma go through separate stages.

The chroma channel and the burst/oscillator circuits are almost identical to those RCA circuits discussed before, with the exceptions given here. The tube types are different—6GH8A tubes for all chroma functions.

The 3.58 oscillator is crystal-controlled, but the burst is fed directly into the cold side of the crystal (Fig. 630). Thus the crystal is used both for oscillation and as a filter for the burst. The large amount of burst forces the oscillator to lock to the frequency and phase of the burst. The tint control changes tuning (and therefore phase) of the oscillator output transformer, whose secondary feeds the 3.58 to the demodulator grids. The best burst test point for an ac meter or scope is at terminal A, the

secondary of T702. The 3.58 test point is terminal A on the secondary of T703. A good dc test point for strength of oscillation and amount of burst is at the grid (pin 2) of the 6GH8A oscillator. Use the external 1-meg resistor on the probe and expect about -4 with no burst and -9 or higher with normal burst. The more burst, the higher this negative reading.
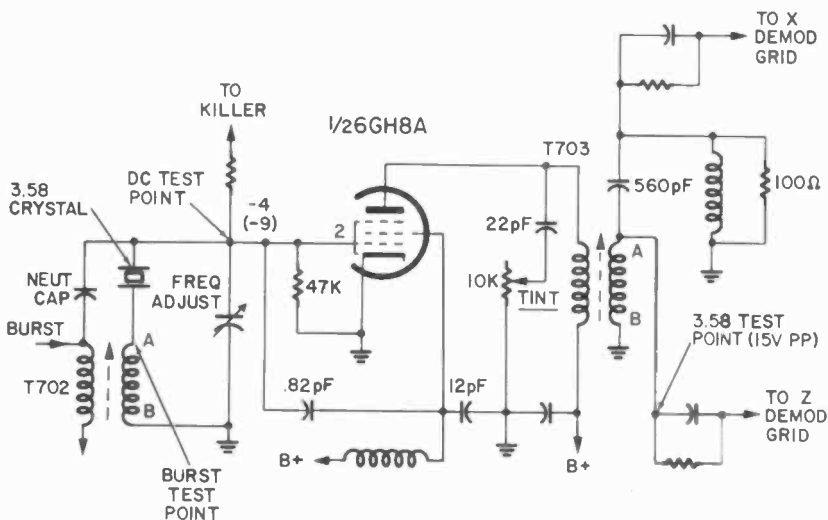
Fig. 630—CTC19's color oscillator is injection-locked with direct burst.

Suppressors of 6GH8A tubes are connected to the cathodes internally, so the screen grid is used for demodulation (Fig. 631). The chroma output from the color control goes to both screens in parallel. The circuit arranges for a small screen voltage at all times regardless of color-control setting. The 3.58, of different phase to each demodulator, goes to the control grid through a paralleled capacitor and resistor to make the grid a peak rectifier. Chroma signal voltage may be read at the top of the color control even with a normal vtvm probe. The screen voltage is not critical but should not measure less than 1.5 volts. The grid voltage is a measure of the amount of 3.58, but should be checked with the 1-meg resistor on the vtvm probe.

The blanker and $-Y$ amplifiers work the same as those described in the CTC16X, although the tube types are different and almost all of the capacitors and resistors have different values.

In this chapter, we have tried to give you some concrete examples of test points, including tips on which probes and equipment to use. We

hope you can take these examples and apply them to any make or model you encounter.

A few of these fast meter or scope tests should give you more accurate, factual data than hours of guessing or blind replacing of parts.
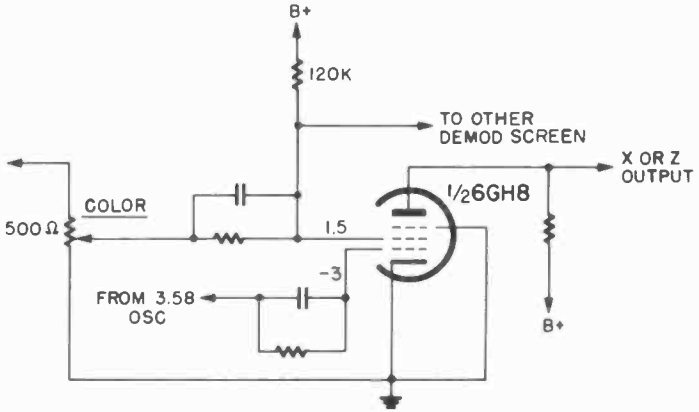
Fig. 631—CTC19 demodulator circuit. 3.58 is fed to grid, chroma to screen.

Chapter 7

Handy Charts for Chroma Troubleshooting

C HAPTER 3 GIVES MUCH PRACTICAL information about simple ways to check receiver performance on off-channel snow, b-w programs with the fine tuning and color killer misadjusted, and finally with the crosshatch pattern and color bars from a good generator. The charts in this chapter serve as quick and easy reminders of these tests and the best sequence in which to use them. They are intended for chroma evaluation and repair tips only, to keep the infinite possibilities for trouble within manageable limits.

Since the color picture is added "on top" of the b-w one, it is essential for everything but the color to be normal before we can judge chroma performance accurately. These b-w characteristics include good video sharpness, focus, width and horizontal linearity, height and vertical linearity, brightness, contrast, horizontal and vertical locking, dynamic and center convergence, screen color and phosphor-dot purity. There should be no hum, drive marks, shading, agc overload, excessive snow, or beat patterns. None of these defects (except perhaps some kinds of hum or shading) are likely to originate in the chroma stages, so check for them and make repairs first, if they are needed.

All exclusively chroma troubles can be classified in just four groups:
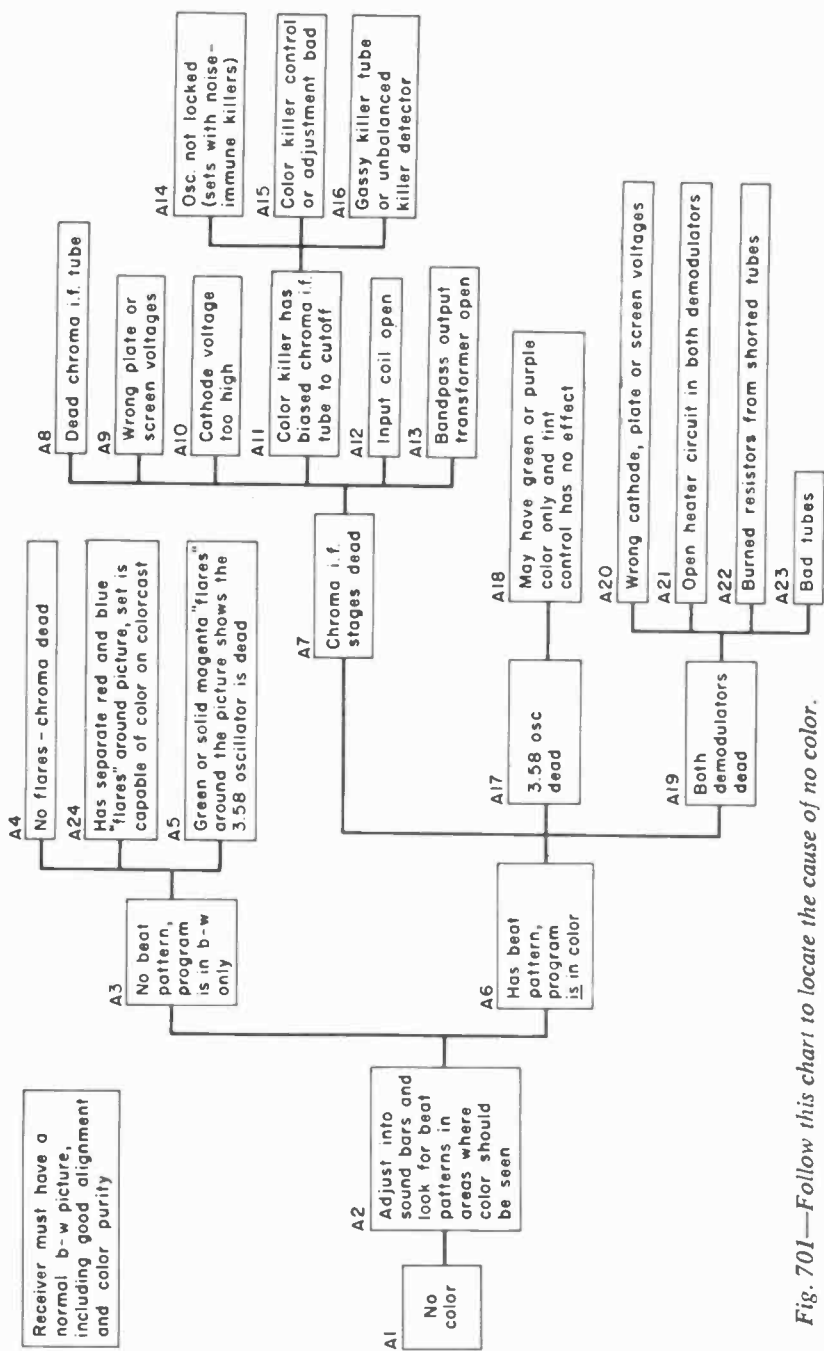
Fig. 701—Follow this chart to locate the cause of no color.

No color
Weak color
Weak locking (or no locking)
Strong, but poor, color

Fig. 701 is the chart for No Color. It begins with the reasonable assumption that a program should be broadcast in color before it can be seen in color. Some programs may be listed as colorcasts, but actually be broadcast in b-w only. We can prove this easily by adjusting the fine tuning slightly into the sound bars and looking for the 920-kHz beat pattern in the b-w picture. Fig. 702 shows how both b-w and color broadcasts should look.

In the absence of a beat pattern, the next step should prove whether or not the set is capable of receiving color when it is broadcast. With the

Fig. 702—Adjust fine tuning into sound bars and look for beat pattern.

set still tuned into the sound bars, turn the color control completely up and look for separate red and blue horizontal lines (or "flares") around the right side of any part of the picture that has sharp detail. These flares look purple from a distance, but up close you can see they are red and blue. If you see them, it proves the chroma i.f. demodulators and the 3.58 oscillator are all working. There may be a locking problem, but the entire chroma channel is alive and should show some kind of color on a colorcast or generator.

Note: this test will not work on any G-E model that uses burst ringing to obtain the 3.58 carrier.

If you cannot see the red and blue flares, the color-killer adjustment may be set too low, so turn it in the direction that should give color snow on b-w (usually counterclockwise). To be on the safe side, I like to leave the killer control set where (even in sets with noise-immune killers) it will barely show color flares when the receiver is tuned into the sound bars. This prevents loss of color on colorcasts with weak burst, or where an imperfect antenna gives weak color on one channel.

Should the receiver still fail to show red and blue flares with the killer disabled and the fine tuning adjusted into the sound bars, we can safely conclude the chroma channel is actually dead.

Joe Bloe might try aligning the picture or chroma i.f.'s by eye if the set he was testing had no color. Is he wrong? Yes, on several counts. The chroma or picture i.f. will *not* cause complete loss of color because of poor alignment alone. Weak color, yes, or lousy color, but that's all. He would only make the alignment *worse*. The alignment adjustments are so tightly interlocking it is not possible to specify one slug for picture gain, one for sharpness, and one for strong color. Color alignment is difficult enough even with all the equipment and know-how; without them it is impossible.

If the b-w picture has a beat pattern that shows it is being broadcast in color, yet fine tuning and color-control adjustments will not produce any color, our play-the-percentage tip is to check the chroma i.f. stages first. The demodulators are very unlikely to cause complete loss of color since there are two or three of them and most troubles would not kill more than one at a time. The $-Y$ amplifiers used in many sets cannot remove but one color at a time, and even then the change in b-w screen color would be a more important symptom than the color loss. Loss of 3.58 will remove the color completely in some makes and models, but in others it will permit either purple or green to be seen weakly. It is smart to memorize which models show which symptom. Notice that the chart lists a dead oscillator twice, first in the analysis of a b-w program (A5) where loss of 3.58 would give either green flares or purple ones.

Note: video i.f. alignment can cause weak color, even when the b→w picture is acceptable.

B1 Weak color

B2 Analyze color bars

B3 Picture has correct hues

B4 Fine tuning misadjusted

B5 Killer control misadjusted, chroma i.f. tube slightly over biased

B6 Weak chroma i.f. tubes or wrong voltages

B7 Poor chroma alignment

B8 Defective color control or cable

B9 3.58 oscillator weak, will give weak locking too

B10 Picture has wrong hues

B11 Bad purity on the screen

B12 May have one color missing

B13 Defect in phase-shifting network to one demodulator

B14 Tint defects

B15 Tint control will not adjust to skin color, weakens burst, which upsets killer action

B16 3.58 osc. plate trans. misadjusted

Fig. 703—Follow this chart to locate the cause of weak color.

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This purple is not the separate red and blue flares which appear to be purple from a distance, but a true color from the red and blue flares covering each other. The second mention at A17 gives the visual symptoms that loss of 3.58 causes on a colorcast. The most important fact here is that the color and fine-tuning controls function normally on the green or purple color, but the tint control has no effect.

Chroma sidebands, 3.58 carrier and demodulators are necessary to obtain color, and the chart reflects this truth by showing some possible defects in each circuit which could eliminate all color from the screen.

The next chart, Fig. 703 is for weak-color analysis. Please notice the added comment saying the video i.f. alignment can be off enough to cause weak color even when the b-w picture is acceptable. Crosshatch analysis as given in Chapter 3 should help to judge this possibility.

The first step is to check the color bars to be sure all three colors are there and in approximately the right percentages. If they are, the weakness is likely to be in the gain of the chroma i.f. stages, or in the amplitude of 3.58 to the demodulators, since low amplitude of either chroma or 3.58 will result in weak colors. B4 through B7 give some suggestions for finding chroma i.f. defects. Notice also the sharpness of the bars. Poor tuning, chroma misalignment, or a defective color control or cable will give blurred bars. Marginal killer voltages, wrong i.f. bias, a weak chroma tube or weak 3.58 will make weak but still sharp bars.

A colorcast may only *appear* to have weak color if a certain scene is supposed to be heavy on one color that is completely missing in the set. B12 through B14 give some possibilities.

At the beginning of this chapter, we listed phosphor-dot purity as one of the conditions that must be correct before we can use the charts efficiently. Here is the reason: Assume poor purity—that is, a situation in which the beam of electrons from the red gun lands between the red, blue and green dots. This would make the screen color nearly white with only the red gun on. Now assume blue and green to be in the same state—each produces a near white. No color would be seen on the picture tube during a colorcast. Only a variation in brightness (or a b-w picture, that is) would be visible. It is a little farfetched for any receiver to be this far out of purity, but it is possible for the purity to be partially bad and cause an *apparently weak* color.

Fig. 704 is the chart to follow for sharp and vivid color that isn't locking at all, is momentarily out of lock, or has weak locking. It is primarily for sets with phase detectors and reactance stages. Receivers with direct sync injection or crystal ringing would usually have dead or weak burst-keyer stages; voltage analysis or scope tracing are best to
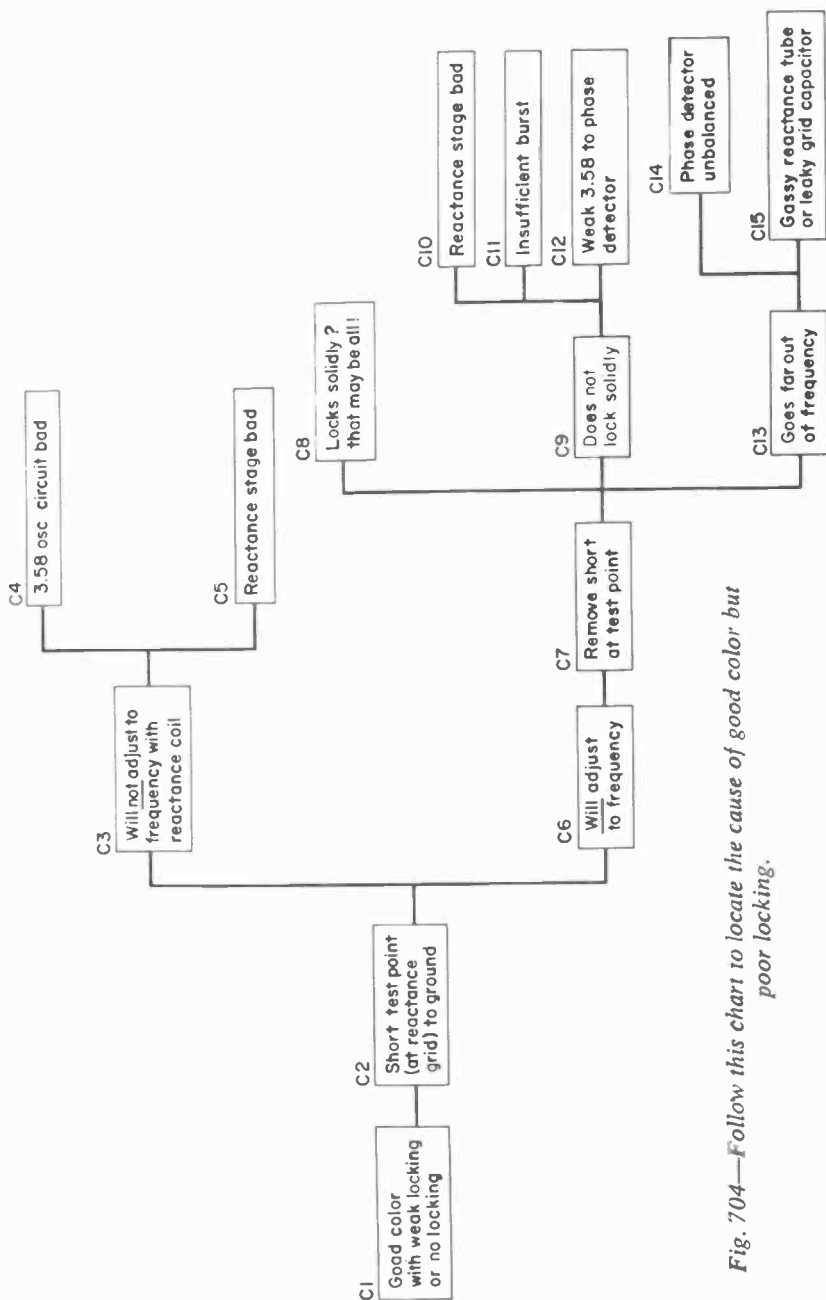
Fig. 704—Follow this chart to locate the cause of good color but poor locking.

C1 Good color with weak locking or no locking

C2 Short test point (at reactance grid) to ground

C3 Will not adjust to frequency with reactance coil

C4 3.58 osc circuit bad

C5 Reactance stage bad

C6 Will adjust to frequency

C7 Remove short at test point

C8 Locks solidly? that may be all!

C9 Does not lock solidly

C10 Reactance stage bad

C11 Insufficient burst

C12 Weak 3.58 to phase detector

C13 Goes far out of frequency

C14 Phase detector unbalanced

C15 Gassy reactance tube or leaky grid capacitor

use with them.

The chart starts with the field adjustment for color locking (where we short out the error-correcting voltage and try to zero-beat the 3.58 oscillator to frequency). This not only gives valuable leads about where we should look if the adjustments do not work right, but many sets will need *only* these adjustments to restore solid locking. The oscillator may have drifted off frequency too far for the sync to be able to correct it (because of normal aging of tubes or components) and may need only to have the locking adjustments touched up. The chart also lists the most likely defects to investigate for weak locking, and where the oscillator goes far out of frequency when the phase detectors are connected to the reactance stage. Did you know that on a strong color signal a good reactance-type control will pull the color into lock from as many as *six* diagonal stripes? But just to be on the safe side, always have the uncontrolled oscillator frequency within *one* stripe of correct frequency.

The chart in Fig. 705 is the checklist for strong, but poor, color, At first thought, you might believe strong color with good locking is all that is necessary. Our job might be easier if that were true. Actually, a host of gremlins can spoil the color rendition. The first decision we must make is whether or not the correct hues are present. If they are, three basic conditions are possible. The colors may be displaced to right or left of the b-w picture. Both incorrect alignment or a shorted delay line will cause this; however, the colors will be normal in the case of the bad delay line. Smeared (or blurred) color means wrong bandwidth and phase shift from misalignment or narrow frequency response. This will also cause some displacement of the colors, with red being displaced more than the others.

Sharp colors can have their share of deficiences also. Beat patterns, ringing (or color overshoot), excessive snow, or alignment ghosts are some possibilities. The beat patterns can be caused by external rf interference, from internal i.f. or color-oscillator radiation, or from misaligned sound-carrier traps that permit the 920-kHz beat to be seen.

Suppose the *hues* are wrong. Are all three hues present? Is something wrong with one or more of them? The chart lists most of the basic causes of poor color when all three hues show up. The color might be out of lock with the stripes where color should be, the purity might be poor over part of the screen and cause wrong colors there, one or more demodulators might be putting out a false hue because the 3.58 applied there is of the wrong phase, hum or shading may be seen in any or all hues, the tint control may not adjust far enough to give true colors, or the proportions of red, blue and green fed to the picture tube may be wrong, so compound colors are false.
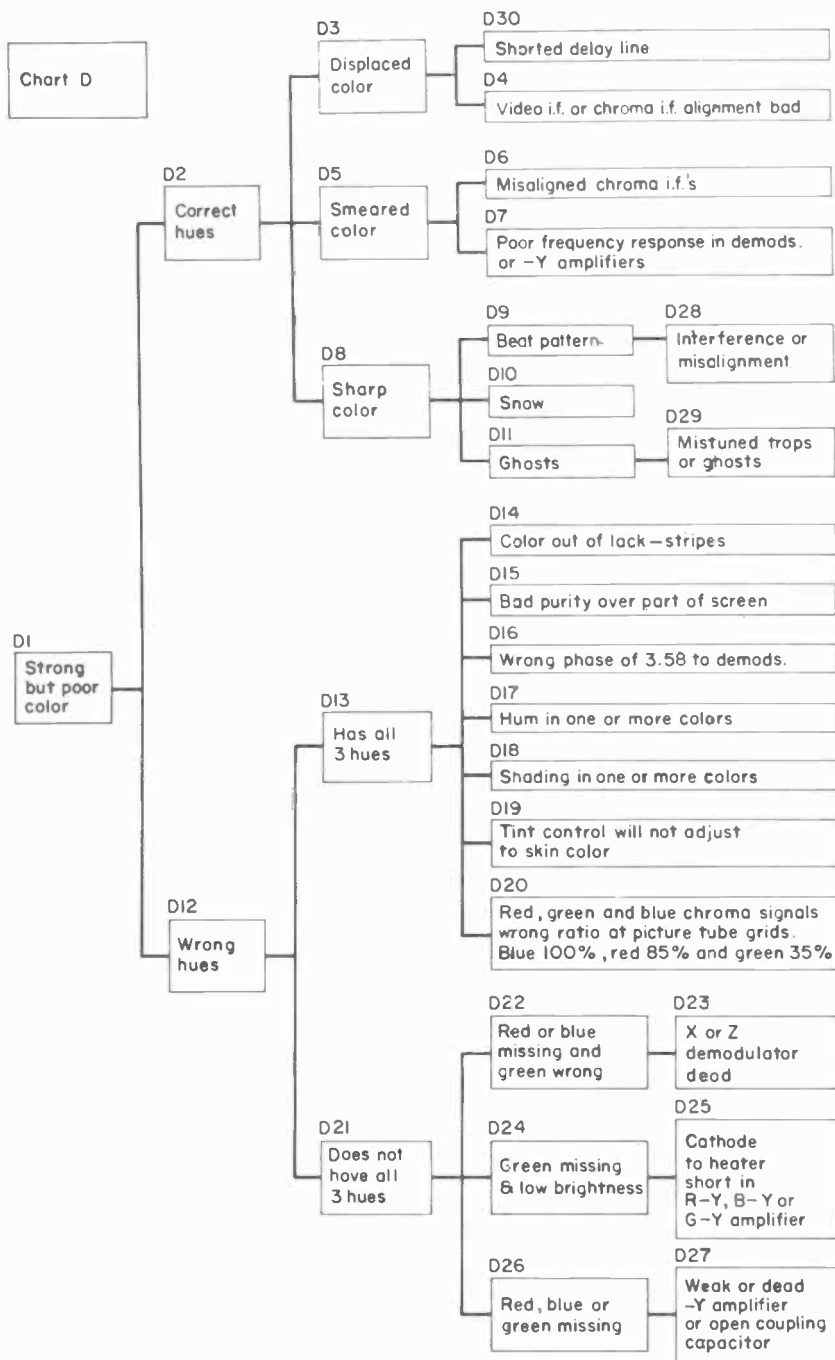
Fig. 705—Follow this chart to locate the cause of strong, but incorrect, color.

One color missing completely can be caused by a dead demodulator, a cathode short in a $-Y$ amplifier, a dead $-Y$ amplifier tube, or a defective component in one of the $-Y$ stages.

A keyed-rainbow color-bar display is the best of all signal sources for evaluating these chroma characteristics. It permits accurate diagnosis in minimum time.

Let's talk about snow in the color part of the picture. Did you ever see a receiver with a satisfactory b-w picture but objectionable snow in the color? Don't be misled and blame the chroma channel, for the signal level here is much too high for tube noise to be a factor (and most snow is tube noise). Most chroma i.f. stages will have over 10 volts p-p at the first grid, and that's way above the snow level. The answer may be as simple as turning the color control down to a natural color saturation point. Many people try for excessively strong color, which emphasizes any defects.

If you look carefully, you will find the snow in the b-w picture multiplied in the color snow. You should still check the same things you check now for b-w snow: antenna coils, tuner condition and alignment, or first i.f. noise. Another problem that could sneak up on your blind side is excessive agc to the rf tube in the tuner. Faulty distribution of the agc voltage could cause the i.f.'s to get too little and the tuner too much. Other possible causes are a gassy first i.f. tube or resistors in the agc lines which have changed resistance. Many late-model receivers will have positive tuner agc voltage on weak channels. Use this rule: Count a positive voltage as zero, zero as zero, and negative as negative. A fast test is to ground the tuner agc supply. Any improvement in snow proves the voltage was wrong.

Chapter 8

Brightness and Screen-Color Problems

BRIGHTNESS AND SCREEN-COLOR PROBLEMS are related because a screen-color change is a brightness change in one color. Some of the sources of these problems may surprise you. For example, do you know *all* the general defects causing loss of raster? Here is the complete list:

1. Defective picture tube.
2. No high voltage.
3. Insufficient picture-tube screen voltage.
4. Wrong grid–cathode bias on the picture tube.
5. No picture-tube focus voltage.

Lack of focus voltage has probably fooled more technicians than any other condition.

Picture-tube defects come in all varieties, from the simple open heater to a loose shadow mask. No light in any of the three heaters can mean a failure in the supply, a bad socket, an open in the internal wires to the heaters, or it might be a poor solder job on the pin (if it is a 21-inch round tube). A desoldering seems to occur in some heater pins where the soldering originally was satisfactory. They can be resoldered if we keep in mind that it is much more difficult to tin the wire properly

after this has happened. One trick I have used successfully is to file the end of the pin down to the end of the wire, apply extra soldering paste and solder with a hot iron and good solder. Any excess solder should be cut off with a pocket knife to avoid spreading the socket contact. The small-neck tubes have welded leads and are not repairable.

A true gassy picture tube will act in one of two ways: The inside of the neck may glow purple, or arcing may occur between various parts of the gun structure. The heavy current that results from either condition may load down the high voltage and fool you into thinking the trouble is there rather than in the picture tube. One fast test is to pull the socket from the tube when the set is on. If an arc follows the socket and the high voltage comes on, as evidenced by the crackling noise from the front of the picture tube, the tube is gassy. If there is no arc, but the high voltage comes on, the trouble may be too little bias on one or more of the guns; we'll discuss that later.

An open in the focus electrode inside the tube will stop the raster, the same as complete loss of focus voltage. A bad socket connection to the focus pin may give a peculiar symptom: A horizontal band of the picture will be in focus, while other parts will be out of focus. This condition is usually highly erratic.

Weak emission on all three guns might cause loss of raster, although often the picture can be seen faintly and will get brighter the longer it is on. Check the operating voltages, then cross-check by checking the picture tube with a CRT tester. Try to verify these defects by at least two tests. White compression, where all the picture from what should be medium gray to white is the same shade of gray, can occur in color tubes also, but often it is in one color alone and is thus obscured. It may appear to be bad tracking. In rare cases, the three guns are equally weak and maintain an approximately constant screen color during warmup. With other tubes, one gun may reach usable current sooner than the others and produce a definite screen color when the picture first comes on.

Picture tube shorts can kill the raster, but should show up in the voltage analysis. Check grid, cathode, screen and focus voltages with and without the socket to find the short.

Loss of high voltage will stop the raster of any set, color or b-w, but there are more possible causes in a color set, because of the high-voltage regulator and the higher voltages. An open high-voltage rectifier, a weak horizontal-output tube or an open damper are some of the few things that do *not* cause excessive heating of the high-voltage tubes and components—often a useful symptom. Many other defects will cause the horizontal-output tube to run a red plate. Suppose a certain set has no high

voltage, but the horizontal-output tube glows a dull red after a minute of operation. It isn't likely to be loss of drive, or the tube would glow brighter, so we take the cap off the high-voltage rectifier and notice if the red plate is gone. If it is, the rectifier, high-voltage regulator tube or picture tube may be bad. Replace the rectifier, but remove the regulator and the high-voltage lead to the picture tube. If the plate is still not red, try the regulator and then the high-voltage lead. If the regulator is the troublemaker, there is little chance of anything but a bad tube or a shorted capacitor from grid to cathode of the regulator. Should the picture-tube high-voltage lead be causing the red plate, remove the base socket from the CRT. This should stop the red plate if the picture tube is drawing excessive current because of a wrong bias voltage, or because it's gassy. As mentioned before, a gassy tube should show a purple glow inside the glass or you should be able to draw an arc from any of the tube pins, even when the heaters are cold. There is one further possibility: The high voltage may be ac rather than the normal dc. If so, the picture-tube capacitance acts as a short to the ac and overloads the horizontal output. This will happen even with the base socket removed from the picture tube. A good fast test, other than a high-voltage probe reading, is to remove the high-voltage lead from the picture tube and connect it to a substitute high-voltage ("doorknob") capacitor whose other terminal is securely grounded. If the high-voltage is still missing and the horizontal-output plate is still red, the high voltage is actually ac. Except for the unlikely possibility of a short from high-voltage rectifier plate winding to filament winding inside the flyback transformer, the only other source of ac high voltage is the rectifier itself. If the first replacement high-voltage rectifier tube gives the same result, better try another; tubes have been known to go bad in the caddy. Other sources of no-high-voltage are the same as with b-w sets, except that with most brands of color sets, hidden failures of yoke and flyback are quite rare. They generally show a visible failure.

All modern color sets have individual controls for the three screens. The controls can be open or intermittent, or the capacitors across them may leak or short; but this usually affects just one color at a time. The most likely cause of low voltage to all three screens would be in the resistors between the controls and the voltage source, or the bypass capacitors in this circuit. Many receivers take the screen voltage from the boosted-boost circuit; this gives higher voltages than B+ or normal boost with an extra diode. filter resistor and capacitor. Failure of any of these parts would lower the screen supply, but usually only down to the boost voltage; this is still enough voltage to make a dim raster.

Wrong grid-to-cathode bias at the picture-tube guns accounts for most

brightness and screen-color problems. The video amplifiers are direct-coupled to the cathodes, and the chroma demodulators or $-Y$ amplifiers are direct-coupled to the grids of the picture tube (Fig. 801).
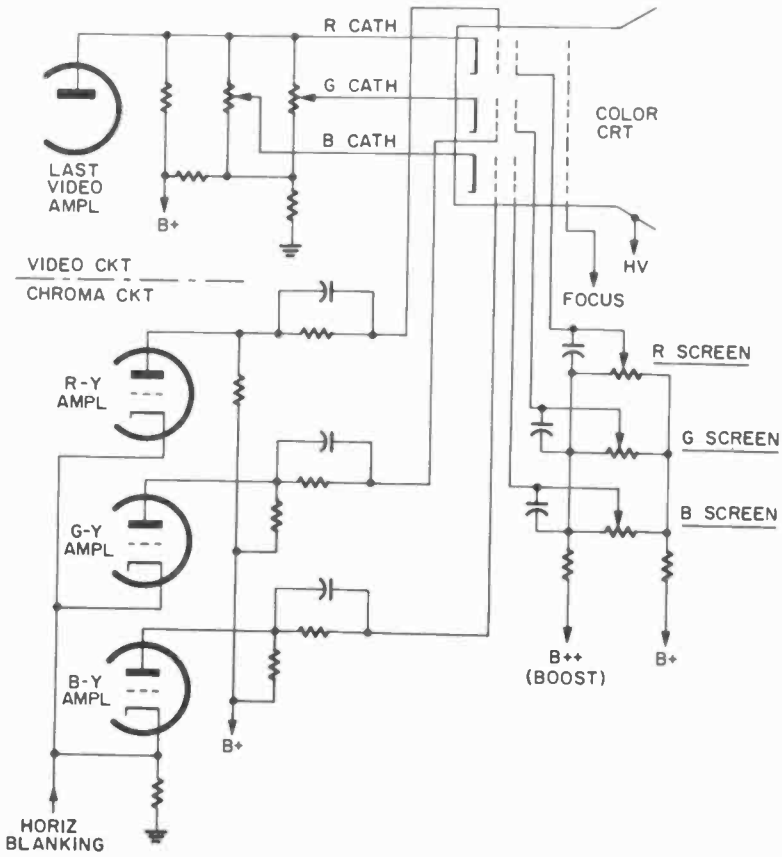
Fig. 801—Circuits that affect brightness and screen color.

It is unlikely for the $-Y$ amplifier voltages in the chroma channel to change enough to cause complete loss of brightness, unless all three $-Y$ amplifiers had less than 100 volts on their plates. A defect in the common $B+$ supply or a cathode-to-heater short are the only possibilities. An open in the $-Y$ amplifiers (less plate current), or in high-level demodulators connected directly to the CRT, will raise the voltage on the associated picture-tube grid and make that color much brighter than the others. A dead heater in one amplifier, perhaps from an open in the

heater wiring or in the tube itself, will cause one color to be so bright the raster will bloom out to black. A complete loss of horizontal blanking in sets with X and Z demodulation followed by three $-Y$ amplifiers will make the raster very dim, but it is usually possible to raise the screen to maximum, run the brightness control full on, run the picture-tube grid No. 1 bias to maximum and have a fairly normal picture. Beware of any adjustments that must be set abnormally high and still just barely do the job.

All modern receivers (with the exception of the TS912 Motorola) control the bias on the last video amplifier to change its plate voltage, and the plate voltage is dc-coupled to the cathodes of the picture tube to change the average brightness. In addition, the video stages are direct-coupled from the detector to the picture tube, so any agc overload or voltage problem in a prior video stage will affect the brightness. The overall test to determine if video-amplifier performance is affecting brightness is to monitor the red picture-tube cathode. The cathode should change about 90 volts or more for proper brightness-control action—this is usually from about 270 to 360 volts. Failure to swing this far indicates video trouble.

Brightness that changes slowly over several seconds or minutes is often caused by a weak or gassy last video tube. Try this first.

Brightness problems can also be associated with loss of video. For example, if one picture-tube cathode shorts to the heater, the video may be lost on one color alone. This looks like extremely bad b-w tracking. But if this shorted cathode is effectively connected to the top of the video drive control by turning the control, video will be lost to all three guns and the brightness control will have little effect. The heater supply for the picture tube has $B+$ voltage on it to minimize heater-to-cathode shorts, and is bypassed to chassis; the bypass causes the loss of video with a heater–cathode short.

Low or high focus voltage will cause a blurred picture with no visible scanning lines. Zero focus voltage will cause loss of raster. Pull the focus rectifier tube from a normal set and notice what happens to the brightness. Incidentally, most picture tubes require a focus voltage of about 20% of the high voltage; therefore if the high voltage is lowered, the focus voltage must be lowered also to maintain best focus. In cases of bad focus, it is an excellent idea to check both focus voltage and high voltage to determine which one is the culprit. Use a high-voltage probe on the meter. Vtvm dc readings are the fastest way of finding brightness problems.

Don't guess, measure!

Screen-color problems

The list of the basic causes of a changing b-w screen color reads much like the brightness-problem list. Field experience shows that the chassis and the picture tube each cause about 50% of the troubles; so don't suspect the picture tube unneccessarily. Uneven emission in the three guns during warmup is quite common, and is not considered harmful if it doesn't continue longer than 4 minutes. There are two ways of finding the cause: Check the picture tube on a tester (from a cold start) and note the readings at 1-minute intervals, or monitor the dc voltages (particularly the grid voltages) during the first 5 minutes of operation. There is one important precaution when you check these grid voltages: any variation above 2 volts is important to this delicate balance of the three colors. Two volts is about the smallest voltage change we can see if the change is made rapidly. A dc vtvm touched to a color-tube grid will change the voltage that much in many sets. A 5-volt change is apparent to anyone with good color perception if it occurs within a few minutes. Most color-tube grids will measure 150 to 190 volts, and, as you know, meters are calibrated every 10 volts at these voltages. Warm up the vtvm for 10 or 15 minutes before making these tests, and estimate the voltages between the meter marks. Read all voltages from the same angle, and write them down at the end of 1 minute, 2 minutes and 4 minutes. If all go up or down but stay within 2 volts of each other, this is considered normal. If two should go up and one down, suspect the one that went down as the troublemaker.

The chart of Fig. 802 can be very helpful in finding these defects. The breakdown that follows here is helpful the first time.

1. The beginning is the statement that the screen color changed.
2. Did the grid voltages go up or down *alike* (we call this unchanged), or did just one go opposite to the other two?
3. If the grid voltages were unchanged, we have three choices:
    A. Emission change in the picture tube. Verify with CRT tester.
    B. Voltage change at screen grid, cathode or heaters. Check them.
    C. An open in grid, screen or cathode circuit, the chassis, wires, socket or inside the tube. These make radical changes: Open grid makes picture so bright, in one color, it may bloom out and kill the high voltage within a second or so. Open screen does the same, but it gets bright more slowly. An open cathode kills that color instantly.
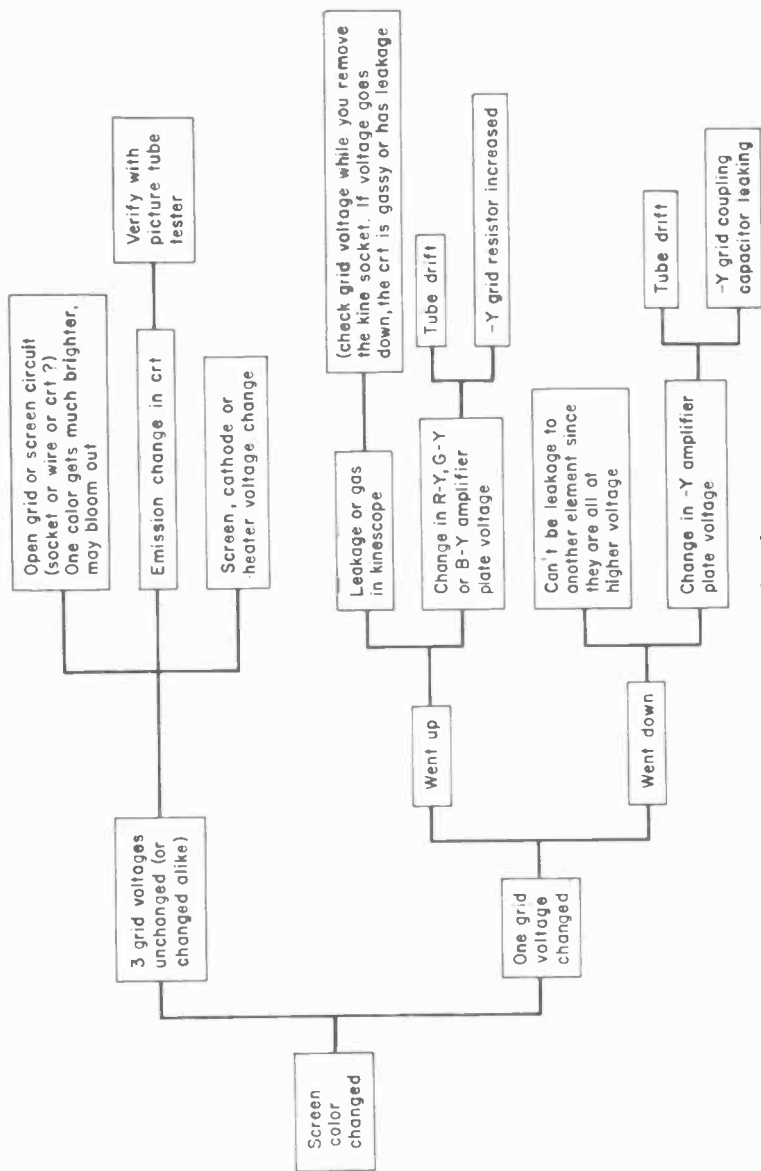4. Suppose one grid voltage changed more than the other two. Did it go up or down? This is significant.

Fig. 802—This chart helps find causes of screen-color changes.

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A. If it went up, the picture tube may have gas or a high-resistance short between elements. Keep the meter on the grid while you unplug the socket; if the voltage goes down, the tube is bad.
B. Changes in the $-Y$ amplifier tubes or circuits. An increase in the grid resistor or a weak tube are two of the few possibilities.
C. If the voltage went down, it can't be gas or leakage in the picture tube since all other elements are higher in voltage than the grids.
D. This brings us back to the $-Y$ amplifiers. Tube drift or leakage in the grid-coupling capacitor are two possibilities. Sets with high-level demodulators might have increased 3.58.

The chart is much simpler, isn't it?

While we are talking so much about picture tubes, let's include some data about screen spots, missing phosphors and related items. Small black spots on the screen, visible only when the set is on and the screen lit, may be caused by dislodged pieces of cathode coating, or other debris, plugging a few holes in the shadow mask. A trick that sometimes works is to turn the set off and degauss it with a large external coil. This shakes the shadow mask and may dislodge the particle while the electrostatic attraction of the high voltage is missing. Very rarely, larger spots appear where the colors are all slightly darker than the rest of the screen. Test these by changing the purity with yoke or purity-magnet adjustments and notice if the spot moves at all. If it does not, the picture tube is defective. Picture tubes with bonded faceplates occasionally have a stripe approximately 1/2-inch wide around the edge of the lighted area of the screen. It may look yellowish and have sharp, well defined edges. This has to do with the bonding process and we can't change it from the outside of the tube.

Two tests should be used on any spots or on any part of the screen where a color is missing. Change the purity, as described in the last paragraph, and see if the spot changes location or color. The second test is: Connect two or more of the picture-tube grids together and see if the trouble is gone, is now present in other colors, or is the same. This is especially good where one color is missing along the right or left edge of the picture. Picture shading from some incorrect horizontal spike is a distinct possibility, and can occur in only one color. Let's say the blue is missing in a vertical band 2 inches wide on the left side of the screen. Just tie the blue and red grids together and see if both are now near normal, or if both are missing on the left. If there is any change beyond the original condition the chassis is at fault not the picture tube.

Chapter 9

Width, High-Voltage
and Focus Problems

M OST CASES OF LACK OF WIDTH CAN be solved easily by installing
new horizontal output tubes. However, other defects can cause a
narrowed picture, so it should be helpful to know what general symptoms
we should see from each "family" of defects. Most troubles will show
a change in horizontal linearity in addition to the width loss; a cross-
hatch pattern enables us to see and analyze them.

The scanning at left side of the picture (as we face the screen) is
contributed by the damper tube, and we all know a weak damper tube
will stretch the picture there. The left side is affected most by an exces-
sive load on the horizontal output stage, which includes the yoke, fly-
back, focus and high-voltage circuits. An excessive load, regardless
of its cause, will pull in the left side and squeeze the picture there. Fig.
901 shows such a condition caused by the 6BK4 high-voltage regulator
drawing about 2 mA—50% too much.

The right side of the picture is determined by the conditions in the
grid circuit of the horizontal output tube. Ac drive and dc voltages
will have their effect. Fig. 902 shows the right side compressed because
of a slightly gassy output tube, but the symptoms are also typical of
leaky coupling capacitors or any other source of positive voltage in the
grid circuit.

Low horizontal-output-tube screen voltage causes loss of width on
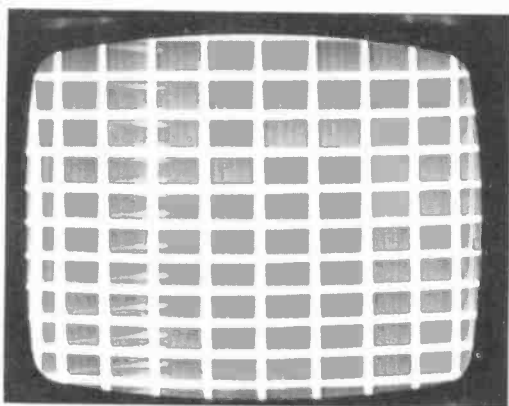
Fig. 901—*Excessive load on horizontal output stage makes picture pull in from left side. High regulator current caused this particular case of left-side nonlinearity.*
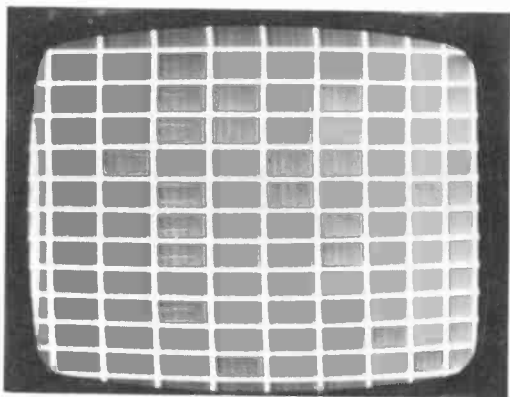
Fig. 902—*Nonlinearity and loss of width on right side of picture is caused by gassy horizontal output tube.*

both sides of the raster, as shown in Fig. 903. A leaky screen bypass or an increase in the value of the screen dropping resistor are two likely suspects.

While we are on the subject of horizontal and width, are you aware that every horizontal output stage is operated in class C, which means that plate current flows for a very short time and is cut off for the rest of the cycle? Because of that, it has much in common with a class-C rf amplifier in a radio transmitter. Its plate load (tuning and antenna loading in a transmitter) affects not only plate current, but screen and control-grid current.

A lower grid bias will increase both screen and plate currents; but a lower ac load on the plate circuit will increase the plate current and *decrease* the screen current. This decrease in screen current will raise the screen voltage, which will increase the plate current further. Perhaps that will explain the puzzle of a set that runs a red horizontal output plate, but has a higher screen voltage than is normal. Perhaps you thought the high screen voltage was causing the excessive plate current, but it is usually the other way around. When the plate-current problem is
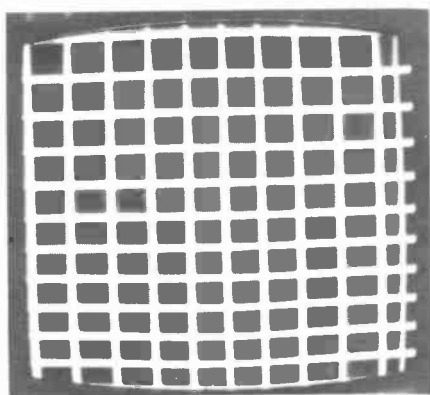
Fig. 903—Loss of width on both sides of raster is caused by low screen voltage on horizontal-output tube.

fixed, the screen and grid-drive voltages will go back to normal. One of my own shortcuts is to measure the screen voltage. If it is high and the tube is running a red plate, I look for a shorted rectifier tube or some such high-voltage problem. But if it is high and the tube is dark and not too hot, I replace the horizontal output tube. Other tips on running down high-voltage loss are in the chapter on brightness and screen-color problems.

Another simple circuit that can cause an outsize number of problems is the high-voltage shunt regulator. Fig. 904 gives a typical diagram. Briefly, here is the way it works: The grid bias is adjusted with the screen dark until the tube draws the maximum picture-tube current for that model of set. When you turn the brightness control up, the additional current drawn by the picture tube causes a drop in high voltage and also a drop in boost voltage. Since the regulator grid is returned to the boost, that makes the grid less positive (makes it more negative to the cathode) and the regulator tube draws less current. As you turn the brightness up, the action continues until at last the regulator current

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is zero. During this time the high voltage has varied only about 500 volts (2%). From zero picture-tube current and maximum regulator current up to maximum picture-tube current and zero regulator current the total high-voltage current has remained approximately constant. This has accomplished two things: regulated the high voltage, and kept the load on the horizontal output stage constant. As a result, width and linearity are held constant, the focus voltage is also maintained. If you turn up the brightness beyond where the regulator current goes to zero, the high voltage goes down and the raster blooms and defocuses.
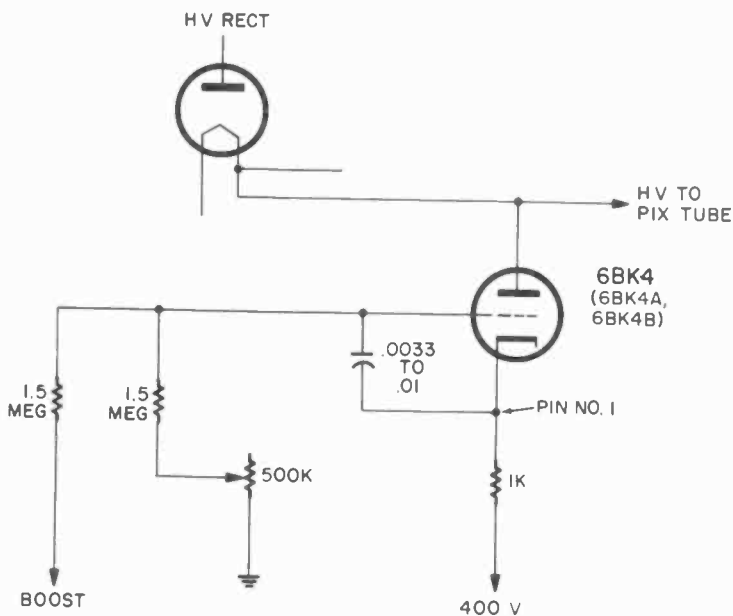
Fig. 904—*Typical high-voltage shunt regulator. Suspect tube and capacitor first.*

That is normal operation. If the regulator is wrongly biased so that it does not draw enough current when the picture tube is turned to black, the picture tube can only draw as much current as the maximum regulator current before control is lost. The extreme case of this occurs when you remove the regulator tube. Now as the picture-tube current changes, so do the width, high voltage and convergence. Also, the high voltage may go above 30 kV when the picture goes dark during scene changes, increasing the possibility of arcs. The changing high voltage also makes the picture tube crackle and may trigger secondary arcs from aquadag coating to ground. Quite often the vertical will roll while the

high voltage is changing, for most vertical oscillators are run from the boost supply. The excessive high voltage probably will ruin rectifier tubes.

At the other extreme, too much regulator current causes a narrow picture, too heavy a load on the horizontal output stage, and shortens the life of all horizontal tubes, particularly the output tube, high-voltage rectifier and regulator.

Perhaps you can see now why I am a fanatic on checking regulator current in every set I service. To make it easy and fast, I made an adapter socket from a "socket saver" intended for a tube tester. (There's a picture of it in the chapter on test equipment.) The cathode circuit (pin 1) is opened and a 1,000-ohm resistor wired in. Other pins are wired straight through. From the resistor, two insulated wires come out to be hooked onto a voltmeter or milliammeter. This resistor increases tube bias very slightly, so just set the regulator current about 0.1 mA low to compensate. A 1-volt drop across the 1,000-ohm resistor means 1 mA of current, so it is easy to remember.

Some factory instructions say to adjust the regulator current so the high voltage is a specified value. In practice, that doesn't always work out right. For example, assume you have a hot set operated on slightly high line voltage; that might make the high voltage about 2 kV high. If you increase regulator current to drop it, the regulator current will be much too high and the regulator tube will have short life. Set the regulator current for the specified maximum first, then measure the high voltage as a cross-check. In general, the newer the set, the higher the regulator current. The 1967 models run about 1.2 to 1.4 mA. This double measurement of current and voltage also gives us a valuable way to check for high-voltage troubles. What if the high voltage was 4 kV
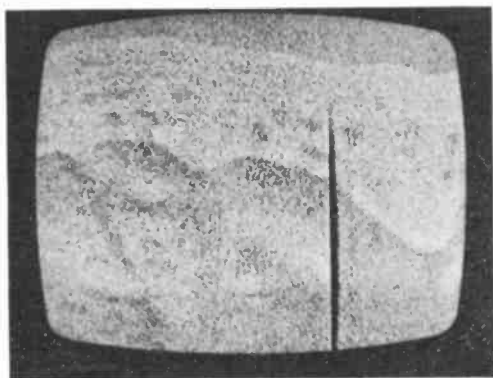
Fig. 905—*One kind of "snivet." There may be two or three vertical lines on right side of screen, usually unstable, and worse on uhf.*

low when we obtained the desired regulator current? Obviously the high-voltage or horizontal output circuit is weak. But if the high voltage was high when the regulator was set for the maximum allowable, probably the line voltage is high and should be reduced. One tip: High line voltage will cause tube failure out of all proportion to the increase. Check it if you want to be a hero to your customer.

Horizontal and high-voltage problems can also cause noise and lines on the screen of the picture tube. Fig. 905 shows one kind of "snivet." They vary in appearance and placement on the screen, but are always found on the right side of the screen and especially on uhf channels.

Fig. 906 shows a huge amount of short-time-constant noise from an
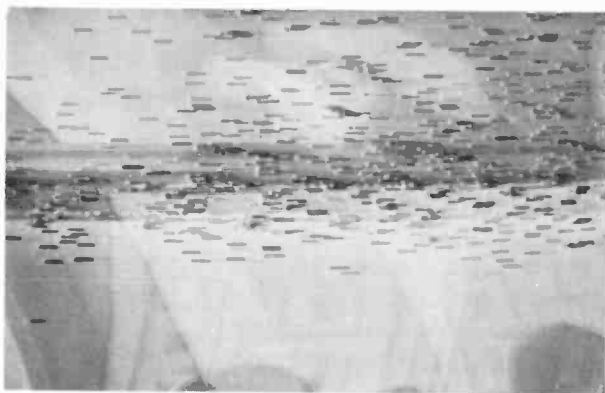
Fig. 906—Arc in 6BK4 plate cap connector generates so much random noise that picture rolls and pulls.
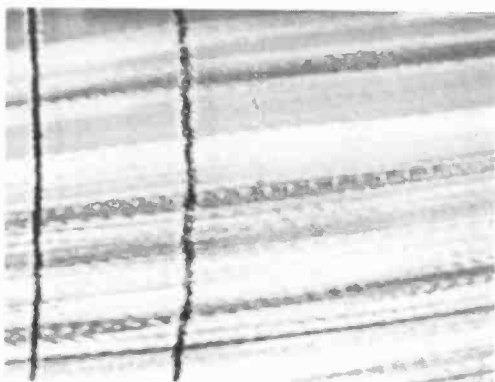
Fig. 907—Thin vertical noise lines are caused by arc in series with high-voltage rectifier.

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arc in series with the plate of the HV regulator; the noise is so intense it causes horizontal bending and vertical roll. This trouble was quite common in older sets. The noise is short, random pulses; they can be anywhere on the screen.

Thin vertical noise lines are usually caused by an arc in series with the plate of the high-voltage rectifier (Fig. 907). Such an arc will manufacture ozone, which we can smell. The key description here is thin, ragged lines.

By contrast, a broad vertical bar of random noise near the left side of the screen is caused by a corona from the high voltage ac to its dc component (Fig. 908). There are only two possibilities here, other than a corona between wires: the high-voltage transformer or the high-voltage
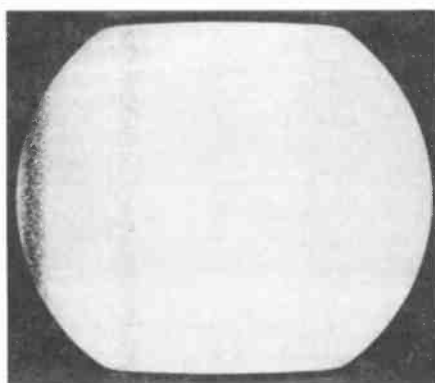
Fig. 908—Broad vertical lines of noise are usually caused by internal corona in high-voltage rectifier. 1,000- or 1,500-ohm resistor wired between tube fialment and regulator/picture-tube wires will reduce noise.

rectifier tube. Usually it is the tube. The effect of the noise on the screen can be minimized by adding a 1K or 1.5K resistor in series with the high voltage (to the picture tube and regulator) and the socket pins. Remember, if you add such a resistor, only pins 4 and 6 can be used for tie lugs.

Wrong focus voltage gives poor picture-tube focus; no focus voltage eliminates the raster. Fig. 909 shows the focus circuit used in most modern color sets. The heart of the circuit is the focus transformer, which varies the focus voltage. The usual schematic does not make clear the physical layout or the phase relationships of the windings. There
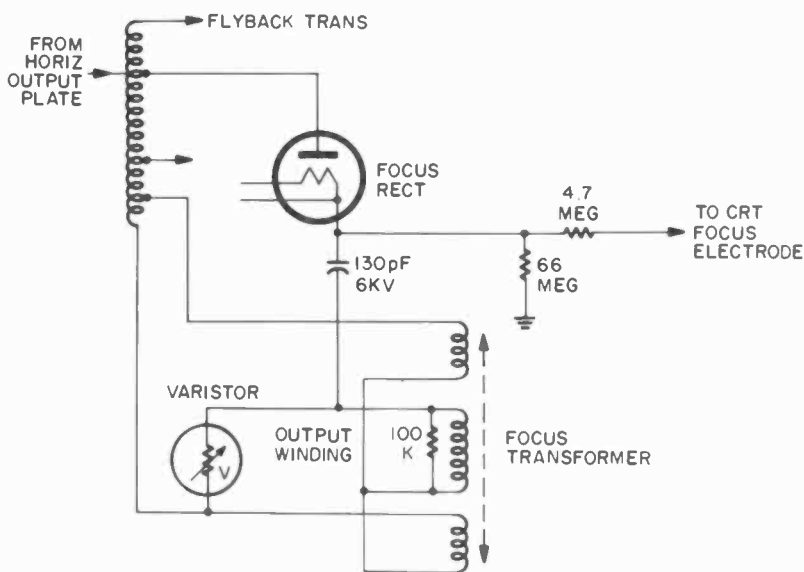
Fig. 909—Focus transformer has two out-of-phase primary windings and one secondary (output) winding. Core is only long enough to be inside output winding and one primary winding at any time. This gives output that is adjustable for voltage and polarity by phase cancellation.

are actually two primary windings of opposite polarity and one secondary or output winding. The iron core is long enough to be moved inside the output winding and only one of the primary windings at one time. Without the core there is little coupling between windings, so the phase of the output voltage is determined by which primary is coupled by the core. With the core exactly in the center, there is a little coupling to each of the primary coils but the equal voltages that result are opposite in phase and thus cancel out. The output gives a variable voltage and

phase which is coupled to the filament of the rectifier through the focus filter capacitor. When the phase of this voltage is the same as that on the plate, it is subtracted from the plate pulse; but when it is opposite, it adds to the voltage at the plate. When the ac to the rectifier is changed, the dc output changes also.

The 4.7-meg resistor protects the focus transformer in case of arcs; the 66-meg resistor prevents the focus voltage from creeping when the picture tube is not drawing any current. An open or leak in the 130-pF capacitor will severely reduce the focus voltage. The 100K resistor prevents ringing, and the varistor functions like a spark gap to protect the coil against arcs. Suppose you have a repair job with either the 100K resistor or the focus transformer burned up. What caused it? Probably a short in the focus rectifier, so it's good policy to replace it too.

Some new sets use a voltage divider on the high-voltage line to supply focus voltage. Whatever the method of obtaining it, the focus voltage should be about 20% of the high voltage. A badly focused picture can be caused by either low high voltage or wrong focus voltage. Check them both to find out which is wrong before you waste time on checking the focus supply.

Chapter 10

Alignment and Interference Problems

T HERE IS NOTHING UNUSUAL ABOUT THE picture i.f. and chroma i.f. circuits of a color receiver, except for the traps and alignment. But that little word "except" is of tremendous importance here, for nothing made by man or beast is so touchy as color alignment.

Common sense tells us a certain overall curve obtained from certain tuned circuits should work exactly the same as a similiar curve made up of a different arrangement of tuned circuits; the overall result is what counts. Well, this time *common sense is wrong*. For example, a correct-looking overall curve, made by offsetting a stagger-tuned coil to make up for an overcoupled stage mistuned in the opposite direction, may look fine on a scope but make a terrible picture. In color TV, *phase* is the most important characteristic of the signal. The entire chroma bandwidth of all frequencies between 3.1 and 4.1 MHz must be tuned and amplified without any undesired phase shift compared to the low video frequencies. This is the heart of the problem: In service work, we can check the overall frequency response by sweep alignment, but we can't tell a thing about phase response.

Just look at the overall i.f. curve in Fig. 1001. It is a fine example of a "textbook" curve *actually achieved in practice*. This curve combined with the textbook chroma i.f. alignment curve gave excellent results— sharp b-w pictures and perfect color. Also the tint and afpc adjustments

fell right into place. All adjustments and results were really flawless.

What about the curve of Fig. 1002? If what I have said about critical curves is true, this set should have a poor picture, right? Wrong, for this receiver is a new one with the manufacturer's original "haystack" alignment curve untouched. It gave excellent color and only slightly less b-w sharpness than the first one. Let's look at the curve in Fig. 1003. If the other two sets gave good color, this one should too, right? Wrong; it had an overpeaked b-w picture with a prominent white ringing line around the right side of any sharp black object in the picture, the color was smeared, with a noticeable 3.58 pattern in the b-w picture, and the tint did not want to adjust to skin color at all. It completely flunked the color-bar analysis described in Chapter 3.

Why should this set, whose alignment curve looked closer to the
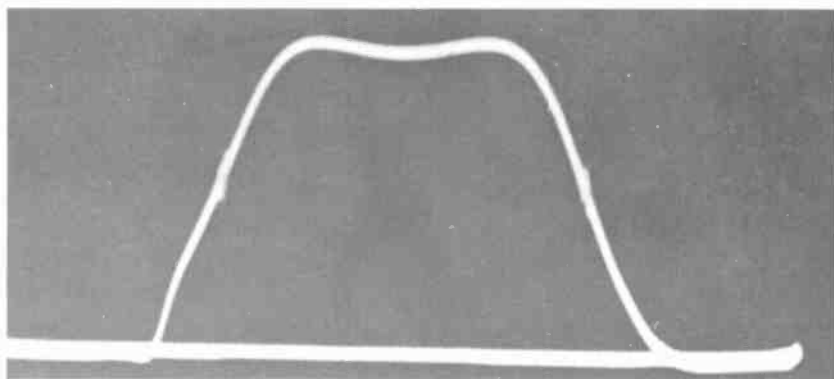
Fig. 1001—Theoretically ideal i.f. response curve.
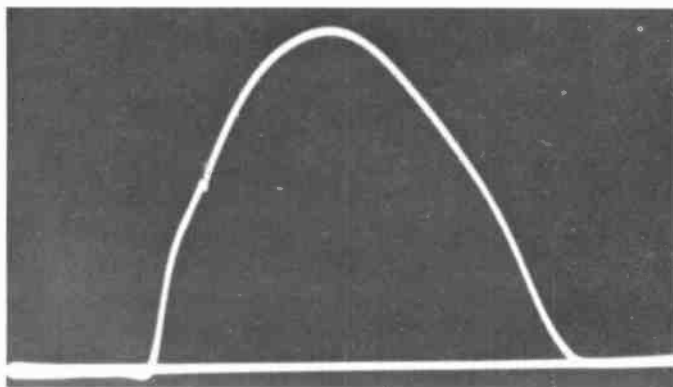
Fig. 1002—"Haystack" curve also gives good color.

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theoretical curve than did the second one, have such a poor picture? The answer is on the sound side of the i.f. curve. Fig. 1004 traces the step-by-step development of the i.f. and chroma curves, then adds them together to form the overall curve from tuner to demodulators. These drawings should make clear the enormous effect the i.f. alignment can have on chroma, since the chroma is riding piggyback on the i.f. response.
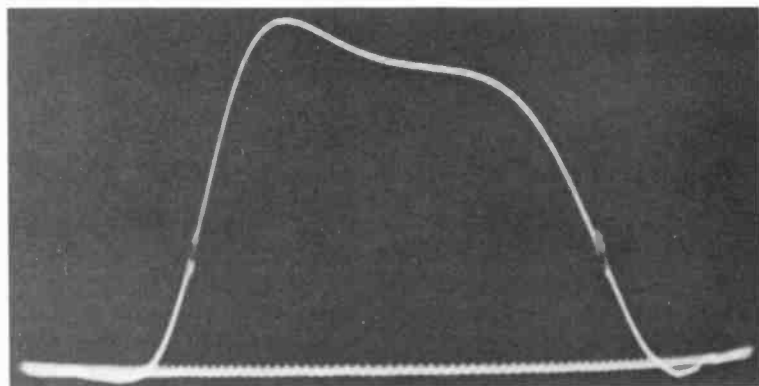
Fig. 1003—"Almost-good" curve gives poor color.

Just to show you that these curves can be obtained, Fig. 1005 shows photographs of a typical set of alignment curves. The overall curve from tuner to demodulators was taken in an entirely different way than the others by using the vsm (video sweep modulation) method (Fig. 1006). The 0- to 5-MHz sweep modulates a 45.75 carrier (picture-carrier frequency in the i.f.) and this signal is inserted into the mixer grid. A video-detector probe is used to demodulate the sweep signal so it can be viewed on a scope. The total frequency response from the mixer grid to any point in the video amplifier can be checked, even to the picture-tube cathodes. This will give a true picture of the frequency response including peaking circuits.

In this case we are interested mainly in the chroma signal, and we can check it stage by stage with the video demodulator probe and the scope. The output of the chroma i.f. is the important test point for total chroma response. Incidentally, it is not advisable to actually change the alignment adjustments during this vsm test (with the exception of the chroma takeoff coil, which can be set to even up the curve). If the results indicate poor alignment, the touchup should be done with direct sweep instead.

Did you notice the little "suck-out" points on the actual curves? These

I.F. CURVES

OVERCOUPLED TUNER AND 1st I.F GRID

42.75 (3.0 VIDEO)   45.0

42.16 (3.58 VIDEO)

47.25 TRAP

41.66 (4.1 VIDEO)

45.75 PIX CARRIER

50% LEVEL

41.25 SOUND TRAP

2nd I.F. PLATE   3rd I.F. PLATE   1st I.F. PLATE

THESE 4 I.F. CURVES COMBINE TO EQUAL...   ...THIS OVERALL I.F. CURVE

CHROMA CURVES

4.1   4.5   3.58

4.1   3.1   3.58   4.5   2.5

4.1   3.58   3.1   4.5   2.5

TAKE-OFF COIL   PLUS   OVERCOUPLED BANDPASS   EQUALS   THIS OVERALL CHROMA CURVE

COMBINED I.F AND CHROMA CURVES

3.1   3.58   4.1   4.5

4.1   3.58   3.1   4.5

4.1   3.1   3.58   2.5   4.5

THIS SOUND SIDE OF THE I.F. CURVE   PLUS   THE OVERALL CHROMA I.F CURVE   EQUALS   THIS OVERALL CHROMA RESPONSE CURVE (FROM TUNER TO DEMODULATORS)

Fig. 1004—Step-by-step development of good chroma frequency response.

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were made by the absorption marker box, and are very useful for viewing *all* the test-marker frequencies at once. And of course in the chroma only the markers from 2.5 MHz are of interest to us, with the low frequencies not visible. We can identify which marker point is which by touching a rivet head on the absorption marker box; that will detune that particular series-resonant circuit and it disappears from the curve. Such markers are used only in the 0- to 5-MHz sweep-frequency range.
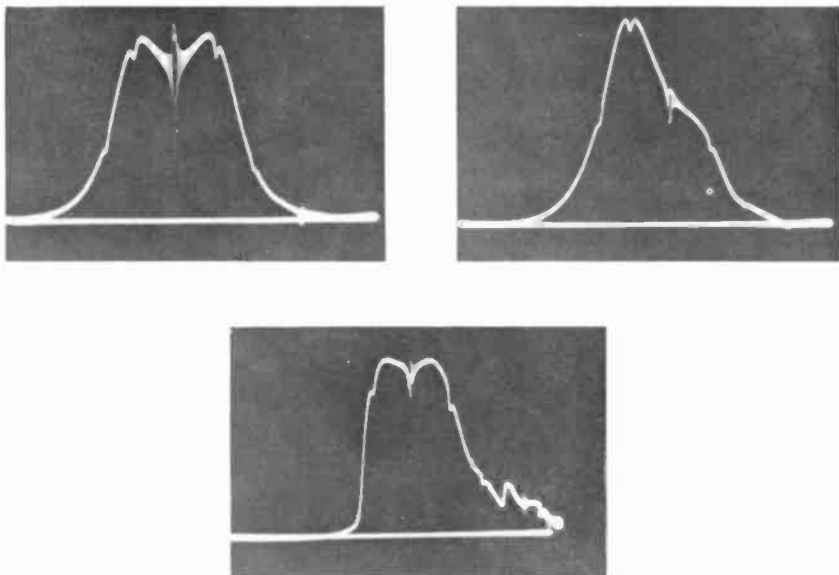
Fig. 1005—Actual alignment curves look like this on scope screen.

When we adjust the fine tuning during a colorcast, the alignment curve and frequency response of the overall chroma signal change radically. (The same thing happens when we use the vsm method and change the carrier frequency.) This is the reason there is only one narrow point on the fine tuning where the color is exactly right. Nothing can be done to make this tuning less critical, for it is a fundamental part of the TV system. But borderline killer adjustments and imperfect alignment will make the situation worse.

A few more points about alignment curves: the 45.75 or picture-carrier side of the curve doesn't have anything to do directly with color, but is quite important to the b-w picture. If the slope is too gradual, the b-w picture lacks "snap" or a certain kind of sharpness; but if the slope is too abrupt, vertical sync will be weak and the fine tuning will be more critical.

Are you somewhat confused by the way one alignment job will have a good curve and poor color while the next one may have a fair curve and excellent color? These variable results come because we can't check phase directly, and we must have correct phase. The closest we can come to good phase response is to make certain each individual tuned circuit is doing the job it is designed to do, and is not also trying to compensate for another's deficiency. Specifically, any overcoupled circuits should be aligned separately from all other tuned circuits, then left alone; *do not change overcoupled circuits as part of a touchup later*. Many sets have the i.f. transformer in the tuner overcoupled to the first i.f. grid coil, even though these two components are in separate locations. This is the most important reason I have for advising you: *Do not exchange color TV tuners* unless you are prepared to do the complete alignment job that may be necessary. Stagger-tuned adjustments are not
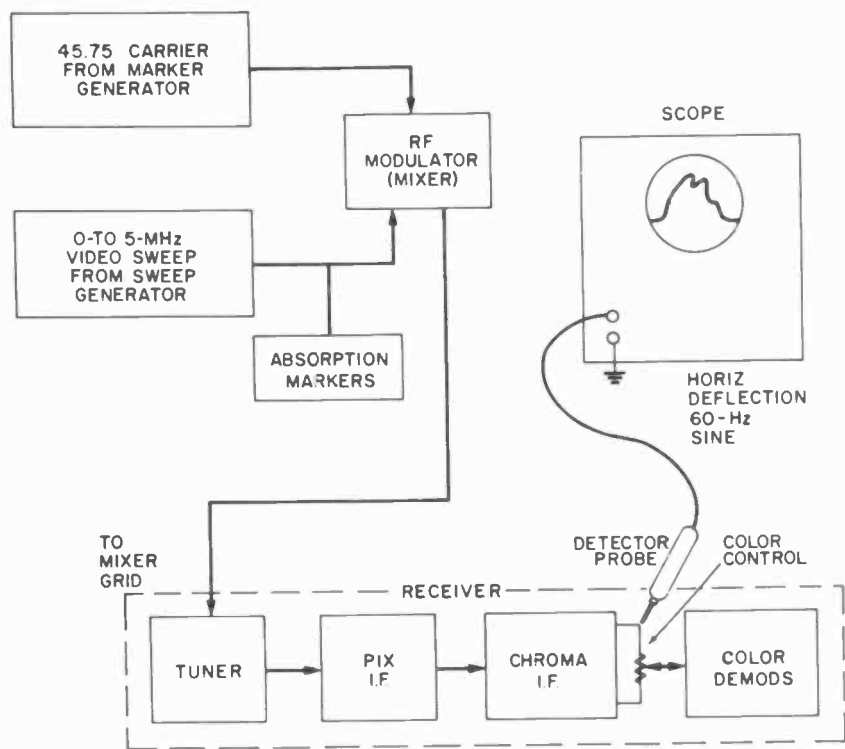
Fig. 1006—How to connect your equipment for an overall i.f.-chroma response test using video sweep to modulate carrier. This is the most nearly infallible test there is in color servicing.

so critical, and can be used to trim up the curve. But in general, to make one tuned circuit compensate for another one that is mistuned is just as impractical as making one link in an actual chain extra strong to make up for a weak one next to it.

There are too many different alignment circuits and methods used today for us to give you a complete procedure for any particular make or model. Follow the instructions given by the manufacturer of the set you need to align. But remember, if a certain load or demodulator circuit is recommended, better use it. Substitutions can change the curve radically. If they specify a certain fixed bias on an i.f. amplifier or blanker, better follow instructions. These few tips plus the basic information about phase vs alignment should enable you to do a fine job of alignment.

Internal and external interference

Closely related to alignment is the type of problem that causes interference lines in the picture at certain settings of the fine-tuning control. Let's say you try the fine tuning from smear to sound bars on each active channel and on one you see herringbone interference lines when the fine tuning is adjusted back away from the sharpest picture. Since it is the fine tuning being adjusted, it seems logical to blame the tuner oscillator, or at least something in the tuner. This conclusion is just as false as the one that says the tuner is at fault when "the sound and picture don't tune in together." It is true the i.f.'s are fixed in their tuning and do not change from station to station, while the oscillator does change frequency. But the *rest* of the true statement is: Adjusting the oscillator changes the frequency of the interference so it moves across the i.f. bandwidth. A marker signal of the same frequency as the picture carrier of the channel to which the receiver is tuned will also march across the alignment curve as the fine tuning is adjusted. All these intermediate frequencies are the result of the heterodyne or beat between the incoming frequency and the oscillator frequency, which is being varied, so the position of this beat signal will move across the fixed i.f. curve as its frequency is changed. Clear?

Perhaps Fig. 1007 will help. We assume a colorcast tuned in correctly so the color carrier and picture carrier are the right frequency and on the right part of the curve, while the interference is in the adjacent sound trap and cannot be seen on the scope or picture tube. If we lower the oscillator frequency 0.75 MHz, the interference frequency becomes 46.5, which is part way up on the curve, so it will be amplified and cause

visible interference lines on the screen. Note also what happens to the b-w and color pictures!
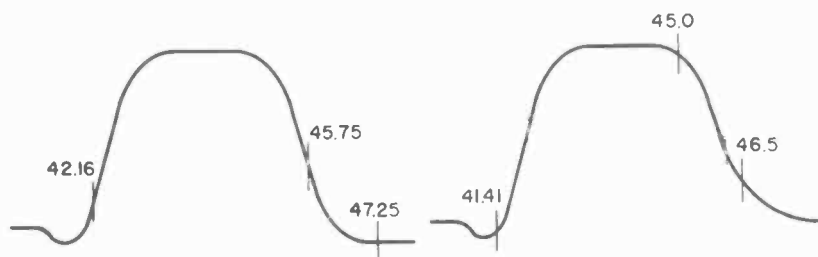
Fig. 1007—Rf interference changes with fine-tuning adjustment. Left curve shows colorcast channel with color carrier at 42.16 MHz and picture carrier at 45.75. Interference carrier, which was 47.25 MHz above or below local-oscillator frequency is in 47.25-MHz trap and does not show up here. Right curve shows what happens when you adjust oscillator (with fine-tuning knob) 0.75 MHz lower. Picture carrier becomes 45.0 MHz and moves to shoulder of curve. Color subcarrier is now 41.41 and is almost in 41.25-MHz sound trap. Interference is now part-way up the curve, at 46.5. Result? Color extremely weak and blurred, b-w picture blurred, interference strong enough to make herringbone pattern.

Interference lines can also be caused by harmonics of the i.f. signal radiating into the lead-in wire or the tuner directly. Such interference will also change with the fine tuning. In a b-w set we can usually mistune the fine tuning slightly and get rid of it; this cannot be done with a color receiver because the mistuning will kill the color.

Rf interference from police short-wave transmitters can often be reduced enough by using tuned or bandpass filters in the antenna lead-in. In extreme cases, the i.f. alignment can be shifted so the interference falls into a trap. Suppose a powerful and very near transmitter is operating on 42.5 MHz. This would cause tremendous interference by being picked up directly by the i.f. wiring and coming through the color channel. Traps would not help here, but the i.f. could be realigned with all frequencies set 1.25 MHz higher. This would make the sound trap tune to 42.50 and completely eliminate the interference.

Another type of interference is peculiar to color receivers, for it comes from radiation of 3.58 from the color oscillator and may cause herringbone on certain channels, particularly Channel 6. I have not had this problem, but I understand that one partial solution is to add small silvered mica capacitors from various points in the 3.58 oscillator and demodulators to ground. Use the smallest size that will help and not impair performance on color programs.

Another rare specimen of gremlin is spurious-oscillation radiation from the 3.58 crystal itself. Again, I have not seen such a thing myself, but understand it causes vertical bars in the color picture. I thought I had such a problem once when a CTC19 RCA had unstable red vertical lines on b-w programs and many straight vertical lines *instead* of the color bars on color. About 30 lines were visible, or three for each color bar. After the 3.58 had been checked and found normal, we finally located the trouble in an open secondary winding of the bandpass amplifier plate transformer—the winding that feeds the color control. This transformer is an overcoupled type with a fairly low-impedance secondary winding that is further loaded by the color control. The open winding apparently lightened the loading on the primary and caused the i.f. tube to oscillate. A part of this false signal came through by stray capacitance across the broken coil leads to the demodulators.

Tuning indicators and afc circuits

I.f. alignment and fine-tuning action are important also to the operation of TV tuning indicators and automatic fine tuning. The tuning indicators operate for the set owner exactly the way meters and tuning eyes do on radios, while automatic fine tuning works just like afc on an FM receiver. Of course, an FM receiver already has a discriminator; one must be added to a TV receiver.

All the models to be analyzed take the signal from the sound detector, for here are many frequencies: sound carrier, picture carrier, color carrier (if the set is tuned to a colorcast), and any other carriers that may accidentally be within the i.f. passband, plus the sum and difference products of all these frequencies, including the 4.5 beat used for intercarrier sound. The picture carrier is by far the strongest of these, and it's used for indication or control. All the sound-detector frequencies are fed to a resonant circuit tuned to pass 45.75 MHz and reject the others. The picture carrier is supposed to be 45.75 after it is heterodyned with the tuner oscillator into an intermediate frequency; whether or not it is actually 45.75 depends on the oscillator frequency.

The two sets with tuning indicators rectify the output from the 45.75 resonant circuit, whose signal voltage is maximum when the picture carrier is 45.75, and less if the carrier is higher or lower in frequency. The dc voltage from the rectifier governs the amount the eye narrows on the Philco 17QT85A tuning eye (Fig. 1008), and in the G-E chassis KC, the dc voltage forward-biases a transistor dc amplifier whose current operates a tuning meter (Fig. 1009). Field adjustment is simple. Just tune in a colorcast, adjust the fine tuning carefully for best color, then

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peak the 45.75 coil for maximum indication on eye tube or meter. The G-E has in addition a minimum-indication pot and another to prevent the meter from going off scale on strong channels.

The automatic-fine-tuning models also take the signal from the sound
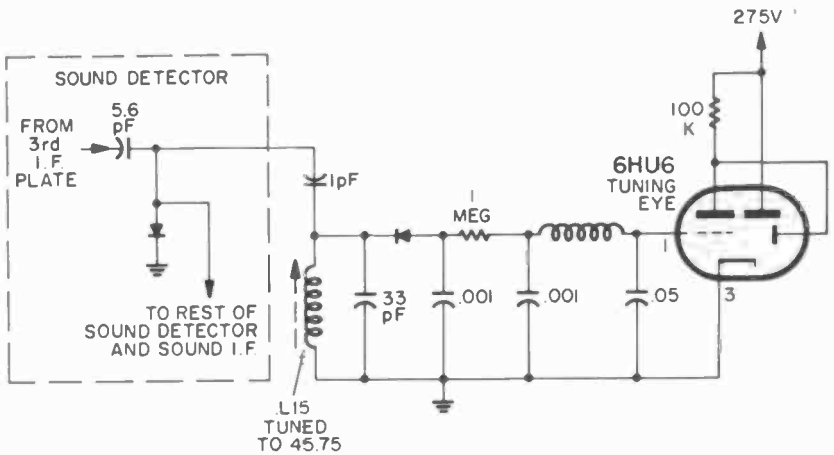
Fig. 1008—Tuning-eye circuit of Philco 17QT85A.
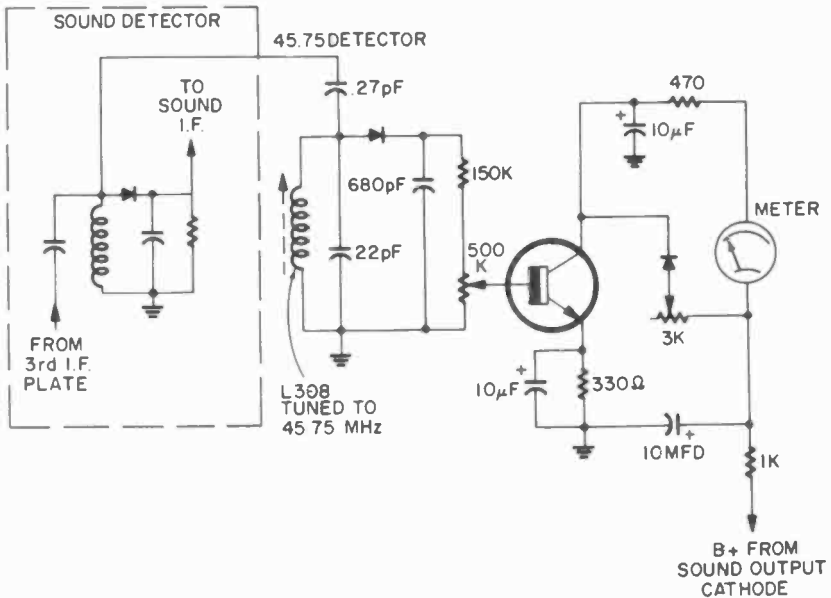
Fig. 1009—General Electric chassis KC tuning-meter circuit.

detector and into a 45.75 resonant circuit. After amplification, the signal is fed to a discriminator, which gives zero dc output at resonance, and positive or negative voltage when the carrier frequency is high or low.

The discriminator dc voltage is fed to the variable-capacitance diode in the oscillator circuit of the Magnavox (Fig. 1010). The diode changes capacitance according to the discriminator voltage applied to it, and the oscillator is tuned in the direction that makes the picture carrier 45.75; when it is, the discriminator has zero output voltage, and the fine tuning is correct.
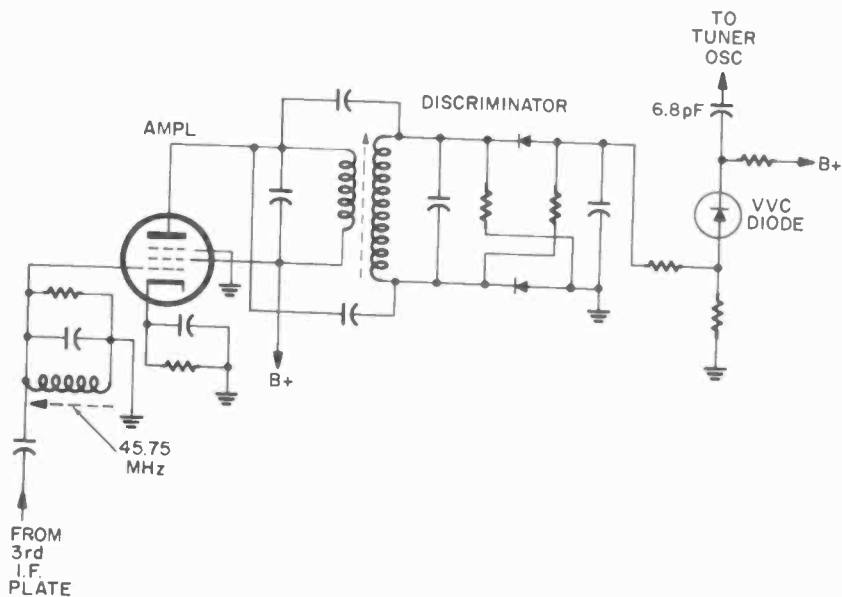
Fig. 1010—*Simplified afc circuit, Magnavox 45; circuit uses voltage-variable capacitance diode.*

The principle of the RCA CTC21's afc operation is the same, but the details are completely different. The diagram in Fig. 1011 shows an absorption trap on the 45.75 input coil to reduce the chance of a strong adjacent sound carrier taking control. There follows a stage of transistor amplification and a discriminator with two diodes. The dc output of the discriminator is increased by a transistor dc amplifier and fed to a capacitance diode in the uhf tuner and to a transistor used as a diode in the vhf tuner. A fixed reference voltage equal to the nominal collector voltage of the dc amplifier is applied to the transistor-diode in the vhf

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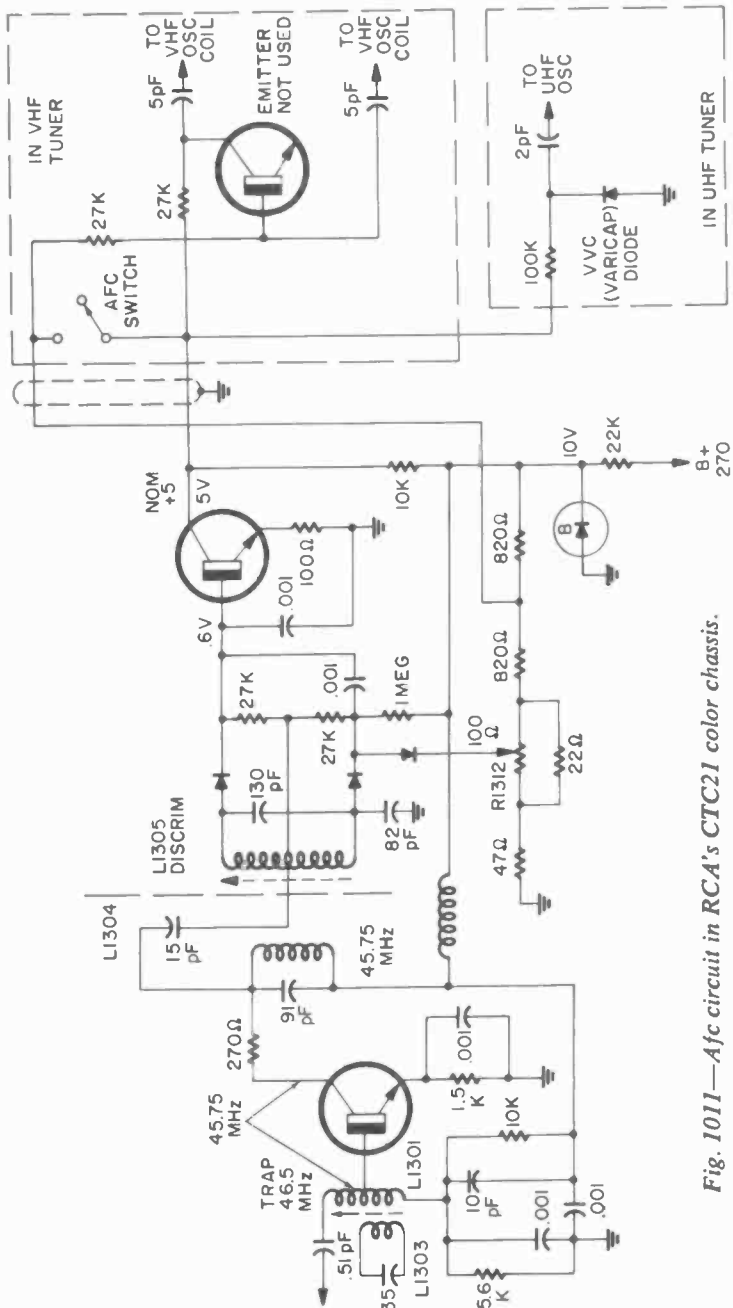
Fig. 1011—Afc circuit in RCA's CTC21 color chassis.

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tuner so that the voltage across it is a replica of the positive–zero–negative discriminator output.

The pull-in range is about 0.5 MHz on either side, so it is best to tune slightly into the sound bars before switching to afc. The field adjustment is a little more complicated on this than on simple indicators because of the reference voltage and the need to set the transistor bias.

1. Slide the service switch to RASTER position. This kills all station signal.
2. Attach a dc vtvm between C146 (reference voltage) and C144 (control voltage) and adjust R1312 for zero voltage on the meter (use the 1.5-volt range).
3. Return the service switch to NORMAL position. Adjust the fine tuning carefully on a color program (this cuts off afc) between beat pattern and smeared picture.
4. Switch afc on, and adjust L1305 (discriminator secondary) for zero voltage on the meter.
5. Remove the meter and check the action of the afc on a color program.

If the color channel is weak or has interference, touch up L1305 with the afc on for the best possible color picture.

Convergence, Purity and Screen-Color Tips

T HE THREE-GUN SHADOW-MASK TYPE OF COLOR picture tube is still champion and virtually without any competition. Red, blue and green pictures still have to be moved together to make a black-and-white picture (*center convergence*); the electron beam from the red gun must illuminate only the red lots, the blue beam the blue dots and the green beam the green dots (*purity*); the curved crosshatch lines (each color line bent in a different way) must be straightened by external magnetic fields taken from the sweep circuits (*dynamic convergence*); and the brightness and contrast of each color must be matched and balanced to create a truly black-and-white picture when all three are on at the same time (*screen color and tracking*). Still the same fundamental necessities; only the controls and the adjustments have changed with the years.

Controls that affect two colors at once, easier screen-color adjustments and closer picture-tube tolerances have all shortened setup time. But we technicians still need one important thing: *patience. All* these adjustments interact and affect each other, some more than others. It is just not possible to do each step only once and get the best results. Vertical adjustments will change horizontal ones, center convergence changes purity, and purity adjustments change centering. This is the important reason behind the recommendation to *follow a certain sequence*—to minimize this interaction.

The basic steps should run in this order: preliminary, purity, screen color, vertical dynamic, horizontal dynamic, pincushioning and color evaluation. Many of these should be done over again several times, perhaps in this order: vertical, horizontal, pincushioning, vertical, horizontal, purity, vertical, horizontal, with center convergence redone whenever it is necessary.

Unless you have just changed the picture tube, many receivers will not need all these adjustments. Some will have defective parts that affect convergence, or whose replacement affects convergence. It is useless for us to try setup adjustments when the set has vertical or horizontal size or linearity problems; or if the focus is poor or there is blooming. Such problems must be taken care of first.

When the only problem remining is one of convergence or purity, then use the crosshatch pattern and give the screen a good "eyeball" examination. Does any one adjustment seem farther out than the others? If so, correct it first; you may find it will not adjust because of some bad part or wrong positioning of the components around the neck of the picture tube. Only when all adjustments seem to work right, but need touching up, should we go through any part of the setup sequence.

There are many variations in the location of convergence components, the action of controls, sliding vs. rotary magnets, and so forth. Yet there are many similarities, and these make it possible to propose a kind of universal setup procedure, with extra notes to explain some of the more important differences in specific models.

SETUP PROCEDURE FOR MOST RECEIVERS

Preliminary adjustments

1. Remove the receiver back and attach antenna and power cable. Mount the convergence panel in a convenient location, if necessary.

2. Tune in a station and adjust fine tuning, vertical and horizontal hold, and brightness and contrast, for a normal b-w picture. The color control should be completely down.

3. Adjust the height and vertical linearity controls for good linearity with ¼ to ½ inch overscan at top and bottom. Adjust vertical and horizontal centering, if necessary, and if controls are provided.

4. Adjust the focus control for the sharpest picture detail (especially on any vertical lines near the center of the picture) when the brightness and contrast are normal. Remember to do this on b-w only, not on color.

5. If there is a peaking switch or control, adjust it for the most pleasing picture, depending on the amount of snow and ghosts.

Purity

Note: purity adjustments should both begin and end with good center convergence (at least the image should not be misconverged more than ¼ inch), for purity is greatly affected by convergence.

1. Connect a switch box to the picture-tube grids and to ground. Check center convergence.

2. Tune in the generator dot pattern by adjusting the fine tuning for sharp but stable dots. Tuning too near the sound bars makes the dots seem to rotate in small circles.

3. Check or correct the yoke tilt according to the lines of dots.

4. Set contrast low and brightness as high as possible without blooming. Switch on red, blue and green one at a time and check them for purity. Visual test is fine if you have excellent color perception, but a 10-power (or stronger) microscope is more accurate since it eliminates reflections from the room. Check the center, all four corners and any other areas that seem questionable. If the dots look fuzzy, stick a piece of cellophane tape on the glass and look through it. If all colors are pure over the entire screen, go on to the next part, **Screen color and tracking.**

5. Degauss the face of the picture tube, especially if set does not have automatic degaussing.

6. Switch red on, green and blue off. Loosen the yoke mounting and slide the yoke back as far as it will go, or until only a small part of the screen is red.

7. Adjust the two rings on the purity magnet to move the red "fireball" approximately to the center of the screen. Ignore any possible neck shadow.

8. Watch the screen in a mirror while you slide the yoke toward the front. Leave it where the purity is best at the edges of the picture.

9. Check for yoke tilt, and tighten yoke mountings when tilt is okay.

10. Center-converge, then check purity of all three colors. Touch up purity-magnet and yoke positioning as needed to give best purity.

Remember, the yoke affects only the edges—the purity magnet of the entire screen. So we can say: Adjust the *purity magnet* if the impurity is in the center or at *one* side or corner. Adjust the *yoke* if the impurity is at *opposite* edges. In some cases, you may have to adjust both slightly for best results.

For Zenith models with "post purity," move the yoke to the rear and center the red "fireball," as in steps 6 and 7. Then degauss externally until the position of the "fireball" does not change with degaussing. Recenter the red area again with the purity magnet and go

on with the sequence. The red ball does not move as much with purity-magnet adjustment on this set as on others.

Screen color and tracking

Screen color and tracking have no effect on convergence, but should be done now so that all colors will be bright enough to be seen easily.

1. Disconnect the generator and tune in a b-w program of normal brightness and contrast.

2. Slide the SERVICE–NORMAL switch to the SERVICE position. This disconnects the video and kills the vertical sweep to give one horizontal line whose brightness is not affected by the brightness control.

3. Turn the CRT bias control all the way down (or slide the picture-tube bias switch to the top position); turn all three screen controls all the way down.

4. Turn up the screen controls, one at a time. Should any controls have to be turned nearly all the way up to show a line, turn up the CRT bias, or slide the bias switch to next lower position. Repeat this until all three colors will show a line with the controls set about ¾ of the way up.

5. Turn the green and blue screen controls down, and the red up enough to make a very dim red line. Turn up the green screen control to make the horizontal line a greenish-yellow color, then turn up the blue to make it blue-white. Juggle these adjustments to make a good white line. The lines may not converge properly because of the lack of vertical sweep, but you can look at them in a mirror to increase the effective distance, or squint to blur the lines.

6. Slide the NORMAL–SERVICE switch back to NORMAL. Preset blue video drive at about ¾ and adjust the green video drive to give a good blue-white picture. Alternately adjust blue and green video drives for best screen color, and check at high and low brightness and contrast to see that color doesn't change.

These adjustments are based on the fundamental facts that screen controls affect the raster color most at low brightness, and grid bias (including the video drive controls as individual contrast controls) affects the tracking most at high brightness.

Motorola differences

In the Motorola TS908, the brightness control is not disconnected with the service (CRT) switch, and the TS918 has no service switch. Use this method for them:

1. Adjust the tint control to mid-position. This is the customer control which changes the screen color from pink to white to blue. Preset the blue video-drive control at about ¾ and the green drive about ½.

2. Turn the master G-1 (bias) control to minimum, and tune the receiver to a blank channel with contrast at minimum.

3. Turn all G-2 (screen) controls to maximum.

4. Adjust the brightness control until the raster is barely visible (turn master G-1 up or down if necessary).

5. If one color predominates in the dim raster, turn down that screen (G-2) control. The screen control for the weakest color should be left at maximum. Alternately adjust brightness and the two strongest screen controls until a dim gray raster is obtained.

6. Leave contrast down and tune the set off-channel. Turn the brightness control to maximum.

7. Turn the master G-1 control up until the raster starts to defocus, then back it off about ¼ turn.

8. Tune in a TV station, and adjust brightness and contrast for a normal picture.

9. If the screen color is not a true gray-white, adjust the green and blue video-drive controls until it is.

VERTICAL DYNAMIC CONVERGENCE

1. Tune in the generator again, but set the pattern for crosshatch.

2. Locate three checkpoints along the center vertical line. Notice that the top and bottom ones are 2 to 3 inches from the edge. See Fig. 1101.

3. Center-converge, then turn blue off, red and green on.

4. Adjust the BOTTOM R&G VER. LINES control (No. 1) so the red and green vertical lines are converged at the *bottom* checkpoint.

5. Adjust the TOP R&G VER. LINES control (No. 2) so the red and green vertical lines are converged at the *top* checkpoint.

6. Adjust BOTTOM R&G HOR. LINES control (No. 3) so the red and green horizontal lines are converged at the *bottom* checkpoint.

7. Adjust the TOP R&G HOR. LINES control (No. 4) so the red and green horizontal lines are converged at the *top* checkpoint.

8. Repeat steps 4, 5, 6 and 7.

9. Turn blue on and green off.

10. Adjust BOTTOM BLUE HOR. LINES control (No. 5) so the blue horizontal line is converged with the red at the *bottom* checkpoint.

11. Adjust the TOP BLUE HOR. LINES control (No. 6) so the blue horizontal line is converged with the red at the *top* checkpoint.

12. You should repeat steps 5 and 6 again, then center-converge and repeat steps 4 through 11 once more.
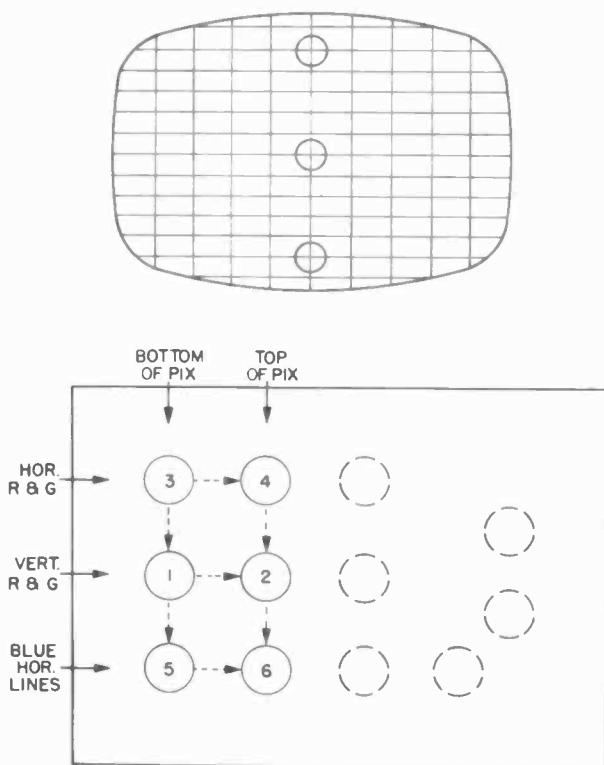
Fig. 1101—*Adjust only for three vertical checkpoints, at center and near top and bottom edges. Drawing shows relevant controls.*

HORIZONTAL DYNAMIC CONVERGENCE

1. Locate three checkpoints along the center horizontal line (Fig. 1102).

2. Switch red and green on, blue off.

3. Adjust the core of the RIGHT R&G VER. LINES coil (No. 7) until the red and green vertical lines are converged at the *right* checkpoint.

4. Adjust the LEFT R&G VER. LINES control (No. 8) until the red and green vertical lines are converged at the *left* checkpoint.

5. Adjust the RIGHT R&G HOR. LINES coil (No. 9) until the red and green horizontal lines are converged at the *right* checkpoint.

6. Adjust the LEFT R&G HOR. LINES control (No. 10) until the red and green horizontal lines are converged at the *left* checkpoint.

7. Repeat steps 3, 4, 5 and 6.

8. Turn green off and blue on.

9. Adjust the RIGHT BLUE HOR. LINES coil (No. 11) until the blue lines converge with the red at the *right* checkpoint.

10. Adjust the LEFT BLUE HOR. LINES control (No. 12) until the blue lines converge with the red at the *left* checkpoint.

11. Center-converge and repeat steps 2 through 10.

Motorola differences

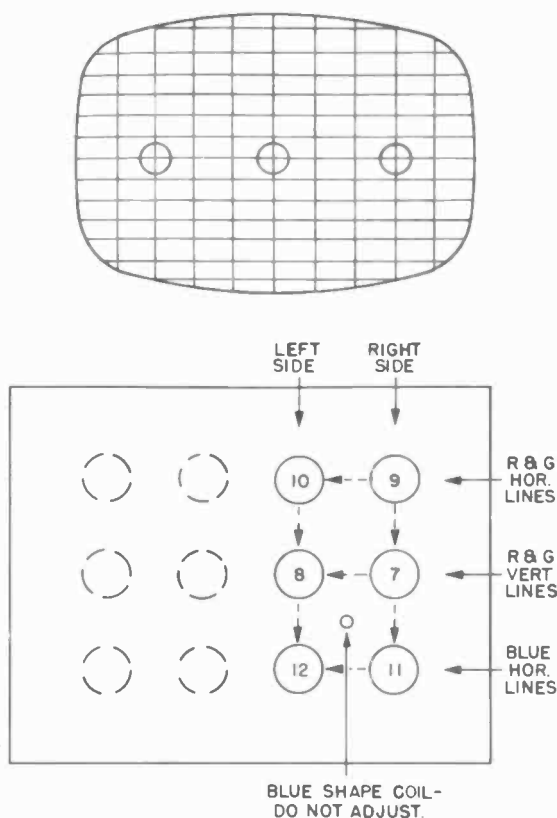Motorola TS908 and TS918 controls No. 9 and 10 do not have quite

Fig. 1102—Adjust only for three horizontal checkpoints—center, near right edge and near left edge. Drawing shows relevant controls.

the same action as those just described, but are close enough so you can check their action at the checkpoints and adjust accordingly. Motorola numbers their controls according to the sequence of use, so there are four adjustments for blue horizontal, including one made twice at different times. Use this sequence for blue horizontal (green switch off, red and blue on):

11. Turn blue amplitude controls (Nos. 11 and 14) fully clockwise.

12. Turn coil No. 13 (BLUE CENTER HOR. PHASE) until it has no further effect on the blue horizontal line. Adjust coil No. 12 until the maximum droop of the blue line is in the middle.

13. Adjust coil No. 13 until there is a slight upward movement at the exact center of the screen, and the line displacement at the right and left sides is the same.

14. Adjust control No. 14 (also called No. 11) until the blue line is converged with, or parallel to, the red horizontal line. Touch up the adjustment of coils 12, 13 and 14 for best convergence with the red line.

15. Center-converge and touch up all the horizontal adjustments again.

You have probably noticed the number of repeats. They are absolutely necessary for best possible results. Do the adjustments over several times, but don't spend too much time on each one, especially the first and second time. This way you will get a good job and probably spend less total time than if you strained trying to get everything right the first time.

Convergence problems

Perfect convergence is not possible on present sets, although occasionally we will find one that approaches it. No adjustments are provided for the corners and no technician can guarantee perfect convergence in the last 2 or 3 inches around the edges. However, the difference between a sloppy job and one that goes as far as the set's condition will permit is often amazing. So do the best possible convergence job on every receiver.

What do we do if the set will not converge as well as the average for that model? Then we have to determine whether a part defect or a wrongly placed setup component is the cause. It is very common to find the convergence assembly, consisting of the dynamic-convergence coils and the adjustable center-convergence magnets, twisted sideways or forward or backward until it is not over the convergence electrodes inside the tube. Convergence voltages and waveforms were never intended to compensate for that kind of condition, and the convergence adjustments

under these circumstances are usually a very poor compromise. For the 21-inch round tubes, the distance between the front of the base and the rear edge of the plastic form holding the convergence coils should be about 3¼ inches, and you should measure it if there is any doubt.

The vertical or horizontal windings of the coils on the picture-tube convergence assembly have opened occasionally. The troubleshooting clue is that some convergence adjustments still work normally, while others don't come within a country mile of working. If the coil is in the red or green assembly, both colors will be affected since these coils are effectively somewhat in series. A bad blue coil changes only the blue adjustments.

The convergence board and its components are a promising source of trouble. Many boards have four selenium rectifiers, which can short or open. To test them, short the hot leads to ground; no change in convergence (especially at the left side) means the rectifier is shorted. A better convergence with it shorted indicates an open rectifier. Borderline cases are best found by disconnecting the rectifier assembly and testing with an ohmmeter. The potentiometers can open or become erratic. Defective ones can be found by rotating the control from end to end and watching the convergence on the screen. No change or an abrupt change at one end indicates an open control, while jumpy results mean the control is worn or erratic. The adjustable horizontal coils can have shorted turns or open windings. Shorted turns usually make a coil run hot, while the others run normally warm. A coil with an open winding will produce no convergence change when it is adjusted. In general, it is very helpful to adjust the control or coil and notice the action. or lack of it.

Chapter 12

Solid-State Color TV

C OLOR TELEVISION RECEIVERS ARE THE last hold-out against the rising popularity of transistor merchandise. Radios and stereo players are almost all solid-state now, and many models of b-w television sets are, too. At this writing, there are no all-transistor color receivers, but Philco has had hybrid tube-and-transistor models for two years. Other brands have transistors, integrated circuits, diodes, varactors, thermistors or voltage-sensitive resistors scattered among the tubes. The trend is clear: Soon all television receivers, b-w and color, will be completely solid-state.

To us as technicians this change will mean many differences in our repair methods. But it matters not whether we use tubes, transistors or shredded coconut as amplifiers; the basics are the same and will remain the same so long as we use voltages and currents in the circuits.

Just ask yourself this question: How would I troubleshoot a television receiver if the tubes were soldered into the circuit without sockets, gave off little heat, seldom became weak, and were painted black so the internal elements could not be seen? When you answer this question thoughtfully, you have made that first and largest step into this new servicing field. Condensed to one sentence, the answer is this: *You will depend more on measurements and less on blind replacement.* This is the theme behind all the servicing methods detailed in previous chapters.

Even if you are impatient with everything except practical servicing tips, I suggest you read through the following preliminaries. I promise

there will be no chemistry or "holes vs. electrons" theory to bore you. Transistors are *not* just a slightly different type of tube, but are a totally new breed of cat. We must understand a few of their peculiarities if we are to service intelligently (which in this case means rapidly and profitably).

An easy way to remember the physical construction of a transistor is to imagine it as a sandwich (Fig. 1201). These three elements can vary widely in shape and thickness; one may even diffuse gradually into another. Regardless of shape, any collector-to-emitter current *must* pass through the solid material of the base—thus the term "solid state."
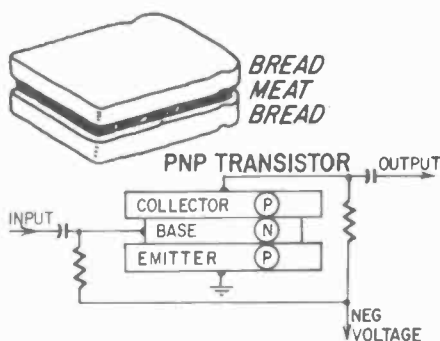

Fig. 1201—A junction transistor is built like a semiconductor sandwich—two p-type (or n-type) layers of bread around an n-type (or p-type) slice of meat.

The positions of the p and n (positive and negative) materials can be reversed to create an identical transistor of opposite polarity. That is, one that requires a reversed voltage supply. There is no equivalent in tubes for this mirror image. This choice of polarities helps the design engineer, but it adds one more variable to confuse us. The *transistor symbol arrow points to the n material,* or, to say the same thing differently, the *arrow points toward the element that has a negative voltage* compared to the other. Or remember this from the middle letter of the type designation: A p*n*p type in class-A operation will have both base and collector *negative* to the emitter, and a n*p*n will have both base and collector *positive* to the emitter. See Fig. 1202. Oscillators and class-C amplifiers usually have an average base voltage that is opposite to the normal class-A bias. Of course, the base must have forward bias for a small percentage of a cycle, but a meter may read this as reversed bias.

Fig. 1202 also shows how we can visualize a transistor as two diodes in series, back to back. This does not explain how you can ever get current from collector to emitter or how an emitter–collector short is pos-

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sible, but it is very useful in anticipating voltage and resistance readings. It is also the basis for a simple but effective method of checking transistors with an ohmmeter.
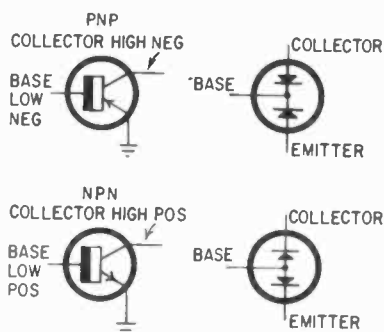

Fig. 1202—The two "sexes" of transistors. Both behave like two diodes connected in series back to back. Collector current doesn't flow at all (in theory) unless the base–emitter diode is forward-biased.

Current cannot flow between collector and emitter unless the base–emitter junction is forward-biased. Forward bias means a voltage of the polarity that gives maximum base–emitter current. The base–emitter current determines the input impedance (which is usually very low compared to tube values), the collector current and the transistor gain. None of these three is a linear function. Fig. 1203 shows an experimental germanium-transistor circuit where the base–emitter voltage is varied upward from zero and the collector current, transistor gain and input impedance are plotted simultaneously. You will notice a definite peak in the gain at a certain base–emitter voltage, and (obviously) if maximum gain is what we're after, we must find and use this voltage. Or we may want to vary this voltage for agc, as we would change the grid-cathode bias on a tube. It is more difficult to change the transistor forward bias because both current and voltage are required. A tube requires only voltage. Also, conventional transistors do not vary their gain as much or as linearly as tubes do when their bias is changed. Field-effect transistors are much better in that respect, and may soon become important in TV tuners.

From Fig. 1203 it would seem that agc action could be obtained by shifting the base forward bias either upward or downward from the voltage that gives maximum gain. That works, but there are many difficulties. Using downward-going agc uses the *cutoff* characteristic, giving less gain, less collector current and a higher input impedance. The upward-biasing scheme makes use of the *saturation* characteristic

to give less gain, more collector current and a lower input impedance. The lower collector current possible with cutoff agc is not important unless the receiver is battery-powered. The higher maximum current from the saturation biasing is not important as long as it is not large enough to cause transistor failure. Both methods lower the gain, so the only important consideration remaining is the effect of input impedances on the tuned circuits in the i.f.'s and tuner.

Tapped coils or capacitive voltage dividers are used to match the tuned circuits to the transistor bases and minimize the loading effect of low input impedance. But the base is still coupled to the resonant circuit, so the lower input impedance caused by saturation biasing will
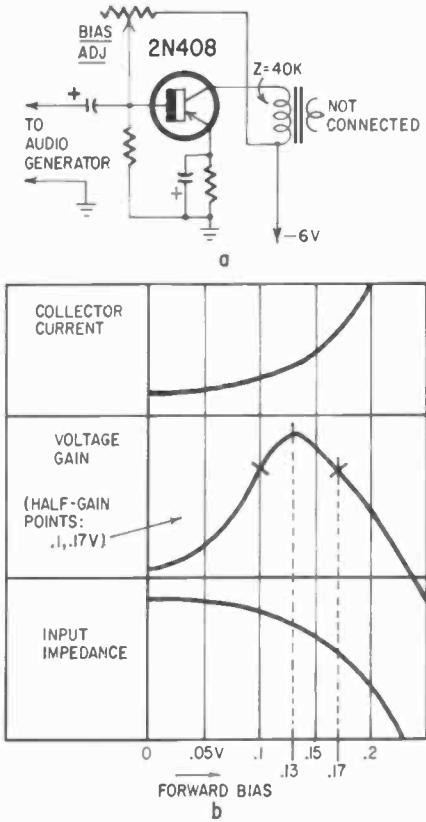

Fig. 1203—*A simple transistor amplifier with very high gain (a). Curves in part (b) show what happens to collector current, gain and input impedance as bias is pushed up.*

usually lower the Q of the tuned circuit. This reduces the signal there and shifts the resonant point slightly. By comparison, the higher base impedance caused by cutoff biasing will raise the Q, increase the signal in the tuned circuit and shift the resonant frequency slightly in the other direction. Notice that this increase in the signal from the tuned circuit opposes the desired transistor gain reduction. Saturation biasing creates less cross-modulation than does cutoff, and this can be important in the tuner rf stage. Cutoff biasing narrows the bandwidth on strong signals and broadens it on weak ones, while saturation biasing broadens the alignment curve on strong signals and narrows it on weak signals—the latter is more desirable. Saturation biasing would seem to be preferable in a b-w receiver, unless the designer has found a way of eliminating any bandwidth change within the range of the agc action. The reason I mention a b-w receiver is that *any* change in bandwidth on weak or strong stations is undesirable in a color receiver, for it will give poor overall color alignment on either weak or strong channels.

If the nominal value of forward bias chosen is not the one that gives maximum gain, two problems can arise. First, the difference in the gain between where the bias actually is and where it should be for maximum gain is subtracted from the total amount of agc action. For example: On the chart in Fig. 1203, assume the bias to be 0.1 volt, which gives 6 dB less gain than the maximum gain possible (at 0.13 volt). With cutoff-type agc action, this will mean 6 dB less total agc gain reduction than if the bias were the optimum 0.13; this can be quite important in strong-signal conditions.

Again from Fig. 1203, assume the receiver to be using saturation-bias agc, with a no-signal transistor bias of 0.1 volt. If the station carrier strength increased, the agc might raise the bias to 0.13, but instead of a gain reduction of 6 dB, the gain would try to *increase* 6 dB. Of course, this example is oversimplified since more than one stage is usually controlled. The gain in one and the loss in another might cancel to make the agc ineffective. For best agc action, the weak-signal forward bias should be the voltage that gives maximum gain. Check for this by changing the forward bias to find this best voltage, if all the usual remedies fail.

The weak-signal forward bias on a tuner rf-amplifier transistor is very critical in minimizing snow. Some b-w receivers have a control to set this bias accurately for the particular transistor being used. If there is no control, we might consider tailoring the resistor values in the forward-bias voltage divider to give the least amount of snow.

The agc circuit of the 16QT85 Philco hybrid receiver is an interest-

ing and complex one. See Fig. 1204. A negative-going detector is direct-coupled to the grid of the first video amplifier (tube), so a stronger video signal makes the video-amplifier plate go more positive. The plate is coupled through a resistor to the base of keying-transistor Q2, whose emitter is adjustable over a small range to permit agc level-setting. The transistor has approximately 160 volts dc on it measured to ground, so it obviously cannot be used to control the i.f. transistors directly when they are powered from an 18-volt supply. Another stage is necessary in between.
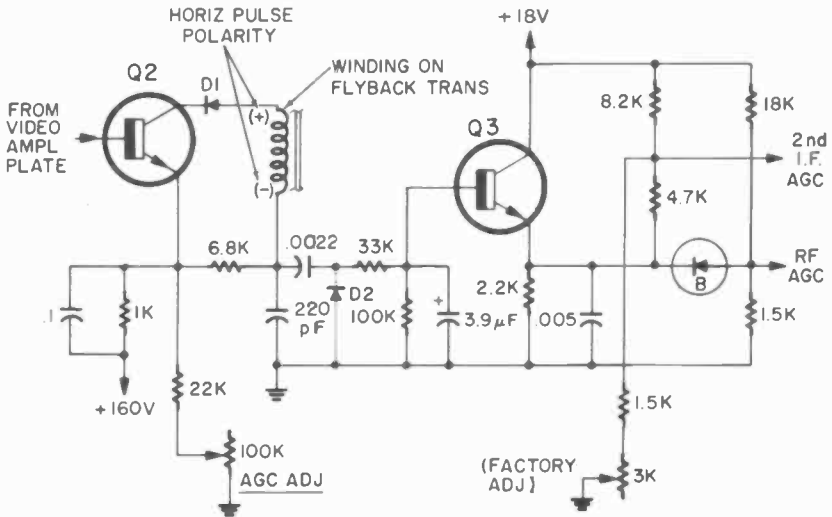

Fig. 1204—Solid-state agc system in Philco 16QT85.

Q2, a keyer stage, functions exactly as its tube counterpart does, except the horizontal pulse is applied between collector and emitter. D1 prevents damage to the transistor from horizontal ringing voltages and the 6.8K resistor is the load across which the rectified dc (with a large amount of ripple) is developed. The dc voltage is not used here. The higher the station signal, the more keyer conduction and the more horizontal-frequency ripple is obtained at the 6.8K resistor. This ripple is capacitance-coupled to shunt rectifier D2, whose output is filtered and applied to the base of Q3, which functions as an emitter-follower impedance-matching device. The more positive dc at Q3's high-impedance base, the more positive dc is obtained at the low-impedance emitter. From the emitter, a voltage divider (with a factory-adjusted control) feeds the agc voltage to the base of the second i.f. amplifier transistor.

(The base voltage for the first i.f. transistor is taken from the emitter of the second i.f., so *both* stages are actually gain-controlled.)

On weak signals, the tuner rf-amplifier transistor receives a fixed forward bias from the 18K and 1.5K voltage divider between power supply and ground. On stronger signals, the emitter voltage of Q3 rises higher than this fixed tuner bias, current passes through D3, a Zener diode, and increases the rf amplifier's forward bias. Both the rf stage and the two i.f. stages are agc controlled in the saturation condition—forward bias is increased (pushed more positive, in this case) to decrease transistor gain.

Other transistor circuits in color receivers

Transistors can now be found sandwiched in between the rows of tubes in many color receivers. Nearly all makes and models use a transistor oscillator on uhf, and these transistors have proved to be far less trouble than the tubes they replaced. Several Motorola chassis use transistors in their anti-pincushion circuits.
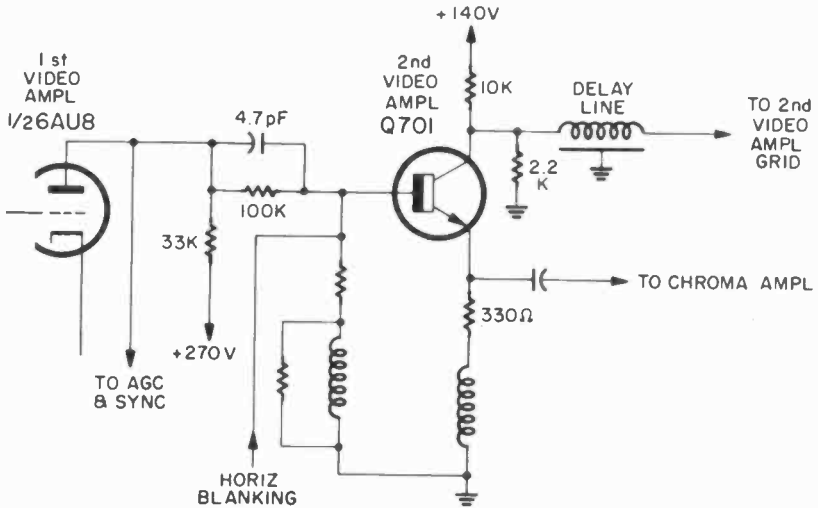

Fig. 1205—*General Electric CB chassis uses npn transistor as second video amplifier.*

The General Electric CB chassis uses an npn transistor as second video amplifier between two tube stages. This seems a natural step, since the tube it replaced was operated as a positive-grid amplifier whose characteristics were almost identical to that of a transistor. The simpli-

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fied circuit is given in Fig. 1205.

Most color receivers feed a pulse (taken from the plate of the vertical-output tube) to the plate of the last video stage to bias the picture tube to cutoff during the vertical retrace time (blanking). This is not completely successful since the pulse is too narrow for complete blanking at the top of the picture, and retrace lines may appear there on low-contrast scenes. The RCA CTC17X chassis (Fig. 1206) uses a transistor as an amplifier–clipper to give better vertical blanking. A positive-going pulse is taken from a secondary winding of the vertical-output transformer and applied to the emitter of an npn transistor. A voltage divider in the cathode of the vertical output tube supplies the
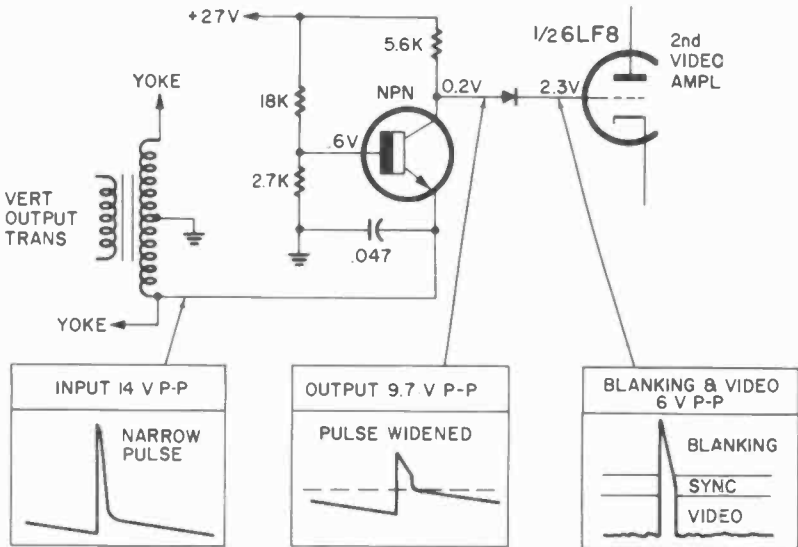
Fig. 1206—Vertical blanking in RCA's CTC17X.

suppressor of the 6JE6 horizontal output tube and also the base and collector of the blanking transistor. The supply voltage varies with the height setting, but is around 27 to 30 volts. With a base bias of around 0.6 volt, and with 14 volts peak-to-peak vertical pulse applied to the emitter, it is obvious the transistor *must* distort the waveform; the 0.2-volt dc collector voltage verifies this conclusion. The distortion is deliberate, for it is needed to clip off the top of the spike, leaving only the wider lower portion. Thus the spike is effectively widened to also blank the top of the screen. Since the input is to the emitter, there is no phase reversal, and the collector has about 10 volts peak-to-peak output.

Two barriers to good vertical blanking still remain. The bottom of the vertical waveform at the collector is tilted between the spikes, and this will cause the top of the raster to be shaded darker than the bottom if the waveform is allowed to remain that way. Also, the voltage output of the transistor is only slightly more than is needed at the grid of the second video stage, and it would be difficult to connect them together in a resistive network without reducing the video voltage too much, or smearing picture detail from capacitance in the long leads. Both these problems are solved by adding a diode between the transistor collector and the tube grid. The dc voltages on the diode reverse-bias it between vertical pulses, making it an open circuit. The collector voltage must rise about 2 volts dc from the pulse waveform before the diode becomes forward-biased and connects the collector and grid together. This clips off the bottom of the blanking pulse at the grid, and allows most of the spike voltage to be applied to the grid. Smearing the picture detail is prevented since the diode disconnects the blanking circuit from the video-tube grid except during the vertical retrace time, when there is no video anyway. Remember: In this set, the vertical blanking pulse will be in all the video stages from the second video grid to the picture-tube cathodes. This will affect the voltages and waveforms you measure with your vtvm or scope. Do *not* connect a scope for viewing alignment where there is blanking voltage, for the extra 60-Hz signal will make the curve completely false.

The most important question to us technicians is what happens when parts become defective. Which parts are most likely to fail, and what are the symptoms? Field experience has shown the transistor to be the most frequent offender, and it usually opens instead of shorting. When this happens, the collector voltage rises higher than the normal tube-grid voltage so the diode will be forward-biased (fully conducting) during *all* of the vertical-scan cycle. The top of the picture will be shaded dark, the picture detail will be slightly blurred, and there may be dark and light vertical bars, most noticeable on the left side of the screen. These vertical bars are caused by horizontal ringing which is amplified by the video circuit and modulates the picture brightness. The bars are worse on early-production sets, before the .047-μF capacitor was added from emitter to ground. The vertical bars and shading may be confined to the top of the picture if the transistor is only partially open. More information is included in the chapter on case histories.

Transistor characteristics important in servicing

Solid-state components will not tolerate overloads, not even for short

periods. Our only protection is to be certain such overloads do not happen. Don't accidentally short a transistor element or voltage so the transistor is overloaded; this applies especially to careless use of test prods. One slip may ruin two or three transistors if the short is in a sweep circuit or other high-power area. The smaller size of transistor equipment makes care and accuracy even more important. Above all, don't randomly short parts of any circuit to ground. Since transistors do not have heaters, they are often used backwards from the usual custom with tube circuits; the collector may go to ground (chassis), while the base and emitter connect to the power supply. A short from base to chassis would be sure to ruin the transistor. The only safe short is from base to emitter, for this removes all the forward bias and stops all collector current. You could use this method for a "click" (circuit-disturbance) test, or you could connect a resistor of 25K to 50K to ground or power supply and then touch the other end of the resistor to the transistor elements without any great danger of damage.

I'll never forget the time I tried checking a large filter choke with a test light (bulb and 3 volts of battery) and got a violent shock when the circuit was broken while my hand was still across the choke terminals. Did you ever have an audio output tube arc across the socket when you operated the set at high volume with the speaker disconnected? A pentode tube's ac output voltage is proportional to the plate impedance, and without the speaker the output-transformer impedance increased many times.

These two examples demonstrate that a sudden stoppage of current through a highly inductive circuit will produce transients many times larger than the dc voltage in the circuit. In a transistor output circuit that involves a transformer, a transient can ruin the transistor completely. There are a few audio circuits with enough negative feedback to prevent any large rise in ac voltage, but the general tip is: Do not operate a transistor output stage without its normal speaker load. Notice too, speakers are not always 4 or 8 ohms, but may be 35 to 120 ohms in transistor circuits. Better play it safe.

The ultimate in transients is a high-voltage arc in a TV receiver. Transistors far removed, circuitwise, from a major arc have been known to fail. Many arcs will trigger smaller ones in the general area, yet there will be no direct connection between them. For this reason, if you must draw arcs to check for high voltage, draw them from high voltage to the high-voltage cage, not to any other part of the chassis.

All transistors are heat-sensitive, even though this may not be apparent to you in casual testing of highly stabilized transistor circuits. The higher the temperature, the lower the base–emitter junction resistance

becomes and the higher the base current becomes. Or, to say that another way, less forward bias is necessary to give a certain collector current when the temperature is higher. Power transistors in circuits with well regulated base and collector voltages are prone to "run away" and destroy themselves when their junction temperature goes too high. The heat causes more collector current, which raises the junction temperatures, which causes more current, which raises the temperature, and so on, until the transistor fails. This is the reason for the emitter resistor in many circuits (from less than an ohm to a few thousand ohms). It helps prevent current runaway by tending to buck base–emitter forward bias as collector current increases.

Avoid extremes of temperature if you want dependable transistor operation. Some transistor radios will quit working altogether if they are left outdoors and become too cold; there is just not enough forward bias to overcome the higher base–emitter resistance. By the same token, the forward-bias voltage on a hot transistor (still having normal gain and collector current) will measure far less than the diagram calls for. Don't be deceived by this apparent discrepancy.

This sensitivity to heat can be used to very good advantage, however, in the many cases of intermittent transistor operation. A transistor TV that is highly intermittent in its cabinet may become stubborn and want to work all the time when removed for testing. Use a small pencil-type soldering iron to heat the leads of the suspected transistors. When you get to the bad one, it will stop working immediately. Spray some cooling spray on the transistor as soon as possible, and the transistor will snap back into operation. Repeat this a couple of times to make sure it was not an accident; if not, you have found a bad transistor. Connecting leads bonded ultrasonically to the germanium or silicon wafer can become loose, and heat may make them move the slight amount necessary to break contact. The specific transistor defect is an intermittent open circuit to one element.

As a dramatic demonstration, I held a match under an operating transistor in a radio until the music stopped. When I removed the heat, the radio played again after a few minutes, apparently no worse for the experience. Don't let this make you careless about applying heat to transistors, for it is a special case. It will work safely only on small transistors in a well stabilized circuit where the resistances in the collector or emitter circuit limit the maximum current to a safe value. Also, the heat should be kept as low as possible, for excessive heat for a long time may rediffuse the junctions and permanently damage the transistor. Silicon transistors can stand higher temperatures than germanium transistors.

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Transistor testing

You may already have your own favorite method or test equipment for checking transistors after they are removed from the circuit. But you might be interested in my method, if only for the information it gives (secondarily) about transistors and ohmmeters. The concept of the method is very simple: Just measure the resistance of collector and emitter when they are forward-biased to the base, measure the same points with reverse bias, then check emitter-to-collector resistance with both polarities. The first two of these tests are the same as if we were checking two diodes hooked back to back. The chart in Fig. 1207 gives the specific tests for germanium transistors. Silicon types will have much higher resistance readings, but will follow the same general pattern.

Type of test	Negative meter lead to:	Positive meter lead to:	Ohmmeter range:	Good reading, in ohms:
Small audio and rf transistors				
Forward resistance	base	emitter	×10	50 or less
	base	collector	×10	50 or less
Reverse resistance (leakage)	emitter	base	×10K	25K or more
	collector	base	×10K	25K or more
Emitter–collector, forward	collector	emitter	×1,000	1K or less
Emitter–collector, reversed (short)	emitter	collector	×1,000	25K or more
Power transistors				
Forward resistance	base	emitter	×1	4 or less
	base	collector	×1	4 or less
Reverse resistance (leakage)	emitter	base	×1,000	15K or more
	collector	base		
Emitter–collector forward	collector	emitter	×10	1K or less
Emitter-collector reversed (short)	emitter	collector	×100	4K or more

All measurements read on a vtvm with a 1.5-volt ohmmeter battery. Vom's or vtvtm's with other battery voltages will give very different results.

Fig. 1207—Handy chart for checking resistance of germanium pnp transistors. Reverse all polarity listings for npn transistors.

You will find many exceptions to the typical readings in the chart. For example, rf, i.f. and low-noise audio types will give higher readings on the reverse-bias (or leakage) tests and on the emitter–collector shorts test. The small class-B types, such as 2N109 or 2N408, will usually read lower. These variations need not mislead you if you keep these guidelines in mind:

1. The forward bias resistance tests should show nearly identical readings on both emitter and collector measured from the base; the lower the resistance, the better. The reversed bias tests (although much higher in resistance than the forward bias readings should also be nearly the same for both collector and emitter measured from the base; the higher they both are, the better. The *exact* resistance is not so important as whether the emitter and collector readings are nearly equal.
2. The emitter–collector forward and reversed readings should show a 1-to-20 ratio.
3. The forward readings will be more uniform than the reversed readings; therefore, the reversed readings are more important.
4. An open lead will make both forward and reversed readings show open.
5. Nearly the same reading on both forward and reversed tests indicates excessive leakage or an internal short.
6. The chances for an open lead are the same for each element.
7. A short or high leakage happens most often between emitter and collector.

If you use transistor resistance checks at all, keep this important thought in mind: You must settle on one type of meter and the best scale to use for each step. A transistor which reads 35 ohms on the ×10 range might read 1,000 ohms on the ×1,000 range. Is the meter at fault? No, the meter is telling the truth. The different readings are caused by the voltage supplied to the transistor during the test. Consider
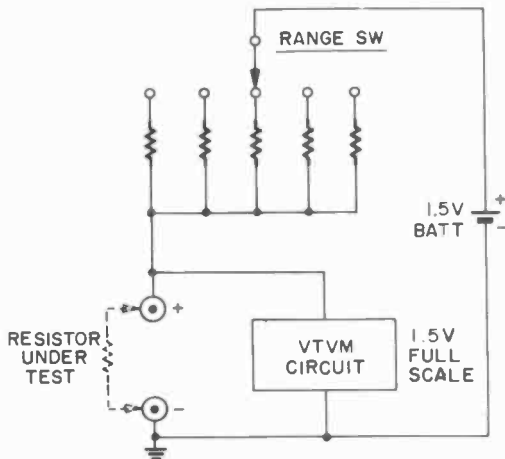

Fig. 1208—Simplified vtvm ohmmeter circuit.

the ohmmeter circuit of a vtvm (Fig. 1208). Basically, it is a voltage divider with a vtvm measuring the voltage across the unknown resistor under test. With no external resistor connected, the full 1.5 volts from the battery appear at the probes regardless of the range used. This is why only one maximum-adjustment knob is needed for all ranges. On the ×10 range, the switch selects a 100-ohm resistor as a standard to compare with the unknown. When the external resistor is 100 ohms, the voltage across it is 0.75 volt and the vtvm reads half scale. The half-scale reading is the value of the standard resistor. If you want to know what voltage is actually across the test probes, read the 1.5-volt scale instead of the ohms scale. The higher the pointer reads, the more voltage across the leads; and the more voltage applied to the transistor under test across those leads, the lower its resistance. Readings near maximum (high resistance) on a low range will be lower than those taken on a higher range, which puts the indication on the low end of the scale. To avoid utter confusion, use the *same* ohmmeter range each time.

Another often overlooked factor is the current flowing through the external resistor or transistor, and this definitely changes with the range. With the test leads shorted together on the ×1 range, the maximum current is 150 mA, at half scale it is 75 mA, and so on. The maximum current on the ×10 range is 15 mA, and this is the main reason it was selected for the small transistors—to avoid ruining them, as currents of 100 mA or higher might.

Weak transistors?

Will these resistance tests show up weak transistors? A fair question, and I'll stick my neck way out and say, "There is no such thing as a weak transistor." Now, you have undoubtedly replaced a transistor suspected of being "weak," and the machine then worked perfectly. I would not argue with your facts, only with the conclusion. It seems likely these cases can be explained by transistor opens or leakage and not by "weakness" as we would apply the term to tubes. A transistor with an open emitter might still feed enough rf through the high base-to-collector capacitance to permit a weak signal to come through.

Excessive base-to-emitter leakage would be equivalent to lower resistance between base and emitter, and would reduce the input impedance. This would reduce the gain. Excessive base-to-collector leakage might increase the bias into the saturation mode, and might give negative feedback; both of these reduce gain. Collector-to-emitter leakage (by far the most likely to happen) would decrease the collector impedance, often a part of a tuned circuit. If the emitter resistor were large enough, the

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increased leakage current (not controlled by the base) would raise the emitter voltage and reduce the forward bias. In an extreme case the emitter voltage will be larger than the base voltage and actually reverse-bias the transistor, although collector current still flows because of the short circuit. The transistor will give no gain with reversed bias. More on this common defect will be discussed under voltage analysis. None of the examples of weak amplification just given are due to a "weak" transistor, so it follows that the resistance method should find virtually all the defective transistors.

Resistance of circuits, and other tests

Resistance measurements are a very important part of troubleshooting in tube circuits since a cold tube measures open on an ohmmeter. Not so with solid-state, for transistors and diodes cannot be turned off. They are waiting to draw current from *any* dc source, including ohmmeter voltages. Here is a good rule-of-thumb: Make the resistance reading, then reverse the test prods and measure it again. If the reading is the same, it is probably accurate. If the two are widely different, the higher one is nearer right. Of course, the power supply for the transistors must be off for this test.

Signal injection with generators or analysts is just as useful as it is in equipment with tubes. You will have to experiment to find the best way of coupling the generator to the chassis under test, for the base circuits are low-impedance, low-signal points, while the collectors are medium-impedance, higher-signal points. It is quite possible for you to obtain the same strength of generator signal in the circuit whether it is applied to the base or to the collector of the same transistor, because of the different impedances. In all cases, use a coupling capacitor between the generator and the transistor. Don't use too large a capacitor, for it might hold enough dc charge from a collector to ruin the transistor when it is discharged on a base. A 1,000 pF is about right.

Signal tracing with a tuned analyst or a scope is excellent, just as it always has been with tube sets. Cable capacitance is less of a problem with transistor equipment, but be careful to avoid accidental shorts.

Circuit voltage analysis

Almost all small transistors are soldered solidly into the circuits. Of the large transistor mountings the easiest to deal with still finds the transistor bolted securely into a socket or to a heat sink. This rightly

discourages wholesale removal of transistors for testing. Resistance measurements are less dependable here than with tubes, so this leaves voltage analysis as the workhorse to narrow the area of suspicion to a manageable size. Except for the differences between tube-grid bias and transistor forward bias, the logic of the analysis is the same. What with the ease of tube replacement, you may never have given enough attention to this method.

The radio i.f. stage, shown in Fig. 1209, is a good one to practice on. The transistor is a pnp type, meaning the base and collector should both be negative measured from the emitter. This is verified by the measured voltages, even though the *supply* voltage is positive to ground. By using the voltages at base, emitter, collector, tap of T2, and the supply voltage, let's analyze nearly every possible parts defect.
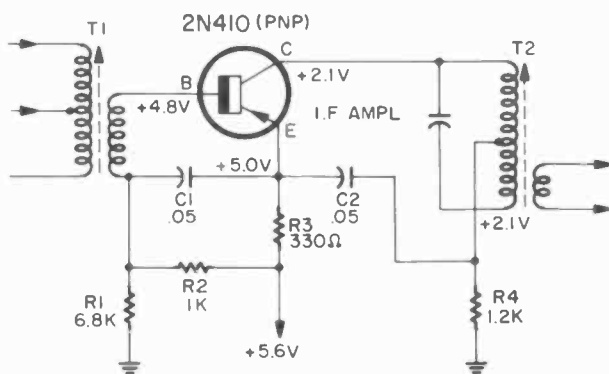

Fig. 1209—Circuit and normal dc voltages in a transistor AM radio i.f. stage.

Puzzle No. 1: Base 5.2 V, emitter 5.4 V, collector 5.4 V and T2 tap 0 V. Find the bad part.

The base–emitter bias is still 0.2 volt, which usually proves both base and emitter circuits to be normal, even though both voltages are slightly higher than they should be when measured to ground. The collector and emitter voltages are the same, and this might be caused by a collector-to-emitter short. However, this would reduce the voltage at the emitter because of the greater current. Also, T2 should be the same voltage, and it is zero. T2 seems to be open between the tap and the collector end. A clip lead across those two points restores the dc voltages to normal (but not the volume).

Answer: The primary of T2 is open and the transformer must be replaced.

Puzzle No. 2: Base 4.8 V, emitter 5.6 V, collector 0 V, and T2 0 V.

Base voltage is normal, showing that the voltage divider supplying the base is okay. Collector is zero, showing no collector current, for its voltage (measured to ground) is caused by the collector current creating a voltage drop across the 1.2K resistor. The emitter voltage is the same as the supply, which indicates no emitter current, hence no voltage drop across the 330-ohm resistor. An open collector circuit would put the *same* voltage on emitter and collector. The emitter resistor might be open, but this would pull the emitter voltage below the supply voltage. In addition, the base has 0.8 volt of forward bias on it compared to the emitter; it should be drawing collector current by the hundreds of milliamps!

Answer: The emitter lead is open inside the transistor. After removing the transistor from the radio, this is verified by a resistance test. Note: The collector might have been open internally, except that the emitter voltage also indicated no drop due to the base current.

Puzzle No. 3: Base 4.8 V, emitter 0.8 V, collector 0 V, and T2 0 V.

The base has a reverse bias of almost 4 volts, although the base-to-*ground* voltage is normal. Collector and T2 voltages show no collector current—very normal for reverse bias. But how did the emitter voltage ever get that low? There is no part, like a capacitor, that can short out and pull the emitter voltage down, and the base and collector voltages indicate no short or leakage to them.

Answer: The 330-ohm emitter resistor is completely open. There are several peculiarities here that could happen only with transistors. The transistor bias measured from emitter to base with a vtvm showed .07 volt of reverse bias, and not the 4 volts indicated by measuring the voltages to ground and subtracting them. Also, the 0.8 volt measured from emitter to ground with a vtvm became zero when measured with a 20,000-ohm-per-volt meter. Worse yet, the voltages measured from the supply voltage to the transistor with a vtvm showed: base -0.74 volt, emitter -0.8 volt, and collector -5.5 volts. This adds up to a reverse bias of .06, which seems about right under these conditions.

The freakish readings that change so much, depending on where we make the measurements, are caused by transistor leakage. This must be taken into consideration, especially in cases of open circuits or elements.

Puzzle No. 4: Base 5.6 V, emitter 5.6 V, collector 0 V, and T2 0 V.

This is an easy one. The emitter and collector voltages prove there is no current there, and the base and emitter voltages are the same, giving zero forward bias. The transistor is merely biased to cutoff. The base

voltage should be 4.8 even with the transistor removed. Therefore, R1 must be open or R2 shorted (not likely).

Answer: When removed for accurate testing, R1 measured open. Note: Almost the same voltages could be obtained if C1 were shorted. Base and emitter voltages would be equal but lower, around 5.3 volts each. This would also remove the forward bias and stop the collector current.

Puzzle No. 5: Base 4.5 V, emitter 4.2 V, collector 4.2 V, and T2 4.2 V.

All voltages are wrong here, but one further check would show that the supply voltage is down to 5.3. This clears the base circuit of suspicion. The emitter and collector voltages are the same; that could be true if the transistor had a very high forward bias and looked like a short circuit. But the bias is 0.3 volt, which should cut the transistor off completely. The next possibility is a short from emitter to collector, and there are two parts that could be shorted: C2, or the emitter and collector inside the transistor.

Answer: When the collector lead to the transistor is unsoldered, the short disappears and the T2 voltage drops to zero. A new transistor restores operation.

Puzzle No. 6: Base 3.5 V, emitter 3.8 V, collector 3.75 V, T2 3.7 V.

The forward bias is 0.3 volt, so the transistor should be nearly a short circuit between emitter and collector, from excessive bias. Yet the emitter voltage is much less than in the previous puzzle, where the emitter and collector were actually shorted inside the transistor. Therefore, there must be more to this than a transistor bias problem. (If it were a bias problem alone, R1 might be too low, or R2 too high.) An extra voltage reading shows the supply voltage to be low also. But a hunch tells us something is lowering the base voltage *too* much. Disconnecting R1 and R2 finally gives us the answer.

Answer: With the resistors removed from the base circuit, the base voltage is still around 2.5 when it should be zero. Internal leakage from primary to secondary of T1 is the defect.

Open circuits in a circuit board do the same thing as open resistors or transistors when you analyze the voltages by this method. You will find almost all troubles in class-A amplifiers to be some variation of these basic examples. The same reasoning applies equally well to tube circuits. It is an excellent idea to practice more of this reasoning on tube sets, so you'll be prepared for the all-transistor color receivers.

Chapter 13

Troubleshooting Examples
and Case Histories

A N OLD SAYING POINTS OUT THAT THE PROOF OF the pudding is in the eating. The proof of troubleshooting methods is in the result obtained. Some of the methods detailed in previous chapters include:

Visual tests to locate the general area of trouble.

Simple tests to evaluate an entire circuit.

Vital checkpoints and how to find them.

Using a vtvm to measure all ac and dc voltages in the chroma signal.

To show you that these diagnostic methods really work quickly and accurately, we will share some actual service case histories. Only the names have been changed to protect the guilty; so Joe Bloe, our all-wrong fall guy, will take the blame for all the mistakes. There will be no special order of presentation, for in actual servicing the problems do not come neatly grouped in categories. I will try to explain the key points of logic, observation and measurements which helped spot the trouble, instead of merely giving the symptoms and the solution. Some of these problems will be simple; others will be rare and complicated, just as they might happen to any of us.

Monday morning's first call, on an RCA CTC15, sounded routine enough since Mrs. Customer merely said the picture was too dark to enjoy. The picture came on with good width, focus and detail; but was so dark you could barely see it. When I turned the brightness control

from end to end, there was virtually no change in brightness. My snap judgement was "video trouble." Vtvm voltage tests are usually the fastest there, even if the trouble is only a bad tube. (Perhaps I should pause to explain that one of my tube caddies had been remodeled to hold a degaussing coil, a large metal mirror, a small mirror, a vtvm, a color-killing switch box, clip leads, simple tools and other gadgets often needed for color repairs. This caddy and a color-bar generator, make a convenient two-hand load that has helped me fix an amazing percentage of color complaints on the first call.)

Anyway, the plate of the 12BY7 tells us the dc condition of all three video stages, and the vtvm on pin 7 showed about 10 volts change as the brightness control was rotated from one end to the other. Also, the reading was slightly less than 200 volts—low even for high brightness. A normal set will read from about 360, with brightness down, to 220 or 240 with the brightness as high as it will go. According to that 200-volt reading, we should have had plenty of brightness—unless there was a second trouble. But first things should get first attention. A new tube gave no improvement, so I checked grid voltage and found it to be about 25, with almost no change caused by turning brightness control. The voltage at the center lug of the brightness control gave nearly the same reading, which ruled out a leaky coupling capacitor or gassy tube. Some thinking seemed to be in order, for one end of the brightness control should be about 12 and the other about −12. The negative voltage is taken from the grid circuit of the horizontal blanker tube, and this wrong voltage pointed toward the blanker stage.

The blanker plate voltage measured 400 (should be 120 to 190) and the grid about −10 (should be −85). The plate voltage indicated no current in the tube, but the grid bias was low and could not cut the current off. The deduction was an open cathode in the blanker tube. Sure enough, a new 6GU7 brought the blanker voltages and the brightness control action back to normal and the problem was solved!

All except "what actually happened?" Where did the −10 volts on the blanker grid come from if the cathode was open? A 1.5-meg resistor is connected from the blanker grid to the 6JE6 (horizontal output tube) grid as emergency protection in case of high-voltage regulator failure. The 6JE6 grid had about −50 on it from rectification of the horizontal-oscillator voltage. The resistor was feeding part of the 6JE6 grid voltage to the blanker, instead of the other way as it should have been. Why wasn't the picture *too* bright, when the original 12BY7 plate voltage was low enough to cause maximum brightness? It should have made the picture bright all the time without variation—if a second blanker function had not canceled it out. The blanker also feeds a pulse to the cath-

odes of the $-Y$ amplifier tubes. Negative grid bias is created there by grid rectification, which lowers the plate current and raises the plate voltage. With the blanker cathode open, no pulse appeared at the plate, and the $-Y$ amplifiers had zero grid bias (the grid resistors return to the cathodes) so their plate voltage was about 90 instead of 160 to 190. This defect alone would darken the picture until it could hardly be seen. But both troubles together nearly canceled each other! The uncontrollable high-brightness video voltage equaled the low-brightness voltages from the chroma $-Y$ amplifiers, giving medium brightness with no control. The screen color had drifted slightly, so I corrected that and checked the color-oscillator locking as a precaution against callbacks. Then that job was over.

The next color call was on a Philco 15M91 with a complaint of no color. It had no color on a bar pattern either, so I grounded test-point M40 with a clip lead. This is where the killer voltage goes to the band-pass-amplifier grid circuit. Grounding it makes sure the killer cannot be the cause of the color loss. Now there was color, but in the familiar diagonal rainbows, showing our problem to be no color locking rather than something in the color killer. Next I grounded TPM26 in the reactance-tube grid circuit. This changed the color stripes from a dozen or so to three. Since a good reactance circuit will pull in from about six stripes, this indicated phase-detector trouble, or at least some trouble involving the reactance-tube grid voltage. With the 6JU8 quadruple diode out of the socket, TPM26 measured about 10 volts (should be zero with the tube out, for then there is no way current can get there) which disappeared when the oscillator–reactance tube was removed from the socket. A new 6GH8 and a touchup of the reactance coil gave perfect locking. Of course, a new tube installed without taking a meter reading might have fixed the set anyway, but the meter eliminated the possibility of intermittent operation giving a false indication.

Friendly Joe Bloe came in the next morning carrying an RCA CTC16 chassis and wearing a sheepish grin. "I thought this was a bad-picture-tube job, until the new picture tube acted the same way. The picture is bright, but has retrace lines and hardly any video," he explained. With the chassis hooked up to my test jig, this was confirmed, along with an item he had overlooked: The brightness control had no effect. A vtvm at the plate of the 12BY7 showed normal voltage variation with bright-ness-control variations (260 to 360) and the scope also showed good video there (see Fig. 1301). Following the video path, we found good video up to the far side of the 18K resistor across the overcoupled peak-ing transformer, but virtually none on S104 lug 3, or at the video drive controls. All those symptoms just because of one open switch contact in

S104!

Sliding the switch back and forth a few times cleared the video trouble and Joe was to replace the switch before delivering the receiver back to the customer. But the chassis was not through with us yet, for we still
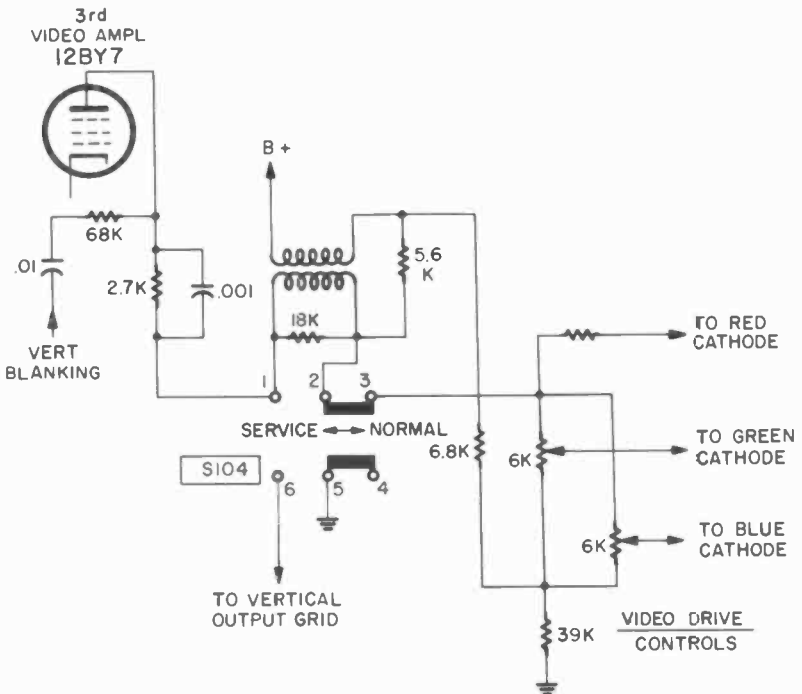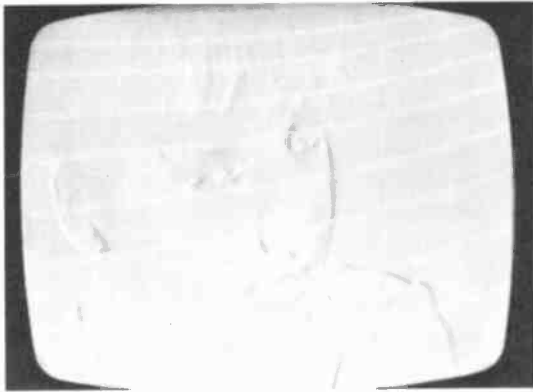

Fig. 1301—*Weak overpeaked video, retrace lines, and no control over brightness—all caused by an open in the NORMAL-SERVICE switch (S104).*

had vertical retrace lines. We could understand the open switch had also cut out the vertical blanking since blanking is fed to the video output plate, but why was there *still* no retrace blanking? There should be about 65 volts p–p at the 12BY7 plate with the tube removed, but the vtvm showed almost nothing. The voltage between the 68K resistor and the .01 capacitor pinned the meter; this pointed a finger at the 68K resistor. Sure enough, a new one stopped the retrace lines. I remembered this circuit quite well from the hours I spent once finding the cause of a case of shaded raster, with the top of the picture darker than the rest. That was caused by a shorted .01 capacitor in the same circuit.

While the test jig had the RCA cables on, it seemed a good time to repair a CTC17 the outside man had brought in. It had no sound, picture or vertical sweep, and a few voltage measurements showed there was no B+ from the 330-volt point on down the line. A visual inspection showed a large 600-ohm B+ resistor burned badly enough to crack into pieces, but no other obvious parts failures. The 330-volt line measured about 400 ohms to ground, and I had to disconnect several of the wires going to other parts of the chassis to isolate that near-short to the vertical output stage. A couple of ohmmeter checks later, I snipped out the .0033-μF, 1,600-volt capacitor and found it to be dead shorted. Fig. 1302 shows the circuit and the location of the capacitor on the underside of the sweep board. The set will run without this capacitor since it is there only to keep horizontal spikes from getting into the vertical sweep and causing a vertical jitter, but don't leave it out any longer than necessary to prove the trouble. The same circuit is used in the CTC17X, CTC21, CTC25 and CTC24, with a .0047 μF in the CTC24.

This seemed to be RCA day, for the next phone call brought a plea for me to check a CTC16X, where Joe Bloe had installed four 6JE6 tubes within the past six months. A case like this one takes us back to fundamentals. What can cause a tube to blow prematurely? Too much power (volts times amps) dissipated by the tube, transient voltages such as arcs, or an innate defect in the tube. There just aren't any more reasons. I went prepared with more than the usual complement of meters, for accurate readings seemed necessary. First I plugged in the line-voltage meter to let it stabilize while I checked the 6JE6 screen voltage with a vtvm. It measured about 300 volts, or roughly double the usual voltage. This symptom added to no raster, but a fairly cool 6JE6, indicated another dead 6JE6. A new tube dropped the screen voltage back to nearly normal and the picture came in okay. By now, the line-voltage meter showed a remarkably steady 125 to 126, which is high enough to worry about. Next step was to take out the chassis-bottom screws and

prop the chassis up with a handy meter case while I changed the power-transformer primary tap for 128-volt operation, unsoldered the ground wire from the 6JE6 cathode pin and soldered in an extra piece of insulated wire long enough to reach slightly past the edge of the chassis. I put the chassis back in place and hooked a 500-mA meter from the added cathode wire to chassis. The manufacturer's specifications call for 230 mA or less in this cathode circuit. This tube drew about 225 until adjusting the efficiency coil dropped it to 215. Incidentally, if you concern yourself not with current, but only with efficiency-coil adjustment, it is easier to monitor the *screen voltage* and adjust for *minimum* voltage.
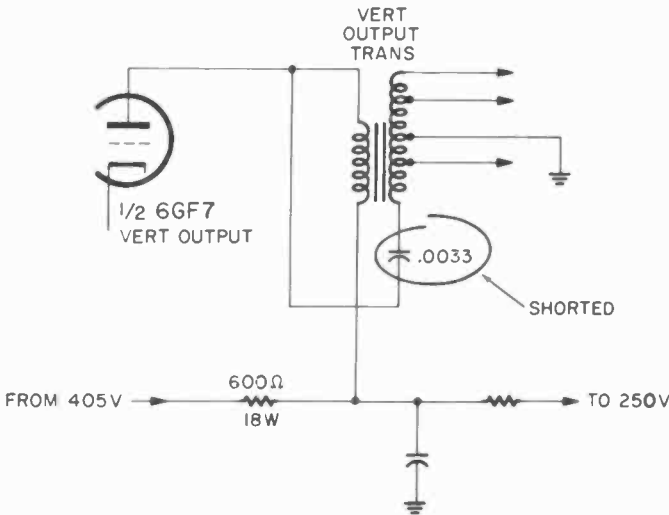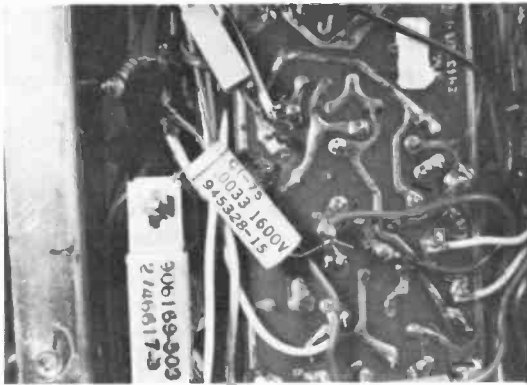
Fig. 1302—Shorted capacitor in vertical output stage of RCA CTC17 causes power-supply dropping resistor to fail.

The reason is: The 6JE6 is operated in class C, therefore a lightening of the plate *decreases* the plate current and *increases* the screen current, which drops the screen voltage.

Next I used my home-made adapter to monitor the high-voltage regulator current, as an added precaution. It was normal.

I disconnected all my test equipment, grounded the new cathode wire, and watched a network color show come on with acceptable color. Just as I was about to button it up, Mr. Customer said the color sometimes had stripes in it after a half hour or so of operation. It took only a few seconds to ground TP703 and find the 3.58-oscillator frequency very near zero-beat. Again, I was prepared to call the job done, when a nagging voice inside me asked why this perfect adjustment would cause the color to be out of lock. A few turns on the fine-tuning knob answered that, for the color jumped out of lock before it blurred and disappeared. Back with the vtvm to 6JU8 pin 1, where a reading of -55 gave proof of excellent burst amplitude. Remembering my own rule, *"When you don't know what to do, keep on doing what you know how to do,"* I went through the series of afpc adjustments. With the 6JC6 burst keyer out of its socket, the voltage at pin 1 of the 6JU8 was only -2 instead of -8, but a half dozen turns of the burst-transformer core brought it up to normal. Back to the colorcast. The color was brighter than before and the locking was perfect. This time I *did* replace the back—and left in a hurry.

Another day, another set of problems. This time a technician friend (?) brought me a Motorola TS918, only a week old, with a complaint of a rough, grainy picture and no hue-control action. He had tried to do the burst and demodulator adjustments according to the manufacturer's instructions, but the method hadn't worked right for him. I added a 5.6-meg resistor in series with the vtvm probe and tried the adjustments again. When I got to the part where the oscillator (with burst shorted out) was supposed to be adjusted for zero beat with the bars standing still, I could not adjust the 3.58 tuned circuit enough to throw it *out* of frequency and lock. At the same time, a beat pattern looking very much like raw 3.58 could be seen on the screen.

Several meter and scope checks didn't uncover anything significant, so I tried the old method: *Fix it first, then figure out why.* While moving parts in the vicinity of the demodulator with a plastic prod, I found one part sensitive to movement. It was the 3.58 trap common to all three demodulator outputs. A good soldering of the ground wire cured the trouble and permitted normal adjustment and color. We still haven't explained why it caused those symptoms.

Brand-new sets have their troubles, too

Another thing I have learned over the years: A trouble present when a set is first unpacked is usually caused by a factory wiring error or vibration in shipping. If the set once operated correctly, but does not now, parts or an intermittent connection are usually to blame.

A small dealer, located just a few doors away, wheeled in a new color set (whose brand perhaps should be nameless, since what follows could happen to any factory) and pointed out that the hue control didn't work. After several ohmmeter checks and an analysis of the schematic, I found two wires reversed where the color and tint wires plugged into the chassis. Later on, I found a couple more sets just like this, and then the repair was fast and easy.
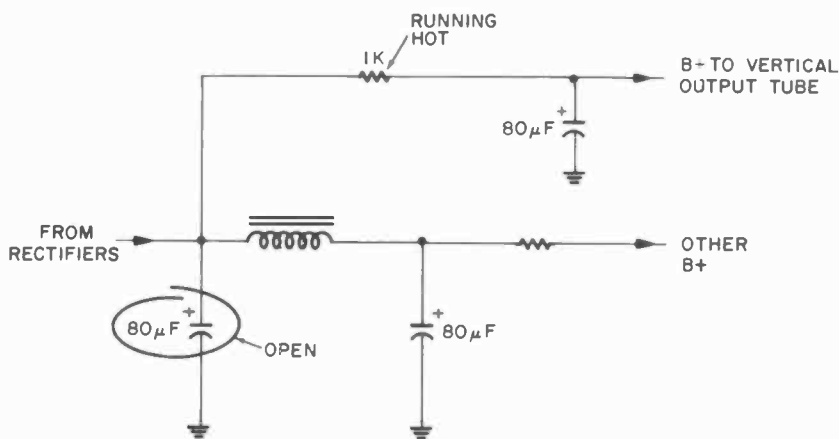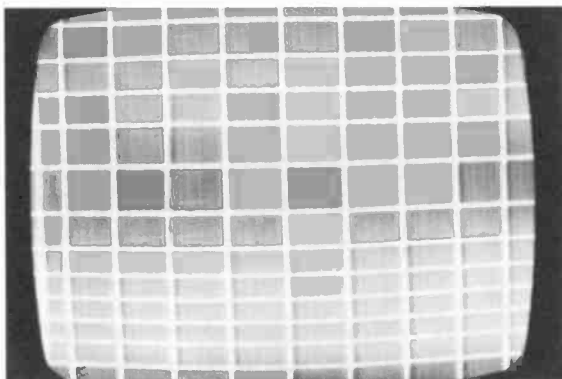
Fig. 1303—Open capacitor and wrong-value resistor caused a real puzzler.

The inspiration for the servicing tip which says: *"When all else fails, suspect the technician,"* was probably Joe Bloe. For example, take the time he brought me an RCA CTC16X chassis he couldn't check properly (after all, he didn't have extension cables or a test jig). It seems a certain 1,000-ohm power-supply resistor had been running hot, so Joe (for reasons known only to him) concluded the resistor was bad, took the chassis to his shop, installed a new resistor and returned the chassis to the customer without turning it on. Said Joe now, " I must have fixed *that* trouble, 'cause the resistor doesn't run hot now, but there is 60-Hz hum in the picture." Sure enough, network pictures had a ripple in them that drifted slowly up or down. A crosshatch pattern clarifies many problems like this. Fig. 1303 shows what we saw: The scanning lines were alternately spread and compressed at the same place a small amount of *120*-Hz hum could be seen.

By now, I know enough to check Joe's work, so I was not surprised to find he had used a 100-ohm resistor to replace the original 1,000-ohm. When the correct value was back in, we forgot all about the picture hum, for the resistor started to burn up again. Figuring from the dc voltage drop across the resistor and its value, the resistor should have been dissipating only about 3 watts—certainly not enough to account for all that heat. Next question: What about ac voltage drop? The scope showed far too much ripple (125 volts p–p) at the input to the filter choke, and a few seconds with a test electrolytic proved the filter input capacitor was open.

In this case, I *could* sift the peculiar symptoms and come up with reasons. With the correct resistor in place, the 80-μF vertical-B + filter was trying to do the work of the open input filter. The heavy pulsating capacitor charging current was going through the resistor and heating it. The 100-ohm resistor was too small to cause much power dissipation from the charging current, and so ran cool enough.

My outside man brought in an RCA CTC17X chassis, explaining that the *height* control changed the *brightness* of the picture. He couldn't think of any parts defect that would cause this, and at first I couldn't either. With the chassis on the test jig, his statement was borne out; the picture brightness was changed quite radically when the height control was varied. More important was something he had *not* noticed; the top of the raster was darker than the rest of the screen. This symptom I had seen before in two different versions. Without the .047 capacitor (see Fig. 1304) from the emitter of the vertical-blanking transistor to ground, prominent vertical lines can be seen in the picture when the transistor is bad. These look quite similar to yoke ringing, except the scanning lines are not bent; the vertical bars are brightness modulation. With the

capacitor in place, the main visual symptom is the dark shading at the top of the picture. In this set, the vtvm reading showed the transistor collector and second-video grid voltage to be the same—and both of them changed a couple of volts when the height control was varied.

Normal operation of the circuit is like this: A pulse from the vertical output transformer is fed to the emitter of the transistor; it is so strong that the transistor clips the waveform (making the output pulse wider) with a slight loss of voltage, and sends it (with phase unchanged) out of the collector to the diode. The diode is an electronic switch that is supposed to close and feed the pulse to the grid of the second video
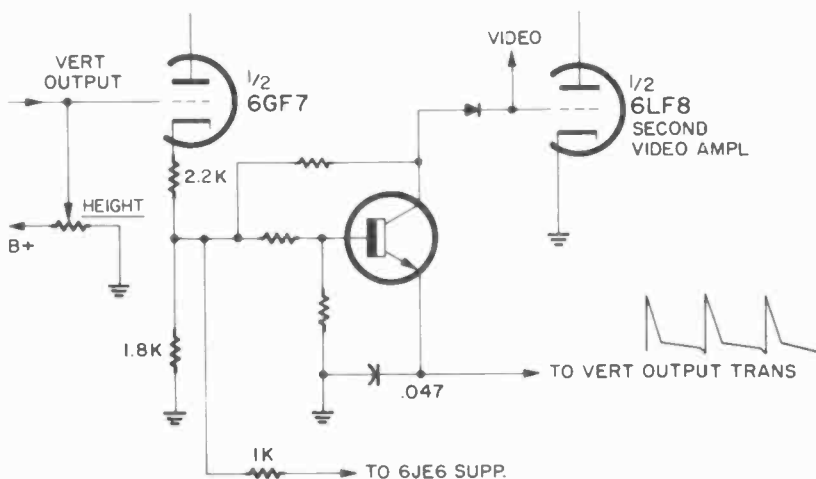
Fig. 1304—*Open transistor in RCA CTC17X causes height control to alter brightness and produces shaded raster.*

amplifier when the collector voltage rises above that tube's grid voltage. In addition to preventing video loss back through the blanker transistor, this action also clips off the slanted portion of the vertical waveform, which would darken the top of the picture if it came through. When the transistor opens, its collector voltage rises permanently above the tube grid voltage and the diode conducts all the time, so any vertical pulse here will darken the top of the raster. The tie-in with the height control results because the height control changes the bias on the vertical output tube, and part of the tube's cathode voltage is used as supply for the transistor. With the transistor open (or partially open), the transistor collector voltage varies with that supply voltage from the vertical cathode. Being coupled to the video grid, the collector swing will change the video-tube voltages right down to the picture tube.

The same diagram (Fig. 1304) also shows another unique problem. The suppressor grid of the 6JE6 is connected to about 30 volts as a snivet suppressor. The 30 volts is obtained from the junction of two series resistors from the vertical output tube cathode to ground. The change in suppressor voltage with height adjustment is not enough to matter, but if the 1K resistor from the supply to the suppressor opens (perhaps due to a gassy or shorted 6JE6), width will be affected. Tests show that a zero suppressor voltage will decrease the raster width by about an inch on each side. Also, if the 1K resistor should open, the width (also focus and high voltage to a lesser degree) may become erratic, causing an occasional 1-inch loss of width.

While we are talking about unusual width problems, here are two lulus, also from RCA's. Both involve wrong voltages at the horizontal blanker grid. The first one was mentioned in the chapter on chroma circuits, where the loss of width was caused by a crack in a circuit board, which removed the 390K grid resistor from the circuit. There are other parallel paths, so the circuit doesn't quit entirely, but the grid voltage rises from the nominal -85 to about -120. This affects the brightness and color-killer adjustments, but the most noticeable change is in the width—the picture is pulled in on the right side about 1 to 1½ inches. The reason for this is the increase in the negative 6JE6 grid voltage without any increase in oscillator drive. Tip: Always check the blanker grid voltage when confronted with width or shading or brightness problems.

Another closely allied problem is shown in the simplified diagram of Fig. 1305, which also shows the connection between the 6JE6 grid and the blanker grid. One particular defect here was very hard to find, because the voltages kept changing as the bad part became worse. The first symptoms were narrow picture, poor focus and agc overload. As a routine operation, I checked the horizontal-blanker grid voltage and could hardly believe it was over -200 and still climbing! By the time the width narrowed and the raster disappeared entirely, the 6JE6 grid was almost -150 and the blanker grid -270. Because the higher voltage is usually the source, it was evident that the excessive blanker-grid voltage was the cause, but it seemed impossible for it to receive that much pulse. The vital clue came when I checked the plate of the agc tube. Normally it will run from a few volts negative to a few volts positive, according to signal strength. Right now it measured the same as the B-boost. This started another head-scratching: How could these points be connected? Two capacitors form a voltage divider for the pulse at the damper cathode; the 68- and 180-pF capacitors are drawn in different areas of the schematic, but they work together to reduce the

pulse to about ⅓ the original voltage. In this case the 68-pF had got leakier and leakier until finally it became a dead short and applied the full damper dc and horizontal pulse to the agc plate. From there the pulse is fed to the grid of the blanker through a capacitor, which blocks the dc boost voltage. Since my hindsight is much better than my foresight, the next time this happens I will merely disconnect the 1.5-meg resistor that goes from the 6JE6 grid to the blanker grid and see if the set works better. A normal set will perform nearly the same without it.
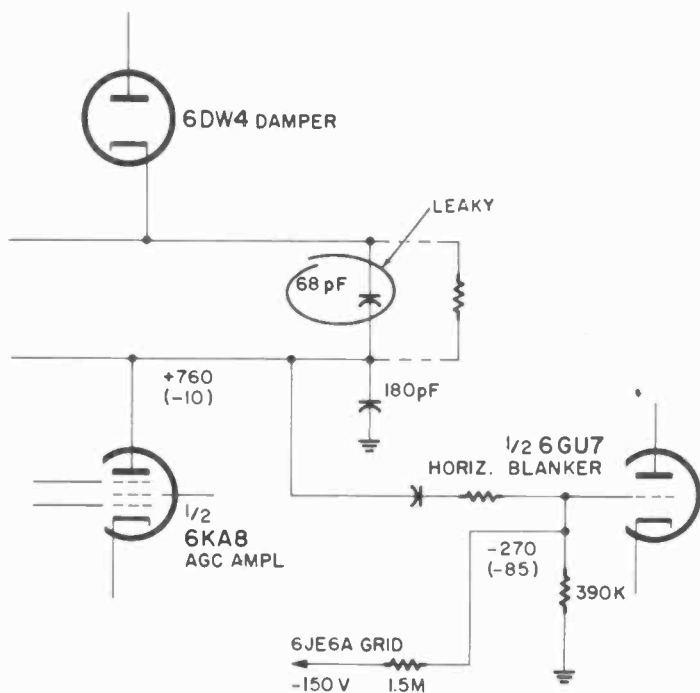
Fig. 1305—*Agc and width problem that can occur in RCA color chassis from CTC15 onward.*

I am a great believer in the value of voltage analysis for finding color defects. In two cases, though, the conclusions I was forced to reach by this analysis were so odd I could hardly believe them. The first receiver, an RCA CTC16X, would come on with a magenta screen (but with all three colors present on a color-bar pattern) and within a few minutes would change to normal raster color without (apparently) any blue bars. My first thought was loss of Z-demodulator signal, so I used my vtvm to measure 3.58 to the suppressor of the 6HZ6 Z demodulator, and the output at the plate. Both tests gave normal voltages, which were checked

against corresponding figures for the X demodulator as a reference. The voltage analysis said the $R-Y$ and $B-Y$ signals were good right up to the grids of the $-Y$ amplifiers, yet I couldn't believe it. The dc voltages on the $-Y$ amplifiers were perfect, yet there were no blue bars. Next I used a switch box to look at the colors singly and in twos. I was still worrying that my voltage method had failed, when my companion, a very sharp color technician, noticed there were weak blue bars with the same crossover as the green bars; and the crossovers were wrong for both. Could a shorted picture tube cause this? Tapping the neck of the CRT would sometimes change the screen from normal raster without blue bars to a magenta raster with all bars. As a final check I hooked the vtvm, on an ac range, between the blue and green grids. It showed almost zero ac when the blue bars were gone and about 200 volts p–p when all the colors were there. It was true! The picture tube was shorting internally from blue to green grid—the first time I had ever heard of such a thing. When the grids shorted together, the raster color changed some, and the blue and green bars mixed to form cyan bars. The brightest was the eighth bar. The meter told the truth and I couldn't believe it.

One good bench technician called me for help on an RCA CTC16X (although it could have been any one of a number of makes or models) with very little red or blue on color, but excessive green. Also, the green screen required a very low setting for good screen color. We went through the voltages from the demodulators to the picture tube (Fig. 1306) with these results: The outputs from X and Z demodulators were approximately correct. $R-Y$ and $B-Y$ plate voltages were quite low (and so of course were the red and blue picture-tube grids) around 80 and 90 volts, while $G-Y$ was normal. The bias from each $-Y$ amplifier, grid to ground, was high (-7 instead of around $+1$) while the cathode voltage was low. This combination of high bias, which *should raise* the plate voltage, and the actual *low* plate voltage, was unusual, and finally led to the firm conclusion the 27K resistors in *both* $R-Y$ and $B-Y$ plate circuits were open. The low plate voltage would be because of the path through the 270K resistors back to the demodulator plates.

It was hard enough to imagine any defect opening both resistors simultaneously, and when the tech said he had just replaced both of them since the old ones were burned, it seemed more unbelievable. I asked him to check from the 400-volt supply to all three $-Y$ plates with an ohmmeter. $G-Y$ was normal, but the other two read about 150K each, showing that the 27K resistors were certainly not in the circuit as they should be. He checked the B+ wiring visually and found two points on the board originally connected together by an insulated wire. The

wire had been under the old burned resistor and had broken from the heat. A new piece of wire finished the repair. Another case where the dc and ac analysis pointed accurately to the trouble, but the trouble seemed impossible.

Do you believe it possible to have color over only a part of the picture tube? It can happen. Fig. 1307 shows how an open .047 capacitor in the color i.f. grid return can do that. Without the capacitor, the color gain is lower because the coil is untuned, and the horizontal pulse at the killer plate is applied to the grid. The pulse waveform is positive-going with a somewhat sawtooth form plus a little ringing. The tube amplifies where the pulse has positive voltage (left side of screen) and has more gain where the ringing makes the voltage higher.

A retail salesman, who uses Joe Bloe for his easy service calls, brought his entire receiver to us in the back of his station wagon. The screen color had been intermittent for some time (Joe's tube-changing had not helped), the picture had been narrow for several days and finally the raster went out entirely. It's easier to judge raster color if you have one,
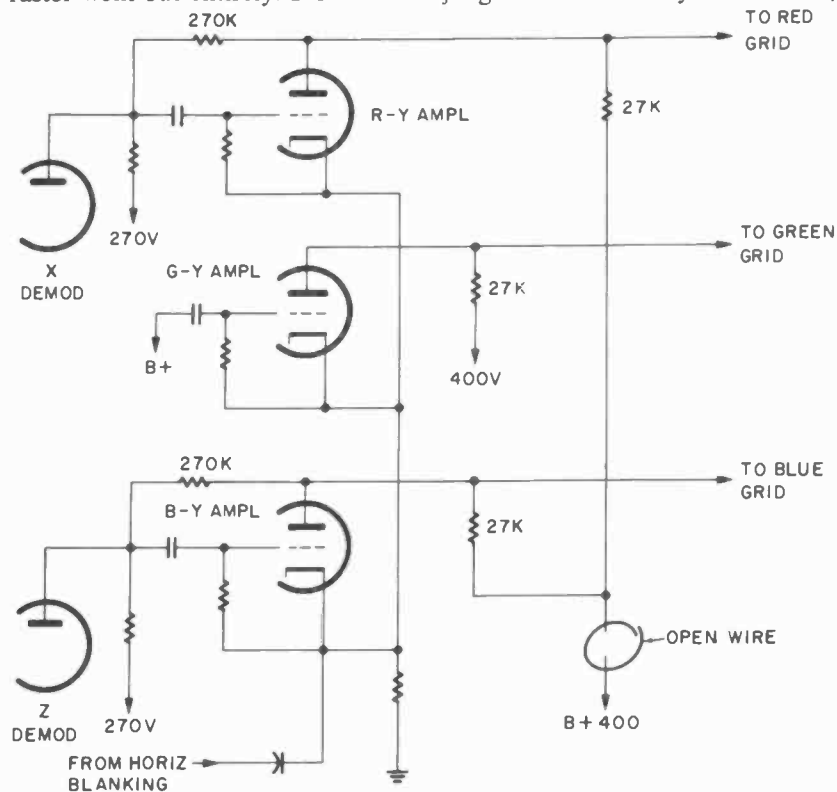
Fig. 1306—Open wire here almost eliminated red and blue from screen.

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so we tried to get a picture first. One of my favorite tricks when checking horizontal failures is to check the horizontal-output-tube grid and screen-grid voltages, since that can be done without pulling the chassis. A high screen voltage means the 6JE6A is already ruined and must be replaced before any other test will work. On this CTC17X chassis, the screen voltage was about 80 and the grid bias −60. Since the tube was running cool, it was a good bet there was no plate voltage on it. Under these conditions the screen draws much more than the rated current. An open efficiency coil, open flyback or dead damper tube are some of the few possible causes of plate voltage loss.
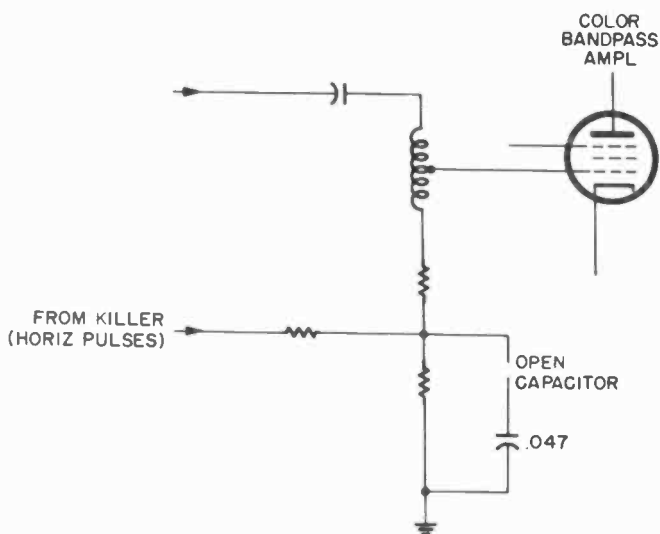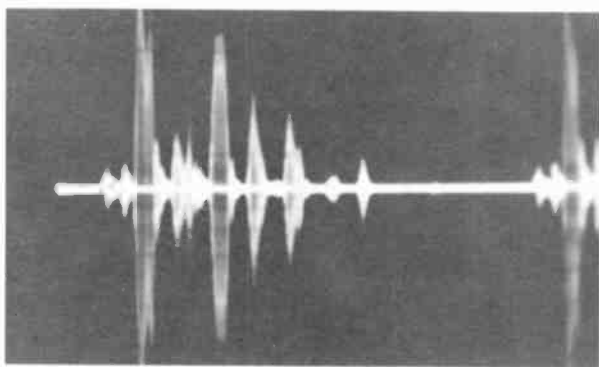
Fig. 1307—Open capacitor killed color on right side of screen.

Luckily, a new 6DW4B damper tube brought the set to life with a full raster. The screen color was a bit off, but it required only a minute to run through the tracking adjustments. Two networks were broadcasting color shows and both had weak red; faces would go from bilious green to sickly purple from tint adjustments, but without good skin color in between. The color-bar pattern confirmed this weak red. Visual inspection showed no burned demodulator resistors, so the 6HZ6 tubes were cross-switched, but with no improvement in the picture. The scope was not handy, so I used the ac range of my vtvm to check the signal voltage at the three picture-tube grids. Sure, I know there is horizontal blanking there which will make all the readings high, but I also know from experience about what I should find under those conditions. The blue grid measured 240 volts peak-to-peak, red grid 220, and green grid about 140; just as normal as apple pie, but there was still not enough red in the picture.

After some head-scratching and two cups of coffee, this was the conclusion: It *must* be the picture tube. The screens were turned down, then up one at a time. Blue and green showed pictures of normal brightness and contrast, but the red picture would blur and lose contrast long before good brightness could be obtained. As a clincher, a picture-tube tester showed about 1/5 red emission compared to blue and green. The reading stayed the same from a cold start and did not creep slowly up for several minutes as it will do in most weak tubes. It was weak all the time.

Why did we get a normal white horizontal line when the set-up switch was slid to service and the screens adjusted? Actually the guns are biased almost to cutoff at that time; only the fact that the entire raster brightness is condensed into that one horizontal line makes the line bright. The tube had that much emission but no more. Yes, a new picture tube provided a good color picture with plenty of red.

It's bad psychology to pull a chassis for the shop during a setup call on a new sale. Try every possible remedy in the home before doing that. Our own standing rule instructs the outside men to call the shop before they even hint to the customer that the chassis might have to go to the shop. When John, one of our outside men, called in to report a new CTC21 RCA chassis with an afc malfunction, we tried hard to find anything he could repair in the home. He said when the fine tuning was adjusted slightly into the sound bars (the recommended method) and the fine tuning knob released to automatically turn on the afc, the tuning would go so far into the sound bars the picture was lost. With the fine tuning set on the other side so color was lost, the set would bring in color when the afc was switched in. That meant the afc would lower the

oscillator frequency, but not raise it.

I asked John to measure the three voltages at the feedthrough capacitors on top of the afc chassis. When he reported 10 volts supply, 9 volts control and 5 volts reference, I told him sadly to bring the chassis in. I had adjusted a few of these sets, and the range of control voltage with adjustment of the internal bias control was from about 4.5 to 5.5 volts. It was obvious this one could not be adjusted that far.

After the chassis was cabled into the shop test jig, the decision to bring the chassis to the shop was proved to be wise. The shortcut or field adjustment of the afc is to ignore the trap and i.f. adjustments, since they are not really critical, and touch up only the discriminator and dc-amplifier bias adjustments. See Chapter 10 for further information about afc. Just slide the service switch to the RASTER position, which kills the picture i.f.'s and consequently any input to the afc circuit, and adjust the bias control (R1312) until the afc control voltage on C144 is the same as the reference voltage on C146. This should be done with the afc switch on the front panel switched off, naturally. Restore the picture with the service switch, tune in a colorcast, being very careful to get the fine tuning correctly set, switch the afc back on and adjust the discriminator secondary slug to again make the control voltage equal to the reference voltage.

In this case, the bias control changed the afc control voltage from 9 to 9.25 volts compared to an even 5 volts of reference voltage; obviously this was not going to work. I removed the shield from the afc chassis, unsoldered the wire leading through the circuit board to the feedthrough capacitor on the front of the main chassis, removed the afc chassis mounting screws and lifted the chassis free. This exposes the underside of the circuit board. A thorough visual inspection is the best test of all. Here, that turned up a blank; the board and each part on it were visually perfect. Next came the vtvm measurements. The forward bias on the dc amplifier transistor was less than 0.5 volt, even with the bias control turned all the way up, when it should be above 0.6 volt. A bias difference of only 0.1 volt doesn't sound like much on a silicon transistor, but forward bias *is* very critical, and this seemed to be the only promising lead. The forward bias comes from two different sources, the 1-meg fixed resistor, and a variable voltage from the bias control through the isolation diode to the low side of the discriminator, with the high side going to the base of the transistor. The voltage at the center lug of the bias control changed smoothly between 0.25 and 0.35 volts, just as the schematic said. A series of voltage checks from the bottom of the discriminator up through the 27K resistors to the base showed an even reduction in the voltage, and the resistors checked good. The

voltage did not change when the 1,000-pF capacitor was removed from base to chassis. The preliminary diagnosis was: bad transistor. A new transistor brought the collector voltage down to about 4 volts, a very normal voltage since we had previously turned the bias control up as far as it would go in an effort to lower the collector voltage. This time the field setup went according to plan, with the control voltage easily adjusted to the required 5 volts. The discriminator slug was already set correctly. The transistor I had taken out showed higher-than-normal leakage from emitter to base when checked by the ohmmeter method described in another chapter.

What happened to the transistor between the factory and the customer's home?

I encourage you to study the methods given here, enlarge upon them and use them as part of your daily servicing. I sincerely believe they will be of great value to you, as they have been to me and to others.

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