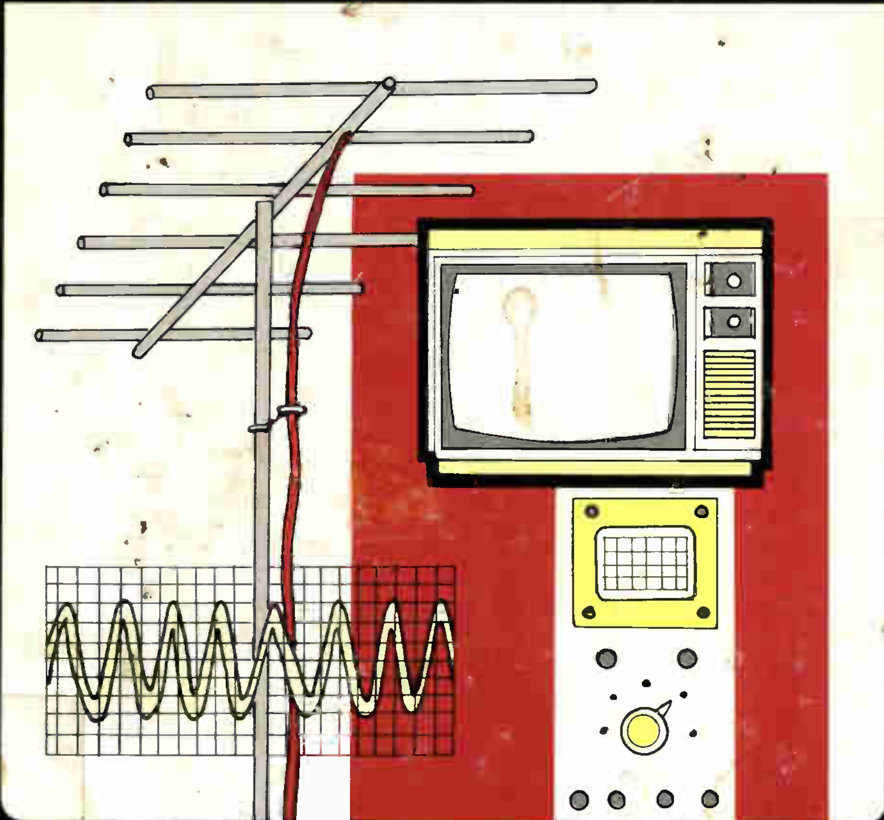
AUDEL®

NEWLY REVISED!

TELEVISION SERVICE MANUAL



By Robert G. Middleton
Revised by Joseph G. Barrile

TELEVISION SERVICE MANUAL

by Robert G. Middleton
revised by Joseph G. Barrile

Rex Miller, Consulting Editor

THEODORE AUDEL & CO.
a division of
THE BOBBS-MERRILL CO., INC.
Indianapolis/New York

FIFTH EDITION
FIRST PRINTING

For information, address The Bobbs-Merrill Co., Inc.
630 Third Avenue, New York, N.Y. 10017.

Published by The Bobbs-Merrill Company, Inc.
Indianapolis/New York
Manufactured in the United States of America

Library of Congress Cataloging in Publication Data

Middleton, Robert Gordon, 1908-
Television service manual.

Includes index.
1. Television—Repairing. I. Barrile, Joseph G.
II. Title.
TK6642.A56 1984 621.388'022'02 83-22313
ISBN 0-672-23395-9

Contents

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

CHAPTER 10

CHAPTER 11

CHAPTER 12

CHAPTER 13

CHAPTER 14

CHAPTER 15

CHAPTER 16

CHAPTER 1

Television Broadcasting

The word "television" is made up of two parts—"tele," from the Greek word meaning *far*, and "vision," meaning *to see*. Thus, television means *seeing from a distance*. As used today, the word means *the transmission and reception of moving visible images so that at a distant receiver the likeness of the original scene can be viewed*.

GENERAL

There is little difference between a television receiver and a common radio receiver. In the radio system, the sound is first converted to an electrical signal, which is transmitted to a distant point. The signal is received and then converted by a speaker into mechanical motion, producing audible sound waves. In the television system, light and sound signals are converted and transmitted to a distant point. Both signals are received and converted back to light and sound by the television set.

Television and radio signals are transmitted through space by means of electromagnetic waves (Fig. 1-1), more commonly known as RF (radio frequency). In radio, we are concerned with

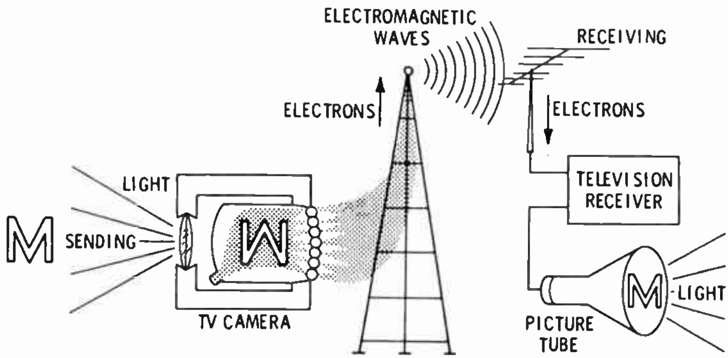


Fig. 1-1. Television signals traveling through space as electromagnetic waves (RF).

the transmission of only one signal, that of music, speech, etc. Television is far more complicated. To display a picture and reproduce sound, several signals must be transmitted simultaneously. Each of these signals will be discussed later in this chapter.

A simplified block diagram of a complete television system is given in Fig. 1-2. The image is picked up by the camera, and an electrical signal corresponding to the image is developed. The signal is then properly amplified, modulated, and transmitted. At the receiver, the signal is demodulated, amplified, and synchronized so that a reproduction of the original image is displayed on the picture tube. For simplicity, the sound circuits are omitted in Fig. 1-2.

THE SCANNING SYSTEM

Since no method by which the entire picture can be transmitted simultaneously is feasible with our present knowledge, a different system of transmitting the picture must be employed. This system is known as *scanning*. In the camera, the scene is focused on a light-sensitive area by an optical lens system. The optical image forms an electric charge corresponding to the light image. This charge pattern is scanned by an electron beam, which moves across from side to side and from top to bottom at a rate set by the sync generator (Fig. 1-2). This scanning converts the pattern into an electrical current with an instantaneous value corresponding to the amount of light falling on the area being scanned.

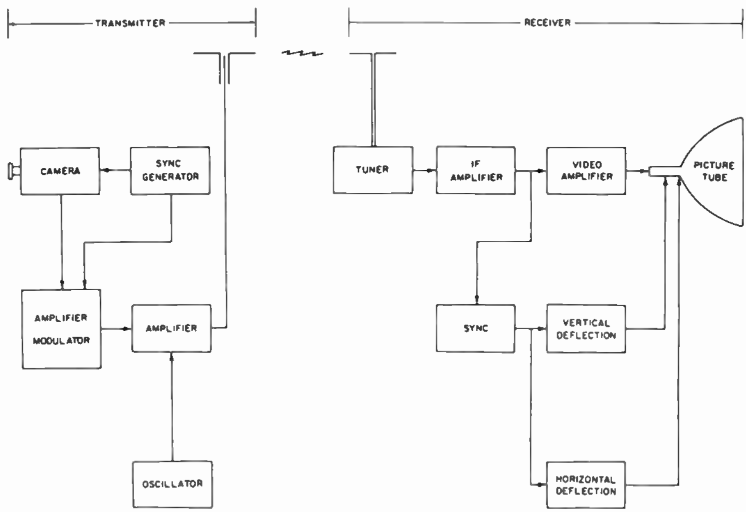


Fig. 1-2. Simplified diagram of a television system.

The electron beam is caused to move across the charge pattern in an approximate horizontal line at a uniform speed and then fly back and scan another line until the beam has scanned 525 lines in the desired sequence. This complete scanning is repeated at the rate of 30 frames/sec. When the electron beam falls upon an illuminated portion of the mosaic, current will flow through the output circuit of the camera tube; when the beam falls upon a partially illuminated portion, a smaller current will flow; and when the beam falls upon a dark portion, very little current will flow. This process is depicted in Fig. 1-3. In this manner, current pulses will be generated that will correspond in time sequence to the light and dark areas of the televised image as they are scanned by the electron beam.

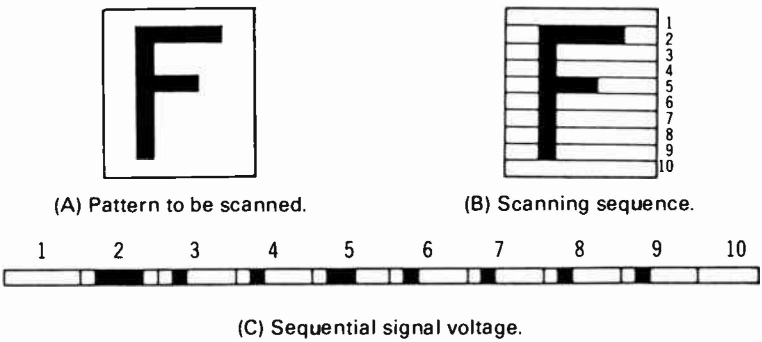


Fig. 1-3. Development of signal voltages by the scanning process.

PERSISTENCE OF VISION

The human eye is a complex system that converts light energy to electrical nerve impulses. The eye has one shortcoming: It can be deceived. The eye will retain images for a brief period of time. A motion picture uses this phenomenon, known as *persistence of vision*. Images shown at a rate of greater than 16 images or frames/sec will not allow the eye to detect any change and appear to be a continuous "moving picture." To allow for a safety margin in movies, the scene changes 24 times/sec. At this rate there is no "flicker" common in movies of the early 1900s. For television, the rate is 30 frames/sec.

Figure 1-4 depicts the projection of a moving-picture film. The transparency is enlarged and focused on a screen by a system of lenses. A rotating shutter is used to project each frame twice, thereby reducing the flicker. The shutter also cuts off the light while one frame is quickly pulled down and the next frame placed in the proper position for projection. Another lamp-and-

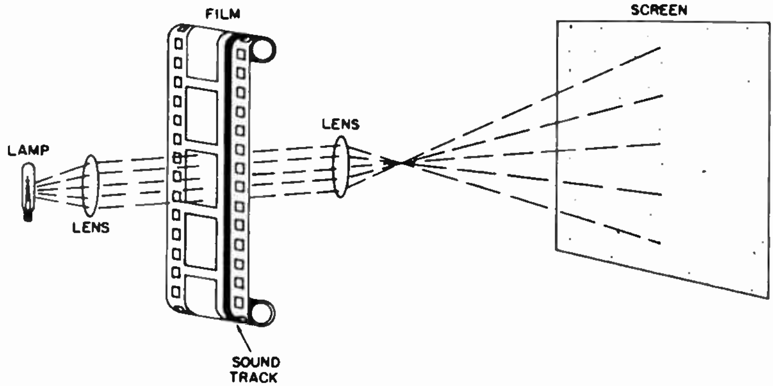


Fig. 1-4. Projection of a moving-picture film.

lens system focuses a beam of light through the optical sound-track and onto a photocell. The photocell converts the light energy to an electrical signal, which is amplified and fed to a speaker. The method used for television is quite similar.

When the television scanning process takes place at a sufficiently high rate, the eye is deceived into "seeing" the entire picture at once even though a small dot is all that is being produced at any one instant. When the beam strikes the face of the picture tube, the face continues to glow for a short period of time. Also, because of the persistence of vision, the eye will retain this image for a short period of time.

INTERLACE SCANNING

The method used for scanning the image in television is very similar to that by which you are reading this page. The eye begins at the upper-left-hand corner and travels across the second line of words. This process is repeated until the end of the bottom line of the page is reached, when the eye returns to the top of the next page.

In a television system, this scanning is done by electron beam instead of the eye. The resulting voltage pulses, termed *video signals*, are then amplified and combined with artificially manufactured signals for controlling the timing of the receiver picture-tube deflection circuits and for extinguishing (blanking) the electron beam during the return time. The resulting composite signal is then used to modulate a high-frequency transmitter.

In the standard interlaced scanning system, scanning of the horizontal lines is not performed in sequence. Instead, the odd-numbered lines are scanned first, that is, 1, 3, 5, etc., and then the beam returns to the top and scans the even-numbered lines. Starting at the upper-left extremity of the picture, as in Fig. 1-5, line 1

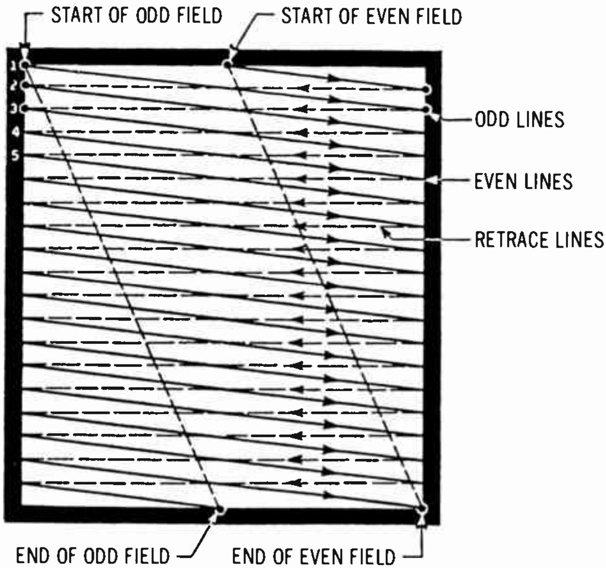


Fig. 1-5. Interlaced scanning pattern on a raster.

is scanned. Instead of proceeding then with line 2, the scanning beam drops two spaces and line 2 is omitted. Line 3 is then scanned, followed by lines 5, 7, 9, and every odd-numbered line of the picture. Upon reaching the bottom of the picture, the scanning spot moves again to the top of the picture and begins another scanning field, which is displaced from the first by the width of one line, so that now lines 2, 4, 6, 8, and all even-numbered lines are scanned.

Since each field is completed in 1/60 sec, both fields consume 1/30 sec. A raster consists of multiple frames, with each frame made up of two fields. Thirty complete frames are scanned in 1 sec, each having been broken up into two projections as a means of flicker reduction.

Given a line frequency of 15,750 and a picture repetition rate of 30 Hz, the number of lines per picture is 15,750/30, or 525 lines, the number of lines per field being 262½, as shown in Fig. 1-5. Notice that the odd field ends on a halfline, and that the even field starts on a halfline.

Approximately 490 of these 525 lines in each frame are active, the remainder occurring during the vertical retrace period (the beam is moving from the bottom to the top of the screen) when the viewing tube is blanked out. It is necessary, of course, that complete synchronism be maintained between scanning at the transmitter and at the receiver. To achieve this, synchronizing pulses are transmitted along with the video signal to lock the receiver oscillators, both vertical and horizontal, into step with those at the transmitter.

Thus, in addition to the video signal, which contains the actual picture, four other signals must be transmitted before the picture can be properly displayed on the screen. The horizontal sync pulse is transmitted to keep the horizontal deflection circuit in the receiver in step with the left-to-right movement of the scanning beam in the camera. Since the return of the beam from the right to the left of the screen (retrace) would produce objectionable interference if displayed on the screen, a horizontal blanking pulse is transmitted to black out this portion of the scan. Similarly, a vertical sync pulse and a vertical blanking pulse are also transmitted to keep the vertical deflection in step and to blank the beam when it is returning from bottom to top. Figure 1-6 shows the plan of the sync and sound sections in a TV receiver.

FREQUENCY BANDS

The entire spectrum of radio frequencies is broken down into several portions called *bands*. These bands and the designations used to identify them are given in Table 1-1.

The assignment of the various types of services (radio, televi-

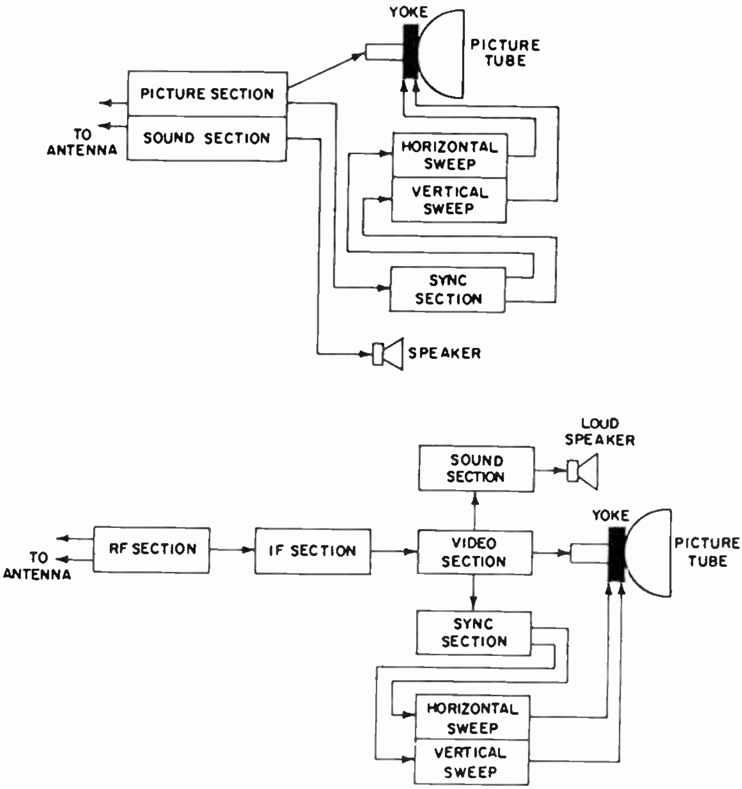


Fig. 1-6. TV picture and sound section.

sion, radar, amateur, etc.) within the various bands has been partially standardized by international agreements. Thus, worldwide communication is possible, and interference caused by one country operating one type of service and another country operating an entirely different service on the same frequency is eliminated. The actual establishment of operating standards, assignment of portions of the frequency bands listed previously for certain specific purposed, and assignment of individual frequencies in the United States are controlled by the FCC (Federal Communications Commission).

Table 1-1. Frequency Bands and Designations

Band No.	Frequency	Classification	Abbreviation
4	3-30 kHz	Very low frequencies	VLF
5	30-300 kHz	Low frequencies	LF
6	300-3,000 kHz	Medium frequencies	MF
7	3-30 MHz	High frequencies	HF
8	30-300 MHz	Very high frequencies	VHF
9	300-3,000 MHz	Ultra high frequencies	UHF
10	3,000-30,000 MHz	Super high frequencies	SHF
11	30,000-300,000 MHz	Extremely high frequencies	EHF

The standard amplitude-modulated (AM) broadcast stations in the United States are located between 535 and 1605 kHz (kilohertz) in a portion of the medium-frequency band. Frequency-modulated (FM) radio broadcasting is assigned the space between 88 and 108 MHz (megahertz) in the VHF (very-high-frequency) band. The frequencies assigned for television broadcasting are located in a portion of the VHF band and a portion of the UHF (ultra-high-frequency) band. Originally 13 VHF channels, each 6 MHz wide, were allocated for television. Later channel 1 was deleted. In 1952, 70 additional channels were allocated between 470 and 890 MHz in the UHF band. The frequency assignments for all 82 channels are given in Fig. 1-7.

The VHF channels are divided in two bands. Channels 2 to 6, called the *low-band VHF channels*, are located between 54 and 88 MHz. (There is a 4-MHz break between channels 4 and 5 for other services.) Channels 7 to 13, called the *high-band VHF channels*, are located between 174 and 216 MHz. (The frequencies between 88 and 174 MHz are reserved for other services.) Special letter designations have been given to frequencies below channel 2 and between channels 6 and 7, and between channels 13 and 14. These letter channels are used by CATV companies to increase their channel offerings to the public.

From the foregoing, it will be observed that a single television channel is 6 MHz wide, in contrast to the entire AM broadcast band, which is only 1 MHz wide. Also, each AM broadcast channel is only 10 to 20 kHz wide. The wide television channel is necessary to transmit both audio and video information with clar-

Channel Number	Frequency Limits of Channel		Center Frequency of Carrier	
	SUBCHANNEL			**CATV**
A	18 MHz	Picture	19.0	T-9
	24 MHz	Sound	23.5	
C	30 MHz	Picture	31.0	T-11
	36 MHz	Sound	35.5	
E	42 MHz	Picture	43.0	T-13
	48 MHz	Sound	47.5	
	VHF LOW BAND			
2	54 MHz	Picture	55.25	
		Sound	59.75	
3	60 MHz	Picture	61.25	
		Sound	65.75	
4	66 MHz	Picture	67.25	
		Sound	71.75	
	72 MHz			
5	76 MHz	Picture	77.25	
		Sound	81.75	
6	82 MHz	Picture	83.25	
		Sound	87.75	
	88 MHz			
	FM BAND			
	88 MHz		88.00	
	108 MHz		108.00	
	MID BAND			
A	120 MHz	Picture	121.25	
		Sound	125.75	
B	126 MHz	Picture	127.25	
		Sound	131.75	
C	132 MHz	Picture	133.25	
		Sound	137.75	
D	138 MHz	Picture	139.25	
		Sound	143.75	
E	144 MHz	Picture	145.25	
		Sound	149.75	
F	150 MHz	Picture	151.25	
		Sound	155.75	
G	156 MHz	Picture	157.25	
		Sound	161.75	
H	162 MHz	Picture	163.25	
		Sound	167.75	
I	168 MHz	Picture	169.25	
		Sound	173.75	
	174 MHz			
	VHF HIGH BAND			
7	174 MHz	Picture	175.25	
		Sound	179.75	
8	180 MHz	Picture	181.25	
		Sound	185.75	
9	186 MHz	Picture	187.25	
		Sound	191.75	
	192 MHz			

Channel Number	Frequency Limits of Channel		Center Frequency of Carrier
	VHF HIGH BAND (Cont'd)		
10	192 MHz	Picture	193.25
		Sound	197.75
11	198 MHz	Picture	199.25
		Sound	203.75
12	204 MHz	Picture	205.25
		Sound	209.75
13	210 MHz	Picture	211.25
		Sound	215.75
	216 MHz		
	SUPER BAND		
J	216 MHz	Picture	217.25
		Sound	221.75
K	222 MHz	Picture	223.25
		Sound	227.75
L	228 MHz	Picture	229.25
		Sound	233.75
M	234 MHz	Picture	235.25
		Sound	239.75
N	240 MHz	Picture	241.25
		Sound	245.75
O	246 MHz	Picture	247.25
		Sound	251.75
P	252 MHz	Picture	253.25
		Sound	257.75
Q	258 MHz	Picture	259.25
		Sound	263.75
R	264 MHz	Picture	265.25
		Sound	269.75
S	270 MHz	Picture	271.25
		Sound	275.75
T	276 MHz	Picture	277.25
		Sound	281.75
U	282 MHz	Picture	283.25
		Sound	287.75
V	288 MHz	Picture	289.25
		Sound	293.75
W	294 MHz	Picture	295.25
		Sound	299.75
	300 MHz		
	UHF BAND		
14	470 MHz	Picture	471.25
		Sound	475.75
15	476 MHz	Picture	477.25
		Sound	481.75
16	482 MHz	Picture	483.25
		Sound	487.75
17	488 MHz	Picture	489.25
		Sound	493.75
18	494 MHz	Picture	495.25
		Sound	499.75
19	500 MHz	Picture	501.25
		Sound	505.75
20	506 MHz	Picture	507.25
		Sound	511.75
21	512 MHz	Picture	513.25
		Sound	517.75
22	518 MHz	Picture	519.25
		Sound	523.75
23	524 MHz	Picture	525.25
		Sound	529.75
	530 MHz		

Fig. 1-7. Television-channel-

Channel Number	Frequency Limits of Channel	Center Frequency of Carrier	
UHF BAND (Cont'd)			
24	530 MHz – 536 MHz	Picture	531.25
		Sound	535.75
25	536 MHz – 542 MHz	Picture	537.25
		Sound	541.75
26	542 MHz – 548 MHz	Picture	543.25
		Sound	547.75
27	548 MHz – 554 MHz	Picture	549.25
		Sound	553.75
28	554 MHz – 560 MHz	Picture	555.25
		Sound	559.75
29	560 MHz – 566 MHz	Picture	561.25
		Sound	565.75
30	566 MHz – 572 MHz	Picture	567.25
		Sound	571.75
31	572 MHz – 578 MHz	Picture	573.25
		Sound	577.75
32	578 MHz – 584 MHz	Picture	579.25
		Sound	583.75
33	584 MHz – 590 MHz	Picture	585.25
		Sound	589.75
34	590 MHz – 596 MHz	Picture	591.25
		Sound	595.75
35	596 MHz – 602 MHz	Picture	597.25
		Sound	601.75
36	602 MHz – 608 MHz	Picture	603.25
		Sound	607.75
37	608 MHz – 614 MHz	Picture	609.25
		Sound	613.75
38	614 MHz – 620 MHz	Picture	615.25
		Sound	619.75
39	620 MHz – 626 MHz	Picture	621.25
		Sound	625.75
40	626 MHz – 632 MHz	Picture	627.25
		Sound	631.75
41	632 MHz – 638 MHz	Picture	633.25
		Sound	637.75
42	638 MHz – 644 MHz	Picture	639.25
		Sound	643.75
43	644 MHz – 650 MHz	Picture	645.25
		Sound	649.75
44	650 MHz – 656 MHz	Picture	651.25
		Sound	655.75
45	656 MHz – 662 MHz	Picture	657.25
		Sound	661.75
46	662 MHz – 668 MHz	Picture	663.25
		Sound	667.75
47	668 MHz – 674 MHz	Picture	669.25
		Sound	673.75
48	674 MHz – 680 MHz	Picture	675.25
		Sound	679.75
49	680 MHz – 686 MHz	Picture	681.25
		Sound	685.75
50	686 MHz – 692 MHz	Picture	687.25
		Sound	691.75
51	692 MHz – 698 MHz	Picture	693.25
		Sound	697.75
52	698 MHz – 704 MHz	Picture	699.25
		Sound	703.75
53	704 MHz – 710 MHz	Picture	705.25
		Sound	709.75
54	710 MHz – 716 MHz	Picture	711.25
		Sound	715.75

Channel Number	Frequency Limits of Channel	Center Frequency of Carrier	
UHF BAND (Cont'd)			
55	716 MHz – 722 MHz	Picture	717.25
		Sound	721.75
56	722 MHz – 728 MHz	Picture	723.25
		Sound	727.75
57	728 MHz – 734 MHz	Picture	729.25
		Sound	733.75
58	734 MHz – 740 MHz	Picture	735.25
		Sound	739.75
59	740 MHz – 746 MHz	Picture	741.25
		Sound	745.75
60	746 MHz – 752 MHz	Picture	747.25
		Sound	751.75
61	752 MHz – 758 MHz	Picture	753.25
		Sound	757.75
62	758 MHz – 764 MHz	Picture	759.25
		Sound	763.75
63	764 MHz – 770 MHz	Picture	765.25
		Sound	769.75
64	770 MHz – 776 MHz	Picture	771.25
		Sound	775.75
65	776 MHz – 782 MHz	Picture	777.25
		Sound	781.75
66	782 MHz – 788 MHz	Picture	783.25
		Sound	787.75
67	788 MHz – 794 MHz	Picture	789.25
		Sound	793.75
68	794 MHz – 800 MHz	Picture	795.25
		Sound	799.75
69	800 MHz – 806 MHz	Picture	801.25
		Sound	805.75
TRANSLATOR FREQUENCY			
70	806 MHz – 812 MHz	Picture	807.25
		Sound	811.75
71	812 MHz – 818 MHz	Picture	813.25
		Sound	817.75
72	818 MHz – 824 MHz	Picture	819.25
		Sound	823.75
73	824 MHz – 830 MHz	Picture	825.25
		Sound	829.75
74	830 MHz – 836 MHz	Picture	831.25
		Sound	835.75
75	836 MHz – 842 MHz	Picture	837.25
		Sound	841.75
76	842 MHz – 848 MHz	Picture	843.25
		Sound	847.75
77	848 MHz – 854 MHz	Picture	849.25
		Sound	853.75
78	854 MHz – 860 MHz	Picture	855.25
		Sound	859.75
79	860 MHz – 866 MHz	Picture	861.25
		Sound	865.75
80	866 MHz – 872 MHz	Picture	867.25
		Sound	871.75
81	872 MHz – 878 MHz	Picture	873.25
		Sound	877.75
82	878 MHz – 884 MHz	Picture	879.25
		Sound	883.75
83	884 MHz – 890 MHz	Picture	885.25
		Sound	889.75

Courtesy Windgard Co.

frequency assignments.

ity and sharpness. It also illustrates that video information must be transmitted on very high frequencies to obtain a satisfactory ratio of carrier frequency to bandwidth.

STANDARD TELEVISION CHANNEL

A standard television channel is shown in Fig. 1-8. As previously noted, the bandwidth of each television channel is 6 MHz, and both the video and sound signal must be transmitted within this limit. The AM picture signal is always at the low-frequency end of each channel allocation and occupies approximately 5 MHz of the total 6-MHz bandwidth. The FM sound signal is always at the high-frequency end of the 6-MHz channel and has a maximum deviation of 25 kHz (a total carrier swing of 50 kHz). The actual frequencies of the picture and sound carriers are included in Fig. 1-7.

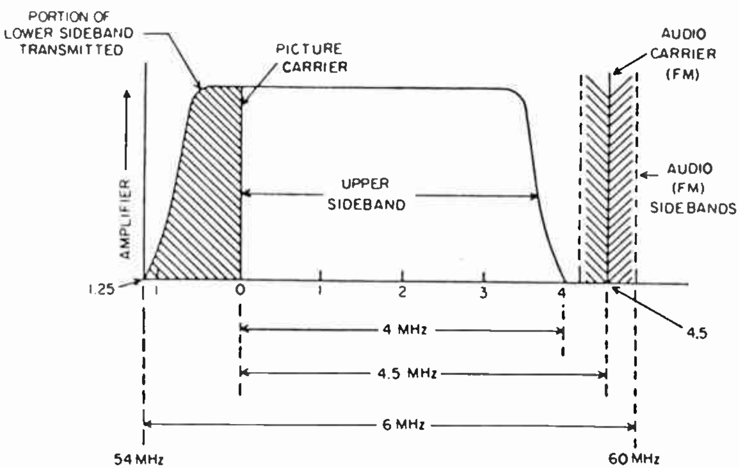


Fig. 1-8. Signal distribution is a standard television channel.

An unusual feature of the AM picture signal is that the high-frequency sideband is approximately 4 MHz wide whereas the low-frequency sideband is only 1.25 MHz wide. This unsymmetrical distribution permits transmission of a better definition picture within the 6-MHz bandwidth. This transmission of one sideband and a portion of the other sideband of the picture signal, as effected in television practice, is termed *vestigial sideband transmission*.

TELEVISION-SIGNAL COMPONENTS

The combination of video, blanking, and sync signals is called the *composite video signal*.

Video Signal

The video (picture) signal is arbitrarily represented as a jagged line in Fig. 1-9. (Note the horizontal scale of this portion of the signal is greatly compressed in Fig. 1-9; if drawn to scale, it would be many times wider than the blanking signal.) You will

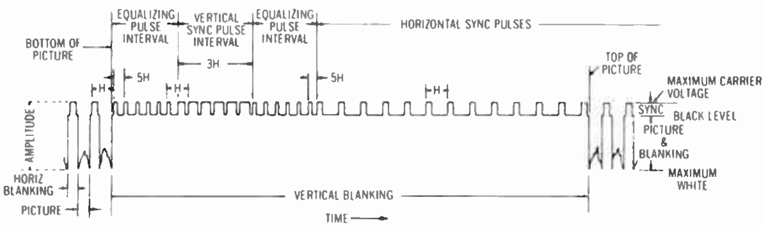


Fig. 1-9. Composite video signal.

recall that the amplitude of the video signal varies in accordance with the degree of brightness at any particular instant. Figure 1-10 shows a typical example. Here, the variations in the tones along line X–X in the picture of Fig. 1-10 will produce the video-modulating voltage of Fig. 1-11.

Notice in Fig. 1-11 that any darker portion of the picture produces an increase in the amplitude of the signal. This type of modulation is called *negative polarity of transmission*. Any black area on the screen is represented by an absence of light. In other

Fig. 1-10. Television subject.

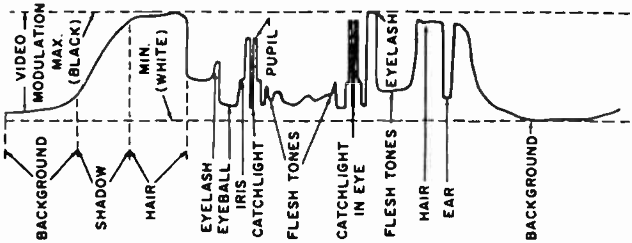


Fig. 1-11. Variations in video voltage of a scanning line.

words, the beam is cut off. This type of transmission is standard in the United States.

Blanking Signal

Two blanking signals are transmitted, one at the end of each line, and the other at the end of each field. Notice in Fig. 1-9 that the amplitude of the blanking signals is greater than any portion of the video signal. Hence, the beam is cut off during the blanking pulses so that the retrace of the scanning beams cannot be viewed on the screen.

Sync Signal

Sitting atop the horizontal and vertical blanking signals is a rectangular pulse, called the *sync pulse*, which is employed to keep the deflection circuits in the receiver in step with those at the transmitter. Since the amplitude of the blanking signal is sufficient to cut the beam of the picture tube off, the sync pulse is said to be in the "blacker than black" region.

If one long unbroken pulse were transmitted for vertical synchronization, the horizontal sync pulsed during this time would be absent. During that time the horizontal deflection circuits in the receivers would lack synchronization and drop out of step. In order that horizontal synchronization be maintained during their vertical retrace period, the vertical sync pulse is broken by serrations. These serrations then maintain horizontal synchronization during the vertical retrace period.

Equalizing Pulse

A fourth group of signals, termed *equalizing pulses*, is also included in Fig. 1-9. These pulses are transmitted to ensure uniform spacing of the interlaced scanning lines and prevent loss of synchronism of the horizontal circuits during the retrace intervals between fields. In Fig. 1-9 all pulse shapes, their relative amplitudes, and their durations are standardized. The only variable is the picture signal, which varies from line to line as the subject is scanned.

SUMMARY

The television picture is broken up into individual elements instead of the entire picture being transmitted simultaneously. A process called interlaced scanning is employed to break up the picture for transmission. In this system, 525 horizontal lines are scanned across the picture. All odd-numbered lines are scanned first; then the beam returns to the top of the picture, and the even numbered lines are scanned. Thus, two fields of 262½ lines each are interlaced to form the complete picture or frame (525 lines).

The horizontal lines are scanned at a rate of 15,750/sec. Each field of 262½ lines is repeated 60 times/sec, and 30 complete pictures are transmitted per second. We see the complete picture without flicker for two reasons: (1) The picture tube continues to glow for a period of time after being struck by the beam; and (2) the persistence of vision of the human eye makes it sensitive only to changes that occur at a rate of 1/16 sec or slower.

In addition to the picture or video signals, blanking signals to black out the beam during retrace when the beam returns from the right to the left side of the screen and from the bottom to the top of the screen, are also transmitted. Sync signals, which keep the receiver deflection circuits in step with the transmitter, are situated on top of the blanking signal.

Negative modulation is employed for the picture signal; that is, an increase in the light intensity of the televised scene causes a decrease in the radiated power. Conversely, a decrease in the light intensity causes an increase in the radiated power. The primary reason for adopting negative transmission is that any noise pulse present with the signal will usually cause an increase in signal strength. With negative transmission, noise will be produced as a black spot, whereas with positive transmission, it would appear as a bright flash of light. The black spots are far less annoying. Also, blanking and sync pulses must be transmitted as black; therefore, with negative transmission, they will appear at the maximum amplitude, ensuring proper synchronization even at low signal strength.

The entire composite video signal, including the picture, sync, and blanking signals, plus the sound signal, is transmitted in a channel 6 MHz wide. To obtain maximum bandwidth, a system termed vestigial sideband transmission is employed. In the United States, 82 channels (12 VHF and 70 UHF) are allocated for television broadcasting.

REVIEW QUESTIONS

1. Radio and television signals are transmitted through space by what means?

2. In radio, how many signals are being transmitted? In television?
3. How many horizontal scanning lines are produced per second?
4. Explain the process used in scanning horizontal lines.
5. How many channels are assigned to television broadcasting?
6. What is the bandwidth of each television channel? Why?
7. How many fields exist in one complete picture or frame?
8. How many lines are in each field?
9. What channels are in the low-band VHF, high-band VHF, and UHF?
10. What range of frequencies is used in the low-band VHF, high-band VHF, and UHF?

CHAPTER 2

Television Transmission

In this chapter, a brief discussion of the television transmission and broadcast practices will be given. This discussion should not be considered as a complete coverage of the subject since that would fill an entire book of this size. Only those points considered necessary for a general understanding of the basic TV transmission system will be given. A block diagram of the basic TV transmission system will be given. A block diagram of the basic TV transmission system is shown in Fig. 2-1.

TELEVISION-BROADCASTING PRACTICES

The televising of live talent programs presents to the video broadcaster many of the same problems that have confronted the motion-picture industry. Rather elaborate backgrounds are frequently necessary, and they require the same attention to techni-

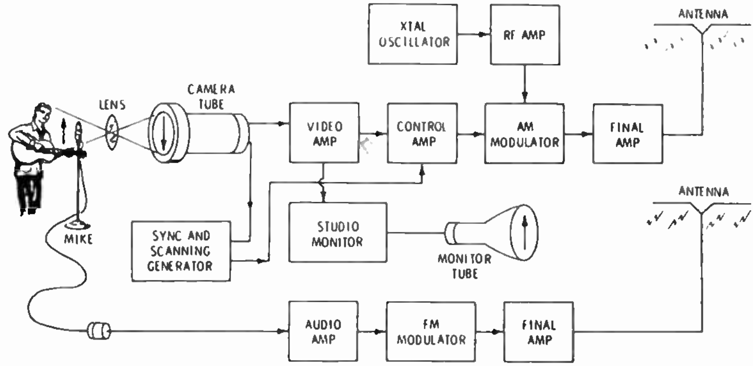


Fig. 2-1. Block diagram of a television transmission system.

cal detail and period authenticity that is evident in well-staged plays and high-grade motion pictures.

However, unlike motion-picture production, which can be interrupted at will, a live television broadcast must be continuous. The problems of sets, lighting, and equipment require much planning and rehearsal prior to the actual broadcast. Indoor and outdoor televising usually require several cameras strategically located so that the scene can be viewed from various vantage points without sequential interruption.

In addition to the telecasting of live program material, extensive use is made of motion-picture film in television programming. For this purpose, special projectors are employed, which, by a shutter arrangement, convert the 24-frames/sec film projections into 30-frames/sec television signals. The film picture is projected directly into a television camera, from which the electrical signal is conveyed to the control room over coaxial cable. Sound pickup from the film is conveyed in the normal manner to the control room over twisted-pair audio cable. Other films are often used for news and commercials. The sound may be provided by a live announcer or may be prerecorded.

Slides are also used for many programs. They offer flexibility in their display order on a program-to-program basis. News, sports, and still commercial broadcasts are common examples. The projection of slides directly into the television camera has led to the development of the *film chain*, or *film island*. This "multiplexing" device employs prisms and mirrors to select which movie projector or slide projector is to be seen by the television camera, reducing the total number of television cameras required.

Videotape recorders are now the accepted medium for most programming. They offer the advantage of being able to record the program at any convenient time for playback at the desired time. Both the picture and sound are included on the magnetic tape, and it is ready for instant playback. No time is lost in processing. Video tapes can be exchanged between stations or distributed by syndicates the same as film. They can also be used for commercials or any other type of presentation.

Network broadcasts, of course, are one of the most common methods of program origination and do not require any program facilities at the local studio. In this type of presentation, the program originates at one point, either live, on film, or on videotape. This program is then sent out via coaxial-cable microwave relay or satellite to the network stations, where it is transmitted to the viewing public. Sometimes, due to time differentials, the network program will be recorded on videotape when it is received at the station and played back at a later hour. A typical videotape recorder is shown in Fig. 2-2.

Remote broadcasts offer still other difficulties. Since the connection by coaxial cable from a remote location to the studio is an economic impossibility, small UHF or microwave relay links are employed to connect the remote site with the studio. The relay equipment is usually contained within a special truck that houses, not only the relay transmitter, but also complete control and monitoring facilities. Of course, if the event is not to be viewed until a later hour, the program can be videotaped at the remote location. The tape facilities can be taken from the remote point and transported back to the studio, or the relay link can be utilized and the recording made at the studio.

CLOSED-CIRCUIT TELEVISION

Closed-circuit television originally designated a local system consisting of a TV camera and several monitors connected by coaxial cables. Today, closed-circuit TV refers also to elaborate private installations, which are widely used by industry, com-

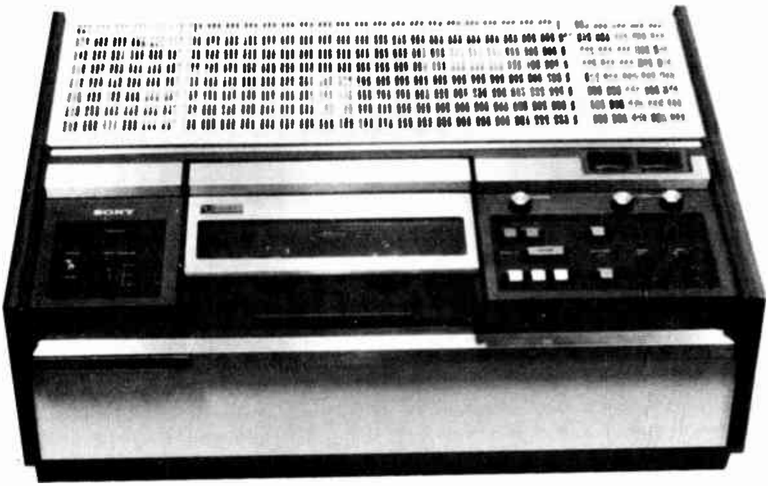


Fig. 2-2. Typical videotape recorder.

merce, and education. Microwave transmission is used in some of the larger closed-circuit TV systems. The basic distinction is in the fact that only private groups are served by a closed-circuit system. Scanning standards are usually the same as used in public TV broadcasting, although slow-scan standards, for example, may be used to transmit signature records in banks.

Equipment used in closed-circuit TV is similar to conventional broadcast TV equipment, except that the units may be less elaborate. For example, the TV camera shown in Fig. 2-3 employs a *vidicon tube*. A video output is provided, which is usually fed to TV monitors via coaxial cables. Videotape recorders, such as the one shown in Fig. 2-3, find wide use in educational installations. They provides a video-frequency signal, which is fed via a coaxial cable to the TV monitors and applied directly to the video amplifier in each monitor. The TV camera may be used when

(A) Closed-circuit TV camera;

(B) Video cassete recorders.

Fig. 2-3. (A) Closed-circuit TV camera; (B) video cassette recorders.

"live" classroom activities are to be transmitted by the closed-circuit system.

Since a typical closed-circuit TV camera produces a video signal with a bandwidth up to 10 MHz, the chief limitation on picture detail and quality is imposed by the TV monitors used in the viewing locations. If the video-signal output is applied directly to the video amplifier in a monitor, the quality of picture reproduction may exceed that of a standard TV broadcast program.

Practically all closed-circuit cameras are transistorized, compact, and can be operated by anyone who understands how to focus an ordinary camera. Closed-circuit color TV has been used chiefly in medical schools but is gaining wide acceptance throughout other institutions and industries as the cost of equipment decreases.

VIDEOTAPE RECORDING

A videotape recorder employs magnetic tape to record moving pictures and sound. A typical method utilizes transverse recording with a rotary head (see Fig. 2-4). The videotape is 2 in. wide and moves past recording heads at 15 or 7½ in./sec. However, four record/playback heads are mounted on a disk that rotates rapidly across the tape at virtually a 90° angle to the path of the tape. The relative tape-to-head speed is increased to 1,500 in./sec. Frequencies up to 5 MHz can be recorded.

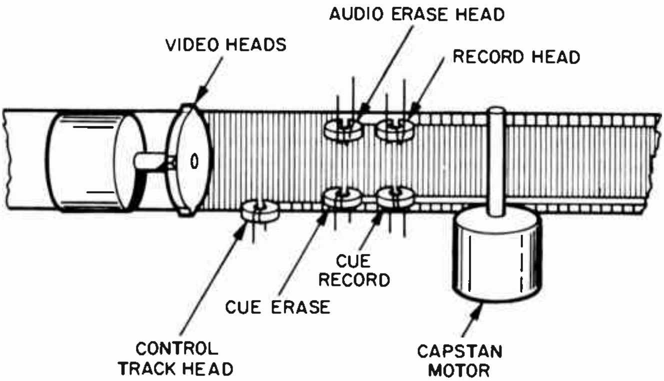
In helical recording (see Fig. 2-5), one or two record/playback heads are mounted on a moving drum and move across the tape in a diagonal curve. The tape may be from ½ to 1 in. wide, and the tape speed may be from 3.75 to 9.6 in./sec. Frequencies up to 3.2 MHz can be recorded by this method.

Newer consumer-oriented machines are now available in ¼- to ½-inch widths and record as long as 6 hours on one video cassette.

TELEVISION TRANSMITTERS

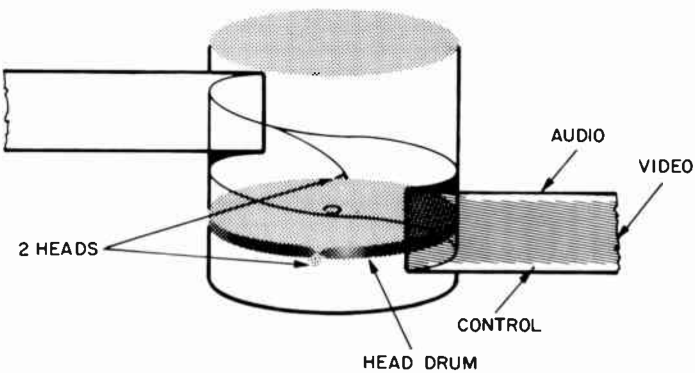
In the foregoing overall description of a television system, no attention has been given to the apparatus necessary in the broadcasting studios for successful transmission of picture and sound. Of necessity, most of the apparatus required to produce the conditions described are extremely complex, and an understanding of them is difficult. However, a *monitor* is comparatively simple and is of interest in this basic analysis.

A typical monitor is shown in Fig. 2-6. It is a simplified type of TV receiver, which contains scanning circuits and a video amplifier, and it permits the station engineer to observe the system



Courtesy Ampex Corp.

Fig. 2-4. Transverse recording method.



Courtesy Ampex Corp.

Fig. 2-5. Helical recording method.

operation. The engineer who does not have a monitor would be "working in the dark." A monitor is supplemented by an *oscilloscope*, as shown in Fig. 2-7. The scope enables the engineer to determine whenever distortion might occur in the video signal.

The *camera tube* is the heart of the television system. Here the image is first "picked up" and starts its long journey to the picture tube. The basic function of the camera tube is to convert the variable-light scenes into varying electrical signals corresponding to the light and dark areas of the picture.

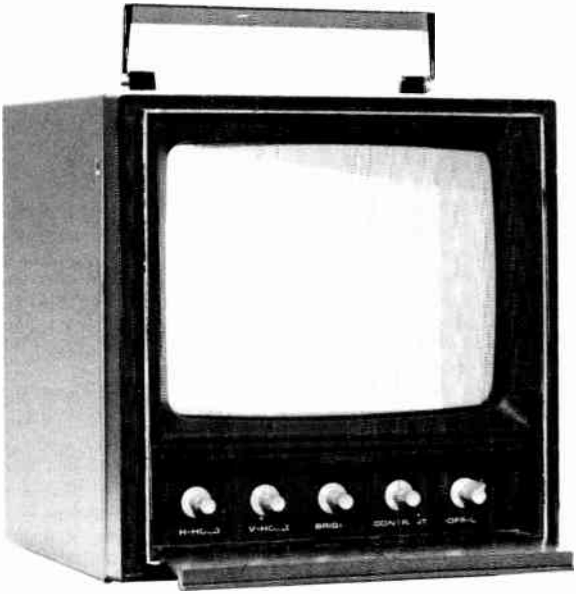


Fig. 2-6. Typical television monitor.

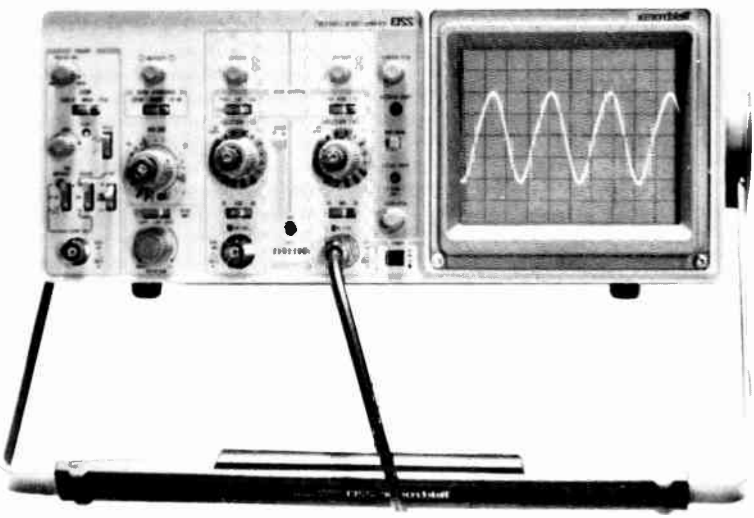


Fig. 2-7. Oscilloscope.

Vidicon

The *vidicon camera tube* (Fig. 2-8) is suitable for black-and-white or color television and is used in both broadcasting and closed-circuit applications. The tube consists of an electron gun, beam-focusing electrode (grid 3), fine mesh screen (grid 4), and a target. The electron gun consists of a cathode, control grid (grid 1), and an accelerating grid (grid 2). A low-velocity beam from the electron gun is focused by an external magnetic field and by the electrostatic field of grid 3. Grid 4, which is connected to grid 3, is positioned near the target, which is composed of a transparent conducting film on the inner surface of the faceplate. Each small portion of the photoconductive layer is an insulator when there is no light on the faceplate but becomes slightly conductive when illuminated.

Grid 4 provides a uniform decelerating field between itself and the photoconductive layer of the target so that the beam approaches the layer perpendicular to it. This condition is necessary for linear scanning. The beam is deflected back and forth and up and down on the target. Since the photoconductive layer has a positive potential, electrons are deposited on it when it is scanned by the beam. This depositing of electrons continues until

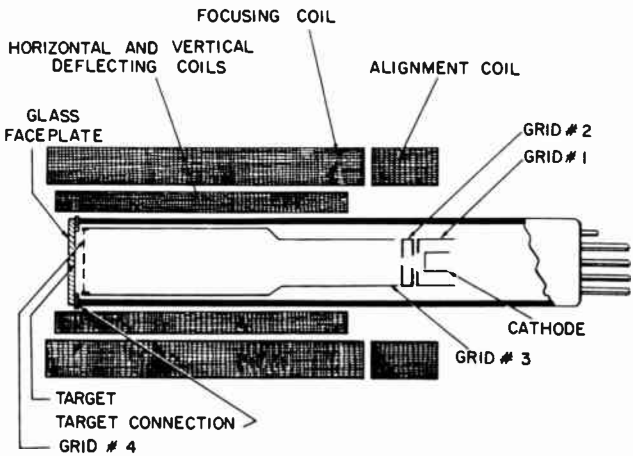


Fig. 2-8. Vidicon camera tube.

the surface potential of the photoelectric layer is reduced to that of the cathode. When this point is reached, electrons are turned back to form a return beam that is not used.

Deposits on the scanned surface of any portion of the layer change the difference of potential between the two surfaces of the portion. When the two surfaces of the portion, which, in effect, is a charged capacitor, are connected through the external target circuit and scanning beam, a capacitive current is produced. This current is the video signal.

Transmitter Timing

Sync Generator—As explained previously, synchronizing pulses, generated at the transmitter, control the deflection of the electron beams in the camera tube and in the receiver picture tube. The sync generator in the transmitter produces the properly timed and shaped pulses for the horizontal and vertical deflection of the beam in the camera. In addition, these pulses are added to the video signal to keep the receiver in step.

Blanking Generator—The proper pulses are for cutting off the camera and receiver during the retrace period are generated in the blanking generator. These pulses are also added to the video signal before transmission to the receiver.

Vestigial Sideband Filter—As discussed previously, only a portion of the lower sideband is transmitted. A portion of the lower sideband is removed to conserve space in the spectrum. This portion of the signal is removed by the vestigial sideband filter.

Sound Transmitter—The sound transmitter associated with the transmitting system is a conventional frequency-modulation system consisting of audio amplifier, frequency modulator, high-frequency transmitter, and high-frequency antenna. Thus, at the transmitting station, there are actually two transmitters: one for the picture signal, and one for the sound.

Functional Units of a Television Transmitter

A basic block diagram of a television transmitter is shown in Fig. 2-9. The viewfinder is an auxiliary optical and electronic device that is attached to the TV camera to enable the operator to see the same scene that the camera is transducing. A stabilizing

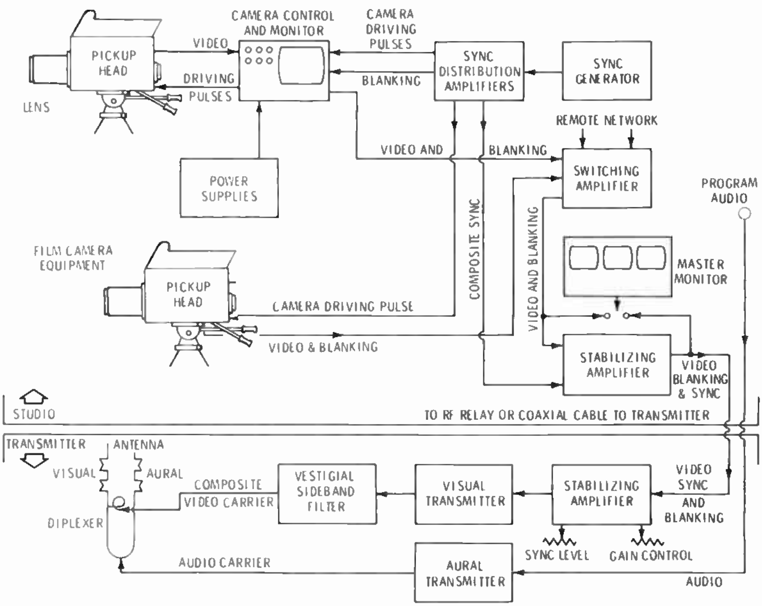


Fig. 2-9. Block diagram of a television transmission system.

amplifier functions to correct faulty video signals from field pickup equipment and transmission characteristics such as noise, switching surges, improper sync-to-signal ratio, and so on. The stabilizing amplifier includes circuits for separating sync signals, wave shapers, sync insertion circuits, and video amplifiers. A vestigial sideband filter is inserted between an AM transmitter and its transmitting antenna to suppress part of one of the sidebands. A diplexer is a coupling unit that allows more than one transmitter to operate together on the same antenna.

Next, observe the functional block diagram of a channel-6 TV transmitter, shown in Fig. 2-10; operating frequencies and the chief frequency responses are noted in the diagram. Note that grid modulation is utilized for the picture signal. This form of modulation preserves the dc component of the video signal without undue circuit elaboration. In the studio chain, the dc component of the video signal is reinserted by means of a clamper (dc restorer). Unless the dc component is maintained, night scenes

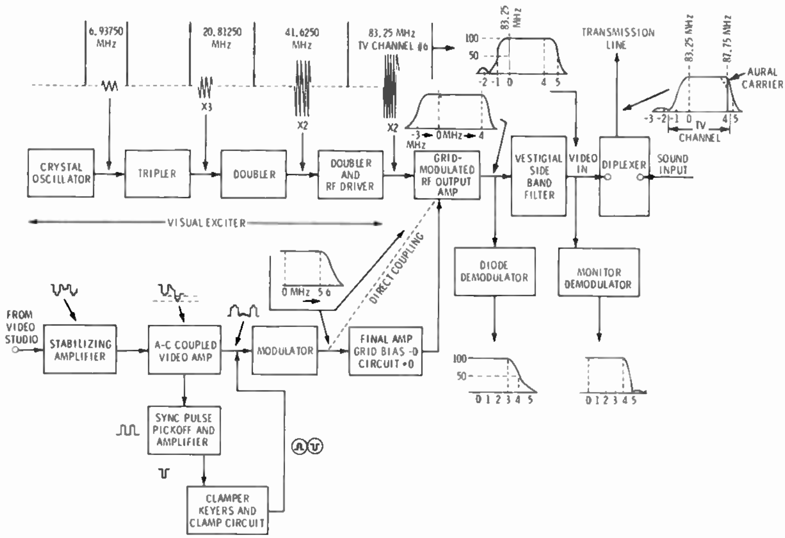


Fig. 2-10. Functional block diagram of a channel-6 transmitter.

will appear too light and day scenes will appear too dark. As explained subsequently, TV receivers may or may not be designed to preserve the dc component of the video signal.

SUMMARY

Videotape recorders are used for many programs. They offer the advantage of being able to record any program for a playback at the desired time. Both sound and picture are included on the magnetic tape and are ready for instant playback because no time is lost in processing.

The most basic type of TV camera tube is the vidicon. The basic function of the camera tube is to convert the variable-light scenes into a varying electrical signal corresponding to the light and dark areas of the picture. Sync generators, blanking generators, vestigial sideband filters, and audio transmitters are all part of the signal transmitted for properly shaped pulses for horizontal and vertical deflection, proper blanking during retrace, and proper sound at the television receiver.

REVIEW QUESTIONS

1. What two types of media are used for prerecorded programming?
2. What is the purpose of microwave links?
3. Why are videotape recorders used?
4. Why is a monitor used in transmitting studios?
5. What is the purpose of the sync pulse transmission?
6. What is the purpose of the blanking pulse?

CHAPTER 3

Television Receivers

In Chapter 2, a discussion of the various stages in a television transmitter was given. In this chapter, the same type of presentation will be given for the television receiver. The function of the television receiver (Fig. 3-1) is to pick up the signal from the television station, amplify it, and employ it to produce visible pictures and audible sound that, in all detail, correspond to the original scene.

In the television receiver, the received signal is amplified and separated into its individual components. These components are amplified and applied in such a way as to produce variations in the intensity of the electron beam of the picture tube. Figure 3-2 depicts the components of the received signal.

Deflection of the beam in the picture tube is accomplished electromagnetically with coils extended to the tube. The oscillators that supply the energy to deflect the beam in the picture tube operate at the same frequency as the deflection circuits in the

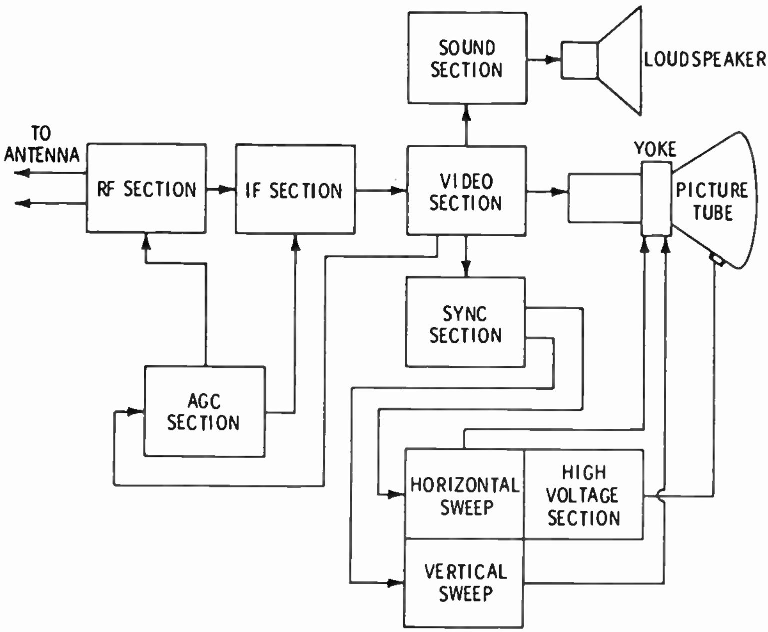
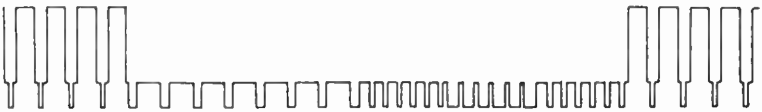


Fig. 3-1. Fundamental block diagram of a television receiver.

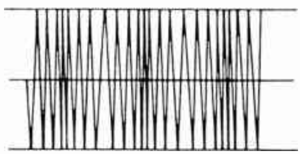
camera by the sync pulses transmitted as part of the composite video signal.

Thus, the electron beam of the picture tube moves in synchronism with the electron beam of the camera tube, and the variations in brilliance at the point of impact on the picture-tube screen correspond to the illumination on the respective areas of the camera tube. In this manner, the image on the target of the camera tube is dissected, and the information on each element is transmitted separately in a manner that permits the television receiver to take the pulses of information and employ them to produce variations in illuminations on the picture-tube screen. Since the deflection circuits keep these pulses of illumination in the same respective positions on the screen, a reproduction of the original scene is produced.



(A) Sync pulses and blanking pedestals.

(B) Camera signal.



(C) Sound signal.

Fig. 3-2. Basic components of the television signal.

BLOCK DIAGRAM OF TELEVISION RECEIVER

It should be understood that all television receivers operate on the same general principles. All use the *superheterodyne* principle. All must have certain basic stages. The actual circuits may differ, but their function is the same.

In order to simplify the study of television receivers, it is customary to employ *block diagrams*. When you first look at the circuit of a complete TV receiver, it looks frightening and very complicated. However, by using the block diagram, the complete circuit can be broken down into its individual sections, each of which has its own function.

The block diagram of a television receiver is given in Fig. 3-3. All the stages, or blocks, shown in Fig. 3-3 are not used in some receivers, depending on their intended price range and application. The blocks shown in dashed lines in Fig. 3-3 are the ones most commonly omitted. Typical stage gain figures for a television receiver are noted in Fig. 3-4.

THE TUNER

Here is how a typical TV receiver works: The signal from the desired VHF TV station and the signals from all other stations in the area arrive at the VHF antenna. All these signals travel down the transmission line to the RF amplifier, which selects only the desired signal and rejects all others. The desired signal is amplified by the RF amplifier and coupled to the mixer. In the mixer stage, the amplified signal from the RF amplifier and a signal from the local oscillator are beat together (heterodyned) to produce a lower, or intermediate, frequency. The mixer and the local oscillator are shown in one block in Fig. 3-3 because, in modern TV receivers, these stages are always two portions of the same tube or integrated circuit.

When receiving a UHF signal, the procedure is slightly different. The signals from the UHF station also arrive by antenna and travel down the transmission line. At the UHF tuner, signals from the desired station are selected and applied directly to the mixer stage. Here the signal from the station and the signal from the UHF local oscillator are heterodyned to form the IF frequency. The IF output from the UHF tuner is then coupled to the VHF RF amplifier. When tuned to the UHF position, the VHF RF amplifier and mixer provide two stages of amplification of the IF signal.

Note that actually two separate IF signals exist at the mixer output. One is produced by the video signal beating with the local oscillator; a typical video IF frequency is 45.75 MHz. The other IF frequency is produced by the sound signal beating with

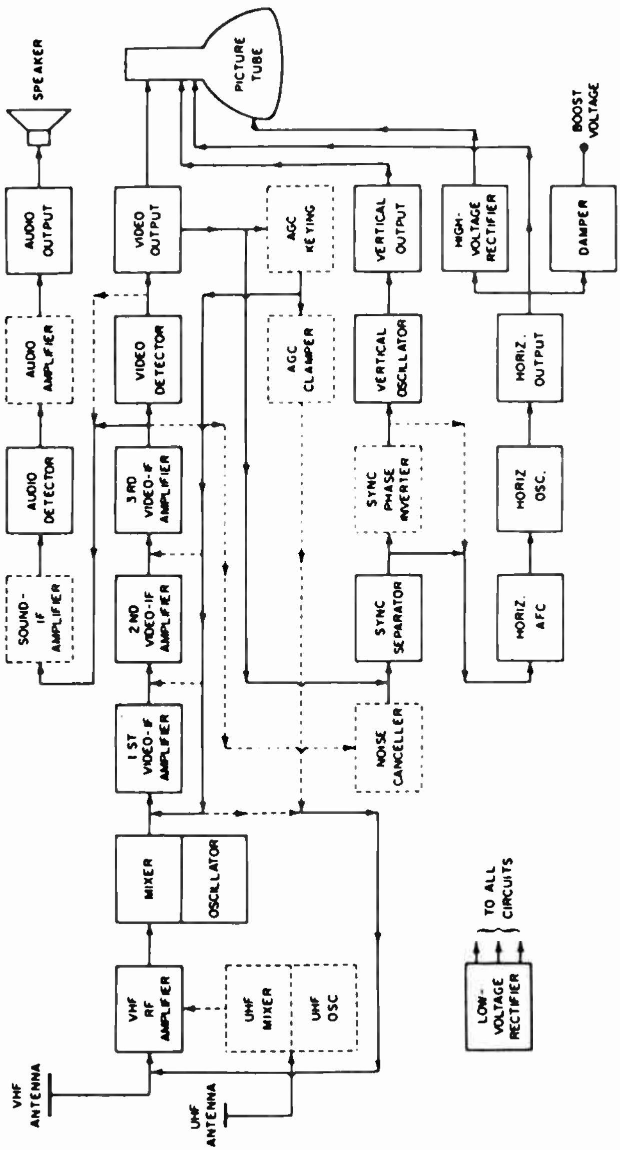


Fig. 3-3. Block diagram of a television receiver.

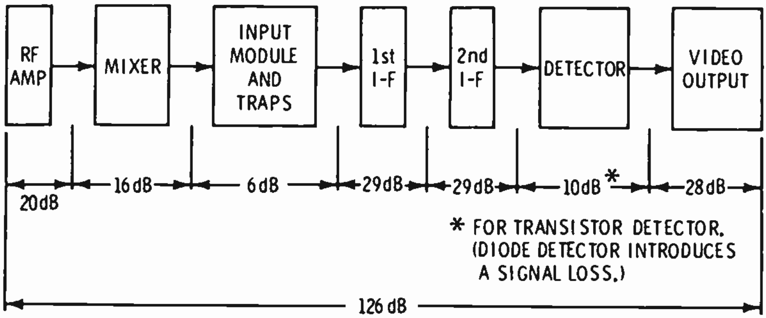


Fig. 3-4. Typical gain figures for a television receiver.

the local oscillator; a typical sound IF frequency is 41.25 MHz. Thus, the two frequencies are separated by the same 4.5-MHz difference established at the transmitter.

For example, assume that it is desired to tune to a station operating on channel 6, with a video carrier frequency of 83.25 MHz and a sound carrier of 87.75 MHz. The local oscillator frequency in this example would be 129 MHz. Thus, when the local oscillator is heterodyned with the station signals, the following IF frequencies are generated:

Local oscillator	129.00 MHz
Minus video carrier	83.25 MHz
Video IF	45.76 MHz
Local oscillator	129.00 MHz
Minus sound carrier	87.75 MHz
Sound IF	41.25 MHz

Notice that, although the sound carrier in the composite video signal is transmitted at the higher frequency, the lower IF is produced by the sound carrier because the oscillator is at a higher frequency than either carrier, and there is an inversion of the frequency relationship between the sound and picture carriers. If the local oscillator were tuned to a frequency lower than the carrier frequencies, the video IF would be lower than the sound IF. Either method will work; however, the former is usually employed because of interface problems that occur when the oscillator is tuned lower than the carrier.

VIDEO IF AMPLIFIER, DETECTOR, AND VIDEO AMPLIFIER

The output of the mixer is coupled to the output of the first video IF amplifier. Remember, the signal at this point contains both video and sound, as well as the sync signals, although the stages are called *video* (or picture) *IF amplifiers*. In the early days of TV, the sound was often separated from the video at the mixer output. The term *video IF amplifier* is a carryover from the days when only the video (and sync) signal was applied to these stages, but in all modern receivers, both video and sound are being amplified by these stages.

The IF amplifiers are tuned to pass a band of frequencies approximately 4 MHz wide and to reject all others. This wide-band response is obtained by using various means of coupling between the IF amplifier stages. Thus, the signal in the video IF amplifiers is an RF signal, varying at the video rate, as shown in Fig. 3-5. Three stages of video IF amplification are shown in Fig. 3-3.

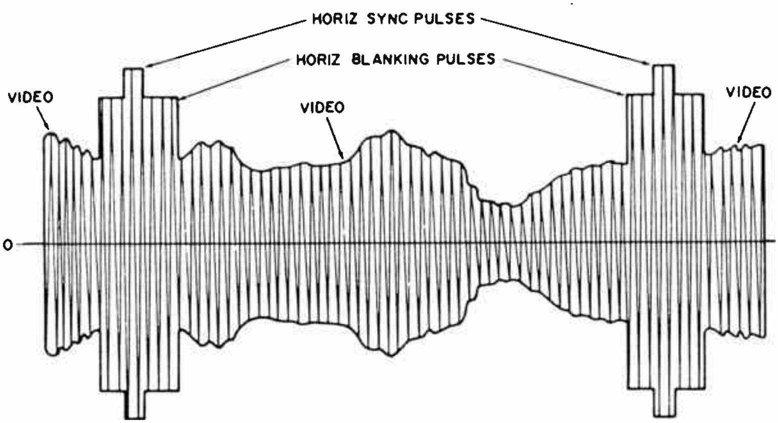


Fig. 3-5. Composite video IF signal.

At the output of the last video If amplifier, the signal is coupled to the video detector. The video detector detects, or demodulates, the video IF signal so that a dc voltage, which varies in step with the original video and sync signals, is produced at the output. This signal is shown in Fig. 3-6.

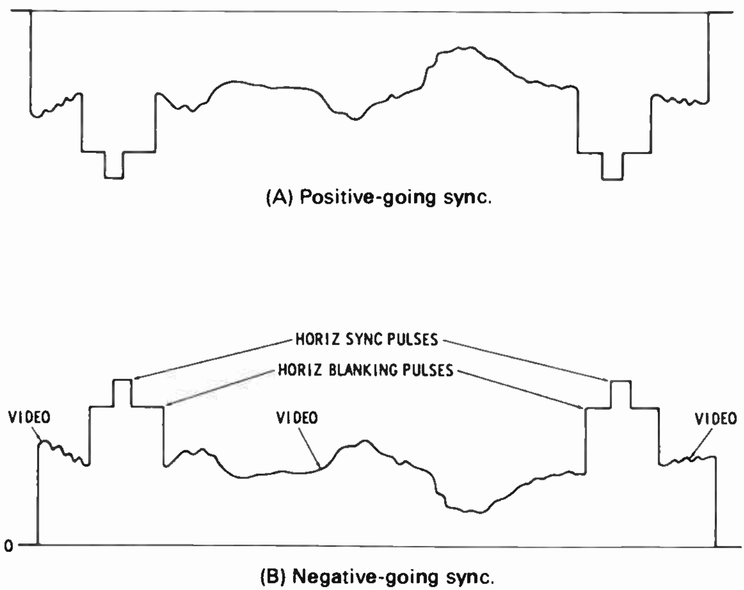
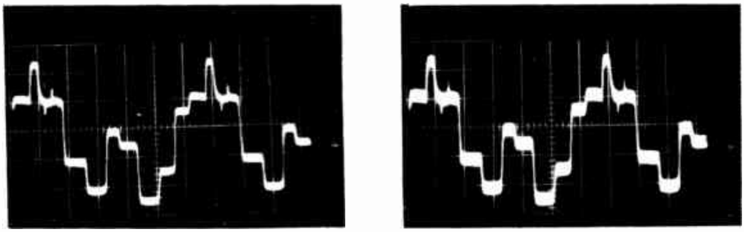


Fig. 3-6. Composite video signal after detection.

In addition to the signal of Fig. 3-6, another signal is produced at the output of the video detector. Recall that, in addition to the video signal, the sound signal is also present in the video IF amplifiers, and that the carrier frequencies for these two signals are separated by 4.5 MHz. These two signals beat together in the video detector, producing a new signal, whose frequency is equal to the 4.5-MHz difference between the signals. This new signal contains all the sound information, and so it is a new sound IF frequency. Because the signal is produced by the beating together of the two signals, it is called the *intercarrier sound signal* and is always 4.5 MHz. Figure 3-7 shows how a 4.5-MHz signal appears as "fuzz" on the video signal.



(A) Moderate level of intercarrier signal. (B) High level of intercarrier signal.

Fig. 3-7. Video signals with a 4.5-MHz, intercarrier-sound signal.

The video-output stage follows the video-detector stage. This stage amplifies the weak signal at the detector output for application to the picture tube. The amplified video signal is applied to the picture tube, where it varies the intensity of the beam to produce the light and dark spots on the picture-tube screen.

The blanking pulses must cut the picture tube off. Thus, if a video signal with negative-going sync pulses (Fig. 3-8) is applied the picture tube, the negative portions will reduce the voltage at the grid so that the beam is cut off. When the more positive portions of the signal are applied to the grid, the beam will flow

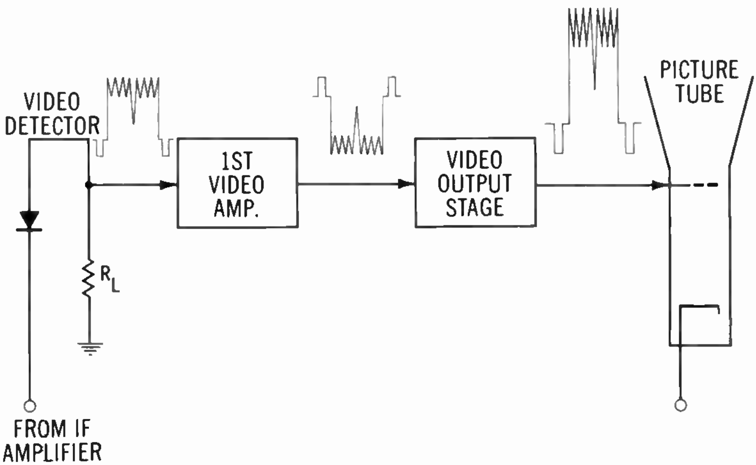


Fig. 3-8. Negative-going sync applied to picture-tube grid.

from the cathode to the screen in the picture tube. The intensity of the beam at any instant and, hence, the degree of brightness of the spot on the screen will depend upon the instantaneous voltage of the signal; the more positive the signal, the more intense the beam and the brighter the spot on the screen.

If a positive-going sync signal (Fig. 3-9) is applied to the picture tube, the results will still be the same, except that the signal must be applied to the cathode of the picture tube. As the positive-going sync pulses are applied to the picture tube, the instantaneous voltage at the cathode is made more positive, which, if the grid voltage remains constant, is the same as making

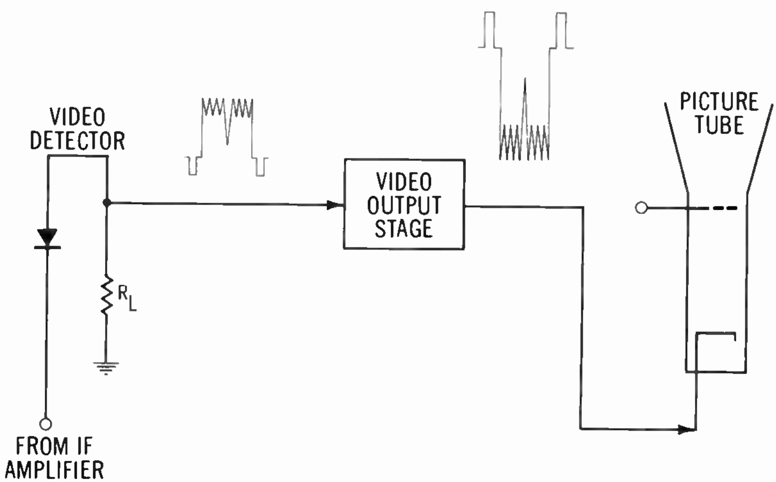


Fig. 3-9. Positive-going sync applied to picture-tube cathode.

the grid more negative. In either case, the difference in potential between the two elements is increased; and it is the difference in potential, not the actual voltage, that controls the amount of conduction of the tube. During the negative portions of the signal, the potential on the cathode approaches that of the grid; thus, the tube is allowed to conduct, the amount depending upon the actual voltage difference between the two elements.

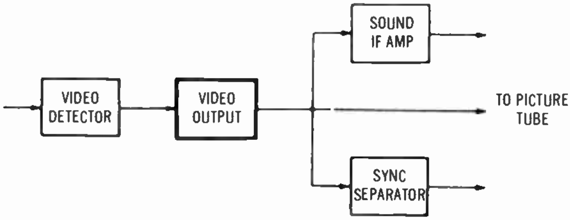
In modern television receivers, the signal may be applied to either the grid or the cathode; either polarity is easily obtained. Recall that each time a signal is amplified by a stage, the polarity of the signal is shifted 180° or reversed. Either a positive- or a negative-going signal can be obtained from the video-detector stage, depending upon the element from which the output is taken. Thus, if the signal has negative-going sync at the detector output and is amplified by a single video-detector stage, positive-going sync pulses will be applied to the picture tube. This is the correct polarity for application to the cathode of the picture tube.

However, if two stages of video amplification are employed, the signal will again be shifted 180°, making the sync pulse polarity negative, the correct polarity for applying to the grid of the picture tube. If a positive-going sync signal is obtained from the video detector, the situation is reversed. With a single video-amplifier stage, the signal is correct for applying to the grid of the picture tube; with two stages of video amplification, the proper signal for application to the cathode of the picture tube is obtained.

SOUND SECTION

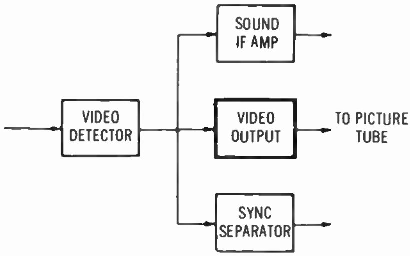
Recall that at the output of the video detector, a 4.5-MHz signal that was frequency modulated with the audio (sound) signal was produced. Sometimes, the sound signal is removed directly following the video detector, and sometimes it is further amplified by the video amplifier before removal. Four methods of sound and sync signal takeoff are shown in Fig. 3-10.

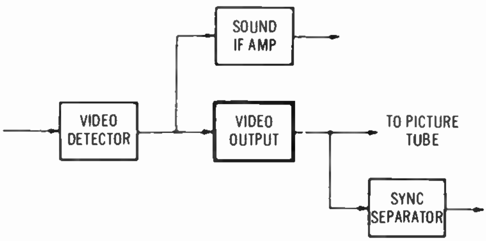
As indicated by the dashed-line box in Fig. 3-3, the sound IF amplifier may or may not be included in the circuit. From this point on, the sound section is very similar to that of an FM radio. The signal is detected by the audio detector, and the audio signal, which corresponds to the original sounds at the transmitter, appears. This signal is amplified by the audio amplifier and audio-output stages, and it is applied to the speaker where the electrical signal is converted to audible sound. Notice, in Fig. 3-3, the audio amplifier is sometimes omitted. When this stage is omitted, audio amplification is provided by the audio detector in addition to the detector action.



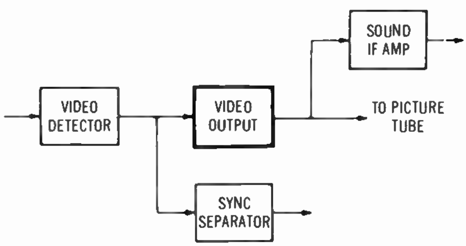
(A) Both following video output.

(B) Both preceding video output.





(C) Sound take-off preceding and sync take-off following video output.



(D) Sound take-off following and sync take-off preceding video output.

Fig. 3-10. Four methods of sync and sound takeoffs.

The sound system just described is called the *intercarrier system*. In this system the sound IF is always 4.5 MHz—the difference between the sound and video carriers. This system is employed in all present-day television receivers. In early receivers, the sound IF signal was removed at the mixer output or at some point in the video IF (usually in the 20-MHz region). In systems employing this type of sound circuits, two or more sound IF amplifier stages are used. Otherwise, the frequency of the IF is the only difference between the dual-channel and intercarrier systems.

AGC CIRCUIT

Just as an automatic-volume-control (AVC) circuit is employed in radios to compensate for changes in the strength of the received signal, some means must be included in TV receivers to compensate for changes in signal strength. In Fig. 3-3, a portion of the signal from the video output is coupled to the automatic-gain-control (AGC) keying. This stage samples the amplitude of the signal and produces a bias voltage for the RF and video IF amplifiers. This bias voltage controls the gain of these stages so that the output signal is fairly constant, even though the input signal varies in strength.

In the keyed AGC system, the amplitude of the video signal is checked only during the period of the horizontal sync pulse. Unlike the video signal, the horizontal sync pulse is always transmitted at a constant level. Therefore keying the AGC voltage to the horizontal sync pulse provides a constant checkpoint. The plan of a keyed AGC system is shown in Fig. 3-11.

In other systems, no keying pulse is used. In this type of circuit, the entire video signal is used as the reference. The circuit is then called the *AGC amplifier*. Sometimes, a combination of resistors and capacitors provides the AGC voltage.

An AGC clamper stage is also shown in dashed lines in Fig. 3-3, indicating that it may not be used in all receivers. This stage removes the AGC voltage from the RF amplifier, allowing it to operate at a full gain until the signal reaches a predetermined level. When this level is reached, the circuit cuts out and allows

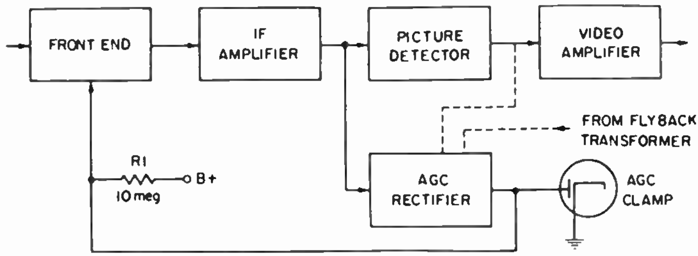


Fig. 3-11. Plan of a keyed AGC system.

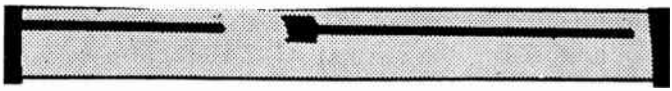
the normal AGC voltage to be applied to the RF amplifier. An AGC clamp is also shown in Fig. 3-11.

SYNC CIRCUITS

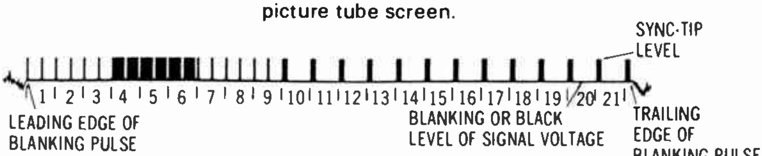
Up to this point, we have said nothing about deflection. We now have the video (picture) signal displayed on the screen and sound emerging from the speaker. In addition, a means has been provided for varying the gain of the receiver so that we have a nearly constant amplitude signal at the picture tube. Now, some means must be provided to deflect this beam back and forth and up and down on the screen exactly in step with the beam in the camera tube at the transmitter.

A portion of the video signal at the video-output stage is coupled to the sync separator. Here the horizontal and vertical sync pulses are separated from the video signal. From the sync separator, the horizontal sync pulses are coupled to the horizontal deflection circuit and the vertical sync pulses are coupled to the vertical deflection circuit. These pulses serve to start each line or field exactly in step with the beam at the transmitter. A noise-canceller stage is often included to prevent any noise pulses in the signal from being coupled to the deflection circuit and causing improper triggering of these circuits. Fig. 3-12 shows what is meant by separated, or "stripped," sync pulses.

A sync-phase inverter may also be included in some receivers. When used, this stage reverses the polarity of the signal so that it will be the proper phase to trigger the deflection circuits. Figure



(A) The appearance of the vertical sync pulse or "hammerhead" on the picture tube screen.



(B) Separated or stripped sync pulse.

(C) The build-up of the hammerhead from sync pulse.

(D) The pulses that comprise the hammerhead.

Fig. 3-12. Stripped sync pulses.

3-13 is a block diagram of a horizontal AFC and deflection system.

DEFLECTION CIRCUITS

The vertical sync pulses are coupled to the vertical oscillator, which generates a signal at a 60-cycle vertical rate. The sync pulses trigger the vertical oscillator so that each cycle will start exactly in step with the transmitted signal The output of the vertical oscillator is coupled to the vertical output stage, where it

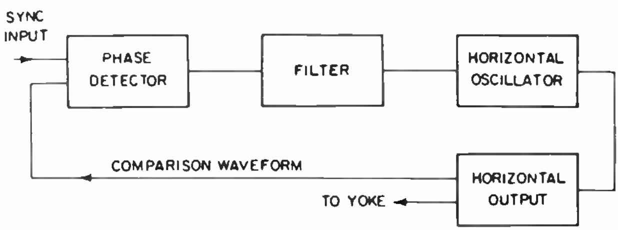


Fig. 3-13. Block diagram of a horizontal AFC and deflection system.

is boosted in amplitude to the proper level to provide vertical deflection of the electron beam.

The horizontal sync pulses are not coupled directly to the horizontal oscillator. Instead, they are first sent to the horizontal automatic-frequency-control (AFC) stage. The AFC then provides a correction voltage for the horizontal oscillator to keep it exactly in step with the horizontal scanning rate at the transmitter. The primary purpose of the AFC stage is to provide greater immunity to noise pulses that might enter with the horizontal sync pulses.

Like the vertical circuit, the horizontal oscillator generates a signal that is amplified by the horizontal output stage. The amplified signal is coupled to the horizontal deflection coils of the picture tube, where it traces the individual horizontal lines across the screen.

The damper is shown connected to the horizontal output stage in Fig. 3-3. During the horizontal retrace period, when the beam is returning from the right to the left of the screen, undesired oscillations would be set up in the horizontal output transformer unless something is done to suppress them. Figure 3-14 shows the appearance of ringing bars. The damper squelches, or clamps out, these oscillations. It also permits the deflection-coil current to decay at a uniform rate so that the left side of the screen will be linear, not distorted.

Note that it was stated that both the vertical and horizontal oscillators generated a signal. The sync pulse is not necessary for the stages to operate. The only purpose of the sync pulses is to keep the circuits operating exactly in step with the ones at the transmitter.

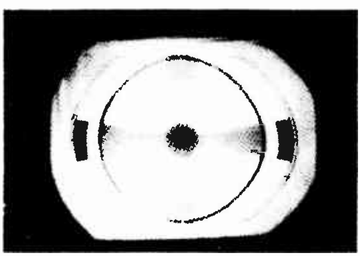


Fig. 3-14. Ringing bars at the left side of the raster.

POWER SUPPLIES

Two separate power supplies plus an additional voltage source derived from the damper circuit are used in all television receivers.

Low-Voltage Supply

The low-voltage power supply provides the voltage necessary for operation of practically every tube in the TV receiver. This circuit is much like the power supply of a radio or amplifier. It takes the alternating current from the line, rectifies it, and supplies the dc B+ voltages necessary to operate the tubes in the TV receiver. Of course, since there are many more tubes in a TV receiver, the TV power supply must be capable of supplying a much higher current than a radio. In addition, the voltage is usually stepped up to a higher value in a TV receiver. Typical B+ voltages in TV receivers range from 125 to 300 volts.

Because all circuits do not require the same operating voltages, a voltage divider is usually connected at the output of the power supply. The different circuits are then connected to the points that supply the proper operating voltages. In addition to the B+ voltages, the low-voltage supply also furnishes the filament voltage necessary to heat the tubes to the proper operating point and, in some receivers, the negative bias voltages. A variation of this supply is now used for "solid state" TV receivers.

High-Voltage Supply

In addition to the B+ voltages, a much higher voltage (15,000 to 23,000 volts) is needed for proper operation of the picture tube. This voltage is obtained from the horizontal deflection circuits. The pulse from the horizontal output stage is stepped up by the horizontal output and high-voltage transformer to a very high value. Then this pulse is rectified by the high-voltage rectifier to provide the high dc voltage. Since very little current is necessary, this high voltage can be obtained from the horizontal output stage without placing too much strain on the stage. Nevertheless, the horizontal output stage is the highest-powered stage in the receiver.

Boost Voltage

Another voltage, called the *boost voltage*, is obtained from the damper stage. The normal damper action of suppressing the pulse in the horizontal output stage results in a voltage higher than the normal B+ developed in the circuit. This voltage is filtered and put to work in the receiver. In modern TV receivers, the boost voltage is employed as the B+ for the horizontal output tube. In addition, it may also be applied to the vertical output, horizontal oscillator, picture tube, and other stages of the receiver as needed.

PICTURE TUBE

Now that all the signals have been properly amplified and processed, let us examine the picture tube (Fig. 3-15). The basic operation of the picture tube is the same as for any other tube; that is, a filament (heater) heats the cathode, which emits electrons. These electrons are attracted by the accelerating anodes,

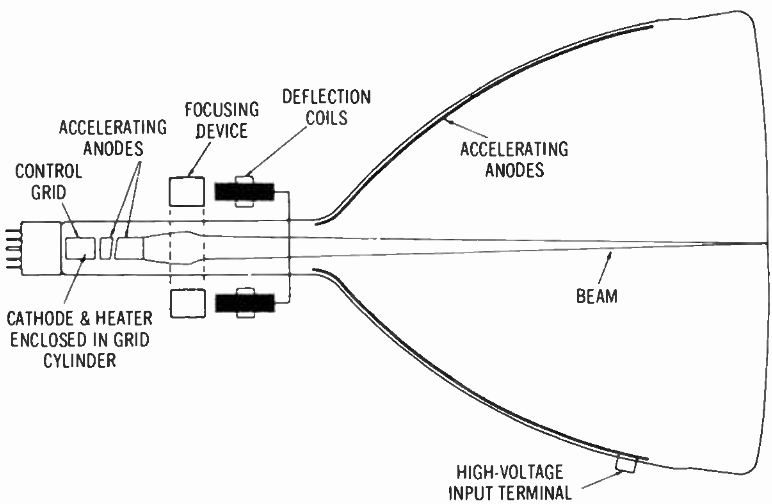


Fig. 3-15. Magnetically controlled cathode-ray tube.

which have B+ voltage on them, and by the second anode, which has the high voltage connected to it. However, instead of striking these elements, the electrons travel to the face of the tube and strike the screen. The screen is coated with a fluorescent material that glows when struck by the electrons. This is the lighted portion you see on the screen.

The magnetic field from the focusing devices concentrates all the electrons in the beam so they strike the screen at one point. A magnetic focusing device, connected around the neck of the tube, is shown in Fig. 3-15. In many receivers, however, this function is accomplished by another element within the picture tube.

The horizontal and vertical deflection currents are applied to the deflection coils shown on the neck of the tube. These currents, flowing through the coils, cause a magnetic field to be produced, which acts upon the electron beam in the tube. These vertical deflection currents cause the beam to be deflected upward or downward from the center of the screen. The deflection is at the 60-hertz rate. At the same time, the horizontal deflection currents cause the beam to be deflected to the left and right at the 15,750-hertz rate. Thus, the beam is caused to scan across the face of the tube from left to right and from top to bottom, in step with the beam at the transmitter.

The video signal is applied to the grid or cathode, as explained previously. The element that has no signal applied to it is connected to a constant-voltage source. As the video signal varies, more or fewer electrons are allowed to pass. When more electrons pass, the beam produces a brighter spot on the particular spot being scanned at that instant on the screen. When fewer electrons pass, fewer electrons strike the screen; hence, a darker spot will be produced at that instant.

Recall that the vertical and horizontal oscillators generate a deflection signal; only the timing of these signals is controlled by the sync pulses. When no video signal is applied to the grid or cathode of the picture tube, the deflection currents will still flow in the deflection coils and the beam will still be deflected back and forth and up and down on the screen. The only difference is that the electrons striking the screen will not form alternate lighter and darker areas. Instead, a constant brightness pattern will be produced. This series of horizontal lines across the tube screen is called the *raster* and is present whether a picture is being produced or not.

This completes the "block diagram" discussion of the TV receiver. In later chapters, the circuits employed in the individual "blocks" will be examined, but in this chapter we attempted to give the reader an understanding of the overall operation of the receiver and how the individual blocks fit together to produce the desired results. Figure 3-16 gives an overview of the basic TV troubleshooting procedures.

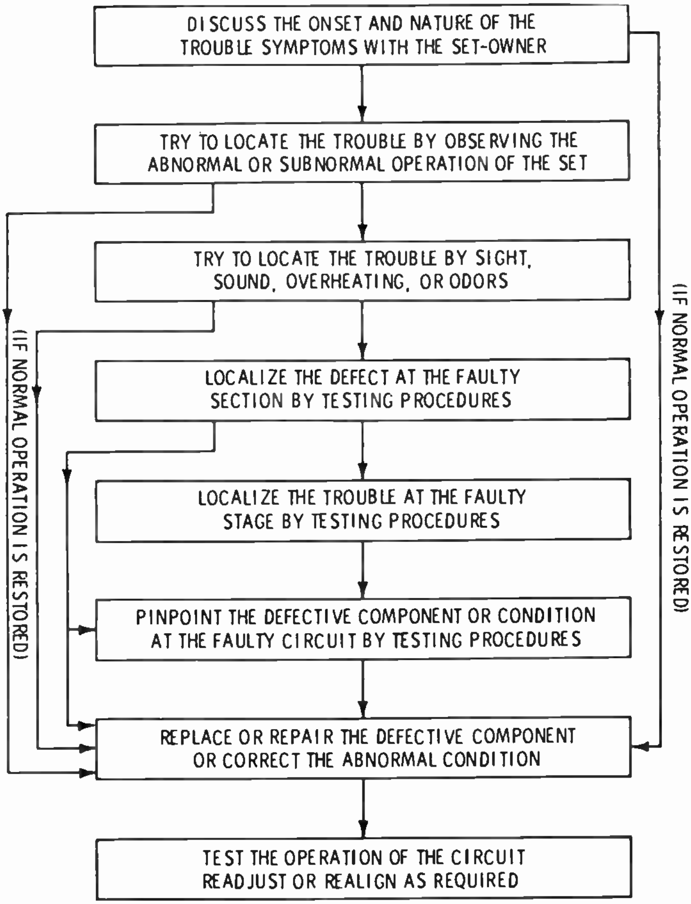


Fig. 3-16. Overview of basic troubleshooting procedures.

SUMMARY

The function of the television receiver is to pick up the signal from the television station, amplify it, and produce a visible picture and audible sound corresponding to the original scene.

In the television receiver, the signal is received, amplified, and separated into its individual components. Deflection of the beam in the picture tube is accomplished electromagnetically with coils that are external to the tube. The deflection circuits in the receiver are kept in step with the deflection circuits in the camera by the sync pulses transmitted as part of the composite video signal.

The signals from the desired VHF or UHF television station arrive at the television receiver antenna. These signals travel down the antenna line to the RF amplifier, where only the desired signal is selected and all others are rejected. The desired signal is amplified by the RF amplifier and coupled to the mixer. In the mixer stage the amplified signal from the RF amplifier and the signal from the local oscillator are beat together to produce a lower, or intermediate, frequency.

The output of the mixer is coupled to the input of the first video IF amplifier. At this point the signal still contains both video and sound, as well as the sync signals. The IF amplifiers are tuned to pass a band of frequencies approximately 4 MHz wide.

REVIEW QUESTIONS

1. What is the purpose of the television receiver?
2. Explain the basic operation of the television receiver.
3. What is the typical video IF frequency?
4. What is the typical sound IF frequency?
5. What separates the sound present in the video IF amplifier?
6. What is meant by *intercarrier?*
7. What is the purpose of the low-voltage and high-voltage supply?
8. What is the source for high-voltage?

CHAPTER 4

Television Antennas and Transmission Lines

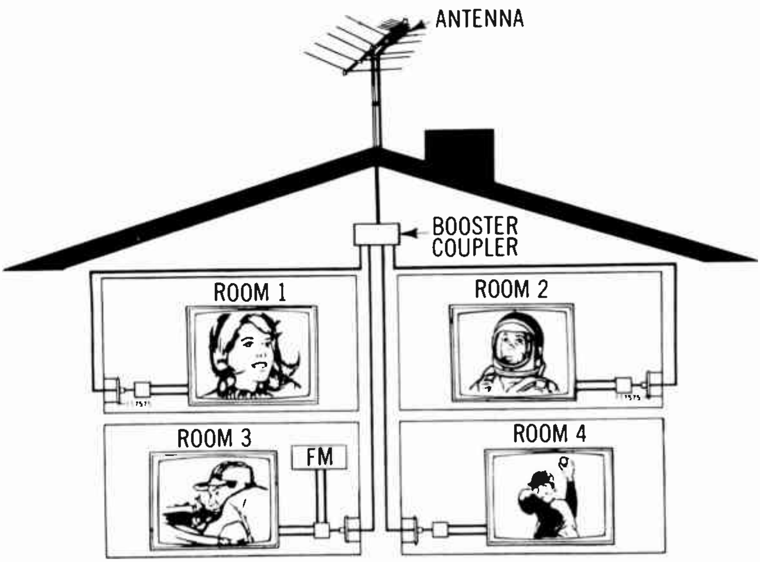
All television receivers, irrespective of their location with reference to the transmitting station, require some type of antenna in order to function properly. Television antennas may be classified according to their location as:

1. Built-in antennas
2. Attic or outdoor antennas
3. Master TV antennas, MATV
4. Community TV antenna, or CATV

Built-in antennas, as the name implies, are those which are a component part of the television receiver. A built-in telescopic antenna is included in many receivers, particularly portables. However, in most locations, it will be found that one of the other types of antennas listed will provide better reception. Built-in antennas are usually connected to antenna terminal screws at the rear of the cabinet. If another antenna is used, the built-in antenna must be disconnected from the terminal screws before the new antenna leads are connected in its place. The most common type of indoor antenna is the familiar "rabbit ears." Although it has several different forms, in general, it consists of two arms arranged in a V shape. Both the length of the arms and the angle of the V are usually adjustable.

Attic antennas are designed for mounting in the attics of small dwellings, from which point they are connected to the receiver in the conventional manner. In general, the same types of antennas are used for an attic installation as are used for outdoor installations. Outdoor antennas (Fig. 4-1) are designed for installation on roofs of dwellings or on towers. They are usually supported by a suitable piece of galvanized iron or aluminum piping or mast, the dimensions of which depend upon the height of the antenna array.

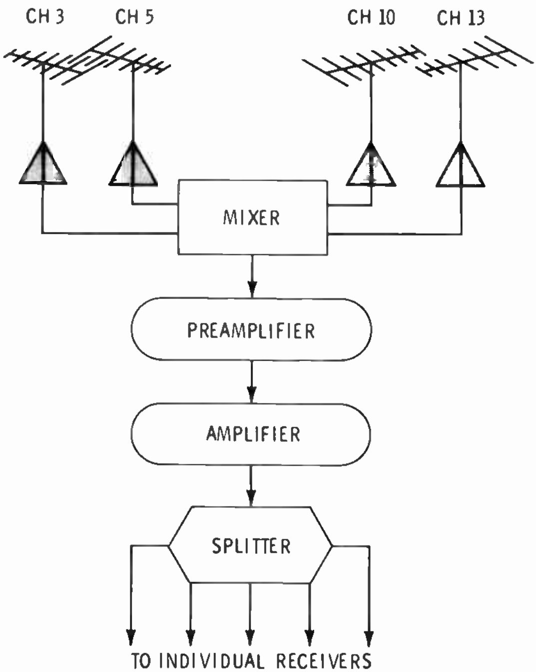
Master, community, or cable TV installations are distribution systems rather than a specialized type of antenna. We find that



Courtesy JFD

Fig. 4-1. TV-antenna arrangement.

quite elaborate antenna arrays are generally used in community systems. This requirement is based on the fact that a community system ordinarily was installed in a "far-fringe" area where the signal level (field strength) is comparatively weak. CATV is now common in cities, suburban, and rural areas. It has increased channel capacity, improved reception of extreme fringe signals, and "imported" signals from "superstations." CATV is considered one of the "new growth" industries in the United States (See Fig. 4-2).



Courtesy JFD

Fig. 4-2. Typical MATV system for an apartment building.

The quality of the picture that is reproduced on the screen of a television receiver is dependent upon many factors, some of which are beyond the control of the receiver. The information presented here is intended mainly to assist the service technician in determining the factor the antenna plays in the normal reception of television.

The strength of the transmitted picture signal that reaches the receiver is a vitally important factor in determining the quality of the picture that is reproduced on the screen. A very weak signal will produce an unsatisfactory picture. In locations where the signal is exceedingly weak, the picture will display a milky appearance, which is usually accompanied by a speckled effect called *snow*.

TELEVISION TRANSMISSION

The very-high- and ultra-high-frequency waves used for the transmission of television picture signals act quite similar to rays of light. They do not bend around corners and are reflected by obstacles in their path. Therefore, television waves do not follow the curvature of the earth, and reliable reception should be anticipated only in the region determined by the line of sight to the horizon in all directions from the antenna tower of the transmitting station.

The *line-of-sight distance*, as denoted in television literature, is the maximum distance that high-frequency radio waves will reach without being impeded by the curvature of the earth. It is shown in Fig. 4-3 and is governed by the following relationship:

$$d = 1.41(ht + hr)$$

where d is the distance between antennas (in miles), ht is the

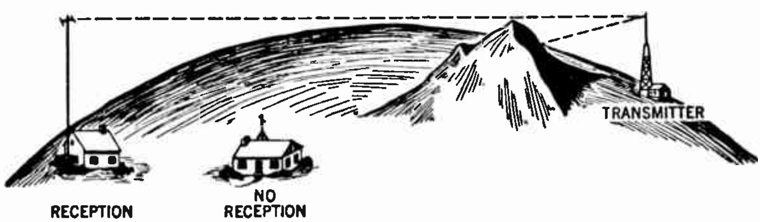


Fig. 4-3. Line-of-sight transmission.

transmitting antenna height (in feet), and *hr* is the receiving antenna height (in feet).

Since signal strength decreases rapidly when the line-of-sight distance is exceeded, it is not possible to reliably predict conditions that might prevail at greater distances away from the transmitter. The technician who installs the television receiver must always carefully check to determine if signals at a particular location are of satisfactory strength.

The characteristic of high-frequency television signals that permits them to be reflected from the walls of nearby buildings or other objects, under certain conditions, may create *multiple transmission paths.* Figure 4-4 shows a reflected signal arriving at the receiving antenna a short interval of time later than the signal

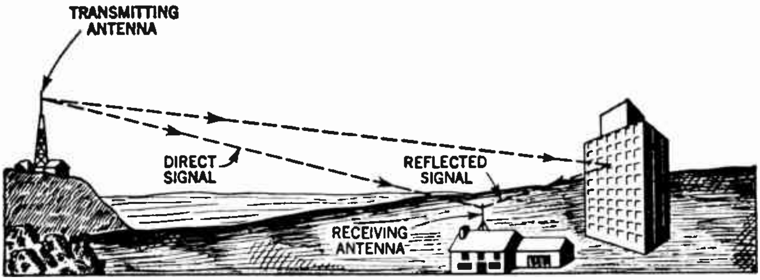


Fig. 4-4. Direct and reflected signal paths.

traveling in a direct path from the transmitter. The effect produced on the picture of the television receiver consists of a multiple image (Fig. 4-5). These multiple images, known as *echoes*, or *ghosts*, can usually be prevented by careful installation and orientation of the antenna.

Do not mistakenly believe that the reason for the line-of-sight transmission is due to the television signal. The only reason for the limited distance is the frequencies used for television transmission. If it were possible to transmit television signals at the low frequencies used by broadcast radio, long distances could also be obtained in television transmission. Of course, this is impossible. As pointed out previously, the entire broadcast band

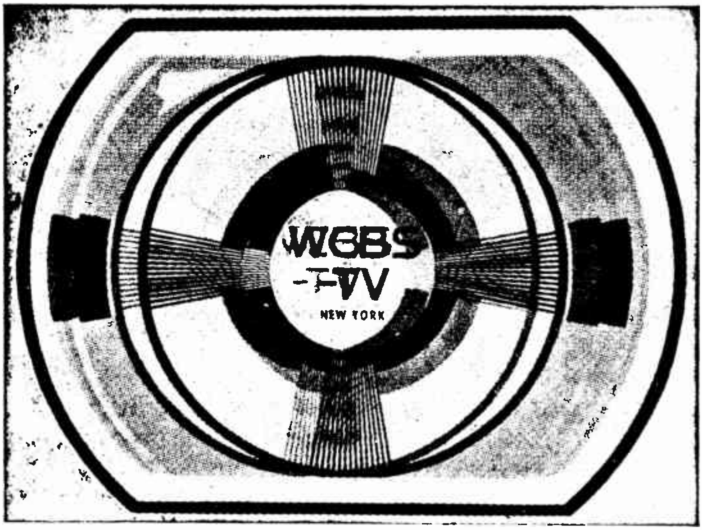


Fig. 4-5. Multiple images, known as ghosts, or echoes.

comprises a bandwidth only slightly over one-sixth that of a single television channel.

Actually, television waves do a certain amount of bending as they travel along the earth. Very-high-frequency (VHF) stations can be received beyond the distance computed to be the horizon. However, at ultra-high frequencies (UHF), the line-of-sight limitations are more pronounced. Also, at UHF frequencies, reflections and ghosts become more of a problem. In fact, a good signal may be received at one point, and just a few feet away no signal will be received because some intervening object has shielded the area. Hence, at UHF frequencies, proper antenna selection and orientation is most important.

The field strength of a signal is expressed in microvolts per meter ($\mu V/m$). The field strength is stated as the voltage developed in a wire 1 meter long at a chosen position in space. If a wire 5 meters long has a voltage of 100 μV induced in it by a certain signal, the field strength of the signal is 20 $\mu V/m$. Thus, the microvolts-per-meter unit is a measurement of the actual field strength of an electromagnetic wave. On the other hand, a field-strength meter connected to an arbitrary antenna merely measures the microvolts of signal picked up by the antenna. Field strength is measured with a field-strength meter such as the one shown in Fig. 4-6.

Fig. 4-6. Precision-type, field-strength meter.

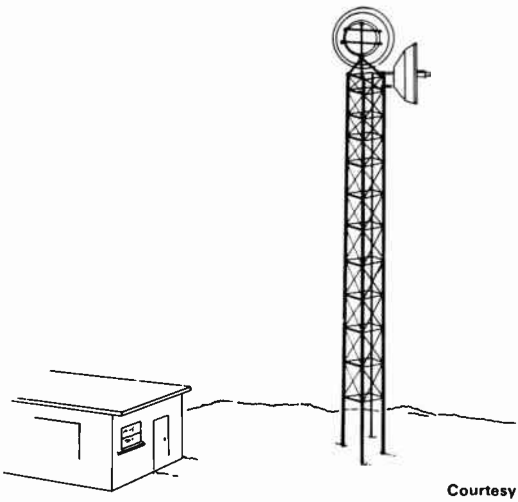
TELEVISION DISTRIBUTION SYSTEMS

Since television transmission is limited to line of sight, an efficient relay system is necessary to link a country into television networks. Three principal systems are presently used for this purpose:

1. The underground coaxial cable system
2. The microwave relay system
3. The satellite microwave system

The underground coaxial cable system consists principally of a special type of telephone cable that is capable of passing a wide range of frequencies without the usual prohibitive losses and distortion. For a successful television transmission over longer distances, however, in addition to the coaxial cable, special repeater amplifiers (relay stations) must be spaced at equal distances from one another.

In contrast, the microwave relay system of increasing the range of television coverage consists of a chain of towers located at various distances, which depend on the intervening terrain. Each tower contains a receiver to pick up the signal from the preceding tower and a transmitter to rebroadcast it to the following tower. (See Fig. 4-7.)



Courtesy Christine Jusiak

Fig. 4-7. Typical microwave-relay tower.

This same principle is employed in transcontinental television broadcasts. In systems such as SATCOM, the signal from the transmitting station is beamed toward the satellite as it orbits the earth. This is still line-of-sight transmission; however, because of the great height of the receiving antenna (on the satellite) the transmitting range is greatly increased.

At the satellite, the signal received from the ground is amplified and sent to the transmitting antenna where it is retransmitted to a receiving antenna on the earth. The signals received are very weak—far too weak for reception by normal receiving equipment. Giant specially constructed antennas are necessary for transmission and reception. These "dishes" are now common sights at television stations and cable TV headends. A new industry, referred to as TVRO (television receive only), has developed. The use of satellite antenna by private groups is now economically possible and shows great promise for growth.

The satellite orbits in a geosynchronous pattern above the earth at a height of 22,300 miles above the equator (Fig. 4-8). The satellite appears to be motionless, but in reality it orbits at the same speed as the earth rotates on its axis. Its position in respect to a given point is constantly changing, however. As the earth tilts on its axis, the position of the transmitting and receiving antennas must be able to rotate manually or automatically to keep in step with the satellite's position. Transmissions from a given satellite are possible only when the satellite is in the line-of-sight range from both stations at the same time.

The satellite signals are not in the same frequency band as that transmitted by a television transmitter. The frequency used by the ground transmitter (satellite receiving frequency) is different from the satellite's transmitting frequency (ground-station receiving frequency). These signals fall in the microwave category, or super-high frequencies (SHF).

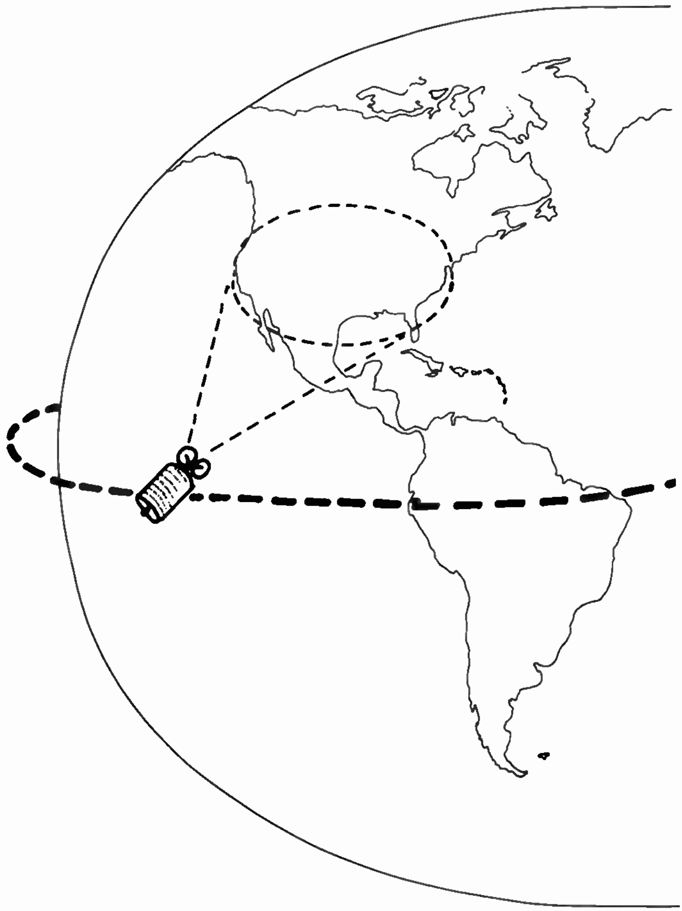
In addition, since different countries have different transmission standards, the signal received from the satellite must be made to conform to the standards in the country where it is being received. Various foreign countries transmit TV signals with more loss lines than the United States. In all cases, the signal received from the satellite must be processed accordingly.

ANTENNA SYSTEM

For the best reception, each antenna should be selected with reference to distance and other factors covering the particular installation. Fundamentally, the three elements present in any television antenna installation are:

1. Antenna
2. Transmission line
3. Receiver

The function of the antenna is to pick up the signal transmitted from the station and to transmit the signal to the receiver through the connecting transmission line.



Courtesy Christine Jusiak

Fig. 4-8. Satellite in a geosynchronous orbit.

Transmission Lines

Two general types of transmission lines act as a transmission link between the antenna and the receiver:

1. The two-wire, parallel-conductor type
2. The coaxial cable type

There are several construction variations in the basic types of transmission lines. In the first type (Fig. 4-9), two parallel conductors are supported a fixed distance apart by means of insulators called *spacers*. The air forms the dielectric insulation between the conductors.

Fig. 4-9. Flat, parallel, television transmission line.

Formerly the most popular two-wire transmission line was parallel-conductor line with standard conductors imbedded in a low-loss insulating material (polyethylene). It had the advantage of low weight, compactness, and neat appearance, together with close and uniform spacing. However, losses were higher in the solid dielectric than in air, and dirt or moisture on the end line tended to change the characteristic impedance. Two-wire transmission lines of this type are still available in impedances of 300 ohms.

Another type of parallel-conductor twin lead is pictured in Fig. 4-10. This type of twin lead is very similar to that of Fig. 4-9, except that the plastic insulating material is arranged in a tubular fashion and the inside is filled with a low-loss foam material. Tubular lead exhibits less loss than ordinary flat twin lead.

The most common type of coaxial transmission line consists of either a solid- or stranded-wire inner conductor surrounded by polyethylene dielectric. Aluminum foil and stranding is wrapped

Fig. 4-10. Tubular television transmission line.

or copper braid is woven over the dielectric to form the outer conductor, and a waterproof vinyl covering is placed on top of the braid. This cable is made in a number of different diameters. It is moderately flexible and so is easy to install. Coaxial cable is available in characteristic impedances of 75 ohms. (See Fig. 4-11.)

Fig. 4-11. Coax television transmission cable.

Receivers

Most television receivers are manufactured with an input impedance of 300 ohms. Thus, if a coaxial transmission line is used, some means must be provided to match the lower impedance of the transmission line of 75 ohms to the 300-ohm impedance of the receiver. A special device, called an *impedance-matching transformer*, or *balun*, is employed between the transmission line and the receiver antenna terminals.

Another example of an impedance-matching arrangement is found in the connection of two television receivers to the same 75-ohm line. In this case, a splitter is generally used, both to provide correct impedance matching and to isolate the two receivers from each other. In other words, unless a suitable degree of isolation is provided, the radiation from one receiver could produce interference in the picture displayed by the other receiver.

PRACTICAL ANTENNA CALCULATIONS

For proper antenna design, it is necessary to know the length of the electromagnetic waves involved. In order to determine wavelengths, it is necessary to know the speed and frequency at which electromagnetic waves travel through free space. In speaking of the frequency of electromagnetic waves, we mean merely the number of waves passing a given point in 1 second, expressed in megahertz [millions of hertz (MHz)].

Since electromagnetic waves of all lengths move at the same speed, the number of waves passing a given point in 1 second will be small if the waves are long and large if the waves are short. Thus, 500,000 waves that are 600 meters in length will pass a given point in 1 second at a frequency of 500,000 hertz. Similarly, if the waves were only 1 meter in length, 300,000,000 would pass each second at a frequency of 300 MHz. For all practical purposes, the actual velocity of electromagnetic waves is 300,000,000 meters or 984,300,000 ft/sec.

Now, if the speed at which the waves travel is equal to $3 \times 10'$ m/sec, the distance it will cover in one cycle will be equal to this velocity divided by the frequency in hertz per second, or:

$$\lambda = \frac{3 \times 10'}{f}$$

where λ (the Greek letter lambda) is the wavelength (in meters), and f is the frequency (in hertz per second).

Since feet and inches are the measurements most commonly used in the United States, the preceding formula can be converted to:

$$\lambda = \frac{984}{f}$$

where λ is the wavelength (in feet), and f is the frequency (in megahertz), and

$$\lambda = \frac{11{,}808}{f}$$

where λ is the wavelength (in inches), and f is the frequency (in megahertz). The values obtained in the foregoing equations are only approximate; however, they are accurate enough for all practical applications.

The length of a dipole antenna is one-half wavelength. Each dipole antenna consists of two elements, each a quarter-wavelength long, as shown in Fig. 4-12. Thus,

$$\frac{\lambda}{4} = \frac{2{,}952}{f}$$

where $\lambda/4$ is the length of a quarter-wavelength (in inches), and f is the frequency (in megahertz).

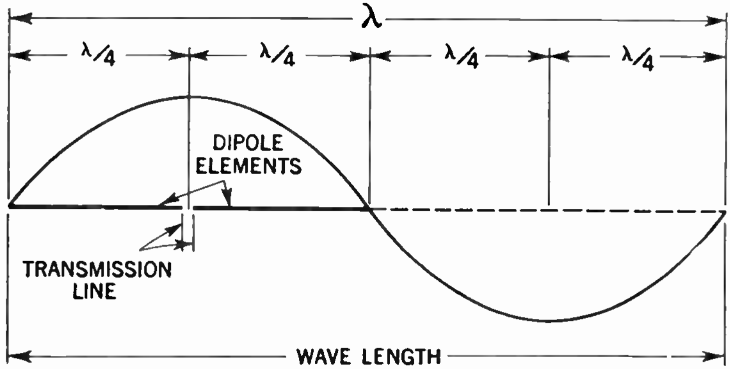


Fig. 4-12. Relationship between wavelength of received signal and length of dipole element.

Due to the electrical characteristics of the antenna material, it has been found that the antenna elements should be somewhat shorter (about 5 percent) than that given in the preceding formula. The formula then becomes

$$\frac{\lambda}{4} = \frac{2{,}952 \times 0.95}{f}$$

$$= \frac{2{,}804 \text{ in.}}{f}$$

From this last formula it is comparatively simple to obtain the antenna dimensions for each frequency by substituting the proper value in megahertz.

Dipole antennas that are to be used in outside installations usually consist of two quarter-wavelength sections of 3/8-in. tubing or rod. The following example shows the general procedure when it is desired to calculate the exact length in inches of each element (quarter-wavelength) of a simple half-wave–dipole antenna.

Example—It is desired to determine the length of a quarter-wave–dipole rod suitable for use on channel 4, where the frequency has an average value of 69 MHz. What is the dipole-rod length?

Solution—By employing the preceding formula, substitution of values gives the quarter-wavelength in inches:

$$\frac{\lambda}{4} = \frac{2{,}804}{69}$$

$$= 40 \quad \text{(approx.)}$$

Using a similar procedure, it is comparatively simple matter to calculate antenna dimensions for any desired channel or frequency.

DIPOLE ANTENNAS

The fundamental form of a dipole antenna consists of two single wires, rods, or tubes, with combined lengths approximately equal to half the transmitting wavelength. It is from this basic unit that various forms of television antennas are constructed. It is also variously known as a *half-wave dipole*, *half-wave doublet*, or *hertz antenna*.

The dipole elements are made of steel-, aluminum-, or copper-alloy tubing and are surface-treated against corrosion. The receiver dipole is equipped with terminals at its adjacent ends for transmission-line connections and must be properly insulated from the mast or supporting structure. The element is then connected to the receiver via the transmission line (Fig. 4-13).

Actually the simple dipole antenna (Fig. 4-14) is seldom used in modern television systems, although it is the basis for practically all television antennas. For this reason, it has been included in our discussion of antennas.

Folded Dipoles

The necessity for separating, insulating, and mounting the receiver dipole at its center tends to weaken and complicate the antenna assembly. Because of this, a considerable simplification may be obtained by employing an unbroken member bent as shown in Fig. 4-15. A television antenna of this type is known as the *folded-dipole type* and is widely used. The spacing between the folded dipole elements should vary inversely with the fre-

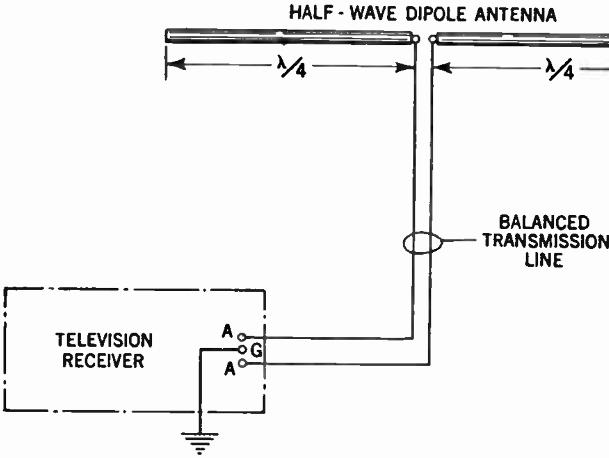


Fig. 4-13. Transmission line connected between half-wave dipole and receiver.

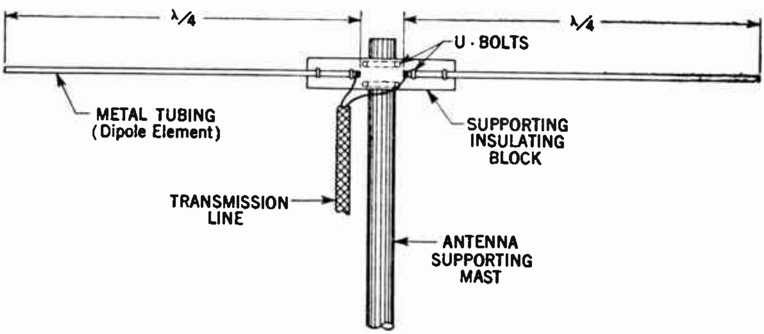


Fig. 4-14. Mounting arrangement and connection of half-wave dipole and transmission line.

quency; that is, the higher the frequency, the smaller the spacing. The element spacing for the center frequency on the low band is usually 2 to 3 in., and 1 to 2 in. for the high band.

One of the first requirements for television reception is that the antenna system should be flatly tuned; that is, it should respond fairly evenly over the waveband involved and also pick up the FM sound transmissions. This compromise is often assisted by

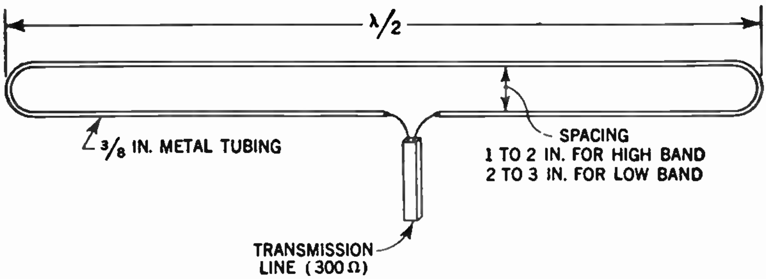


Fig. 4-15. Dimensions of a folded-dipole antenna.

choosing the length of the antenna to resonate at a frequency that is intermediate between sound and video transmission.

The polarization of the signal waves to be received may be either vertical or horizontal. An antenna placed in the horizontal plane radiates horizontally polarized signals, whereas an antenna placed in a vertical plane radiates vertically polarized signals. To obtain maximum energy transfer, the receiving antenna should be polarized in the same manner as the transmitting antenna. In the United States, horizontal polarization is used at the transmitter; hence it should also be employed at the receiver. Horizontal polarization means that the dipole element should be placed in the horizontal plane, that is, parallel with the ground. (See Fig. 4-16.)

In England, vertical polarization is employed; hence the dipole should be placed perpendicular to the ground or standing on end by American standards. Either method will work. The important

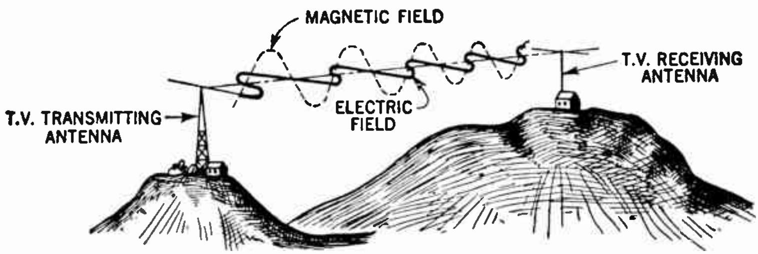


Fig. 4-16. Magnetic and electric fields of horizontally polarized signal waves.

factor is that both transmitting and receiving antennas should be placed the same.

PARASITIC ELEMENTS

A parasitic element, as employed in television antennas, is a dipole slightly too long or too short for exact resonance at the desired frequency. It is mounted at some fraction of a wavelength before or behind the driven element (dipole). Parasitic elements are not cut at the centerpoint and are not connected to the transmission line. The centerpoint of the element is electrically neutral and can be grounded. This is convenient for lightning protection because it permits making the entire antenna structure of conductive tubing, such as aluminum, and grounding the central supporting mast at the base.

Current induced in a parasitic element by the advancing wavefront produces a local field about it that is coupled to the driven element because of the physical closeness. Spacing and tuning of parasitic elements are adjusted so that the currents produced in them by the received signal produce fields that add in correct phase to reinforce the field of the received signal at the driven element. For signals from the opposite direction, the action is exactly reversed; and the signal is substantially canceled in the driven element.

Director and Reflector Elements

A director element is about 4 percent shorter than the driven element for average element spacing and is mounted in front of the driven element on the horizontal support member, which holds all the elements in proper relationship. The spacing between the director and driven elements can vary from about 0.08 to about 0.15 wavelength in practical antennas. Closer spacing will increase the front-to-back ratio but makes the array tune more sharply, which is a disadvantage when many widely separated television channels must be received on a single antenna.

Wider spacing helps broaden the tuning of the array but lowers the front-to-back ratio.

A reflector element is about 5 percent longer than the driven element at usual spacing and is mounted on the supporting bar behind the driven element, as shown in Fig. 4-17. While the spacing between the elements is shown as 0.25 wavelength in Fig. 4-17, it will vary from about 0.10 to 0.25 wavelength in an actual antenna. The effects of changing the spacing are quite similar to those produced by similar changes in the director length.

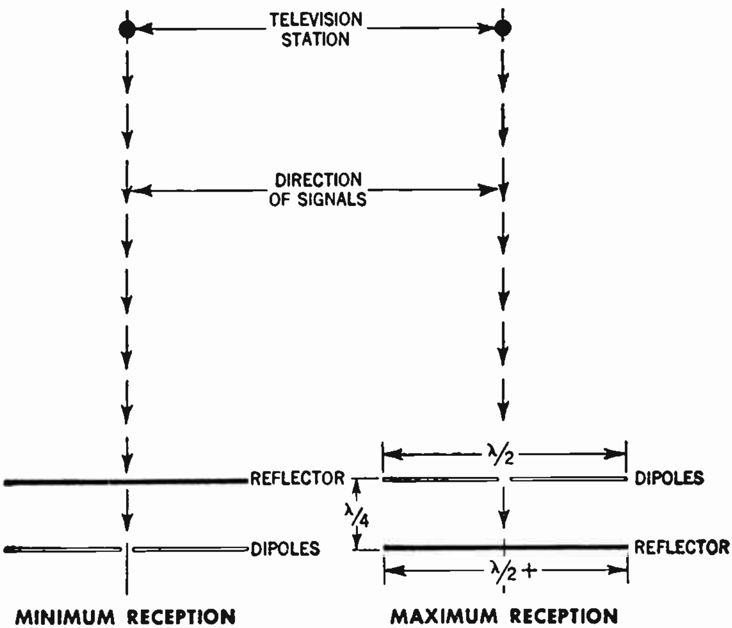


Fig. 4-17. Location and effect of the reflector element on signal reception.

The effect of the reflector is critically dependent upon the spacing between reflector and dipole. When the spacing is a quarter-wavelength, radiation from the reflector will exactly reinforce that from the dipole in a forward direction. This effect is most easily explained when the dipole is considered as a transmitting antenna, as follows:

Radiation from the dipole travels both forward and backward; in the latter direction, it reaches the reflector and induces a current in it. Since the radiation has traveled a quarter-wavelength on its way to the reflector, it will be 90° lagging in phase relation to the dipole where it originated. A current of this phase lag is therefore set up in the reflector, which, in turn, reradiates the signal.

By the time this secondary radiation has returned to the dipole, it is an additional 90° late in phase, making a total phase lag of 180°. However, the oscillations in the dipole will have progressed through a half-cycle during this half-wave time interval and will be 180° ahead of the initial condition when the radiation left on its way to the reflector. In other words, the radiation from the dipole will be a half-cycle ahead of the reference point, while that returning from the reflector will be a half-cycle late, bringing the two to the same point in the period of an oscillation.

Being in identical phase, the radiations from the dipole and reflector reinforce each other in the forward direction. The reverse is true for signals from the backward direction, that is, from the direction of the reflector. Here the two signals cancel. If the current induced into a reflector is as great as that flowing in the dipole, each would produce the same radiated field strength. The forward radiation would therefore be doubled, while that to the rear would be exactly canceled, giving zero backward radiation.

The problem of radiation and absorption (transmission and reception) by an antenna system is strictly reversible in all ordinary conditions. Whether the antenna is regarded as a transmitter or receiver, these directional effects will be exactly similar, provided, of course, that the waves arrive in the plane in which the dipole and reflector are situated.

In practice, the resistance of a reflector will never be zero; and while the current in it can be made equal to that of the radiator if both are connected to a feeder, the current in a parasitic reflector must always be less than that in the dipole that gave rise to it.

Therefore the forward radiation is never exactly doubled, and the backward radiation is never fully cancelled.

ANTENNA DIRECTIVITY PATTERN

The horizontal antenna dipole is inherently directional, being most effective to signals arriving in the broadside direction and least effective to those arriving from a parallel direction. This effect is usually represented in the form of a polar diagram, or *directivity pattern*, in which the radius of the curve from the center of the antenna elements represents the relative response in any given direction.

The function of an antenna pattern is primarily to enable the service technician to evaluate the efficiency of an antenna and assist in the proper orientation on the site of installation. Designing and plotting an antenna pattern is generally performed by antenna manufacturers, but plotting may be accomplished as follows:

A minimum usable value of signal strength is chosen on the basis of what the average television receiver will require for satisfactory reception. Determine all the points in the area surrounding the antenna where exactly this value of field strength is found and plot by bearing from true North (or some other convenient reference direction) and distance in miles (or some other desired linear unit. With a sufficient number of points plotted, a continuous smoothly curving line is drawn joining them all; one may be reasonably certain that all the area enclosed by this curve will provide at least the minimum required signal.

In practical service work, directivity patterns are always plotted in terms of voltage gain because this unit is most convenient to use in connection with the field-strength meter, which is usually a part of the television service technician's equipment. Antenna receiving patterns are usually made by rotating the antenna about its vertical axis and plotting values of voltage gain radially outward from the center of each change of angle.

The complexity of an antenna has a direct bearing on its efficiency as well as its directional effects. Roughly, the voltage developed in the antenna is proportional to the combined lengths of the elements multiplied by the field strength of the signal. This length is measured in units of half-wavelengths. A reduction in the voltage realized at the antenna terminals results from the mutual coupling of the elements.

A comparison of the theoretical efficiency of various types of antennas are as follows:

Elements	Types	Voltage Gain
1	Simple dipole	1.0
2	Dipole and reflector	1.6
4	2-Bays	2.3
6	3-Bays	2.8
8	4-Bays	3.2

The reference value of 1.0 shown for a simple dipole is the universal standard of comparison. This reference dipole is cut to a half-wavelength for each channel measured.

As previously noted, the voltage developed by a half-wavelength antenna is proportional to the length of the antenna. Therefore, for purposes of additional elements, multiples of half-wavelengths are used.

The receiving antenna height, particularly in fringe areas, is an important factor in its efficiency, or *signal capture*, as shown in Fig. 4-18. The possibility of interference is shown by the irregularity of the curve representing signals in the high-channel group. This particular effect, however, is not predictable and can be determined only by proper orientation.

The field pattern (directional-response pattern) of a typical dipole antenna is shown in Fig. 4-19. For sake of simplicity, the directions are given as North, South, East, and West in both the schematic antenna and the polar diagram. From this diagram, it will readily be observed that the maximum signal strength is obtained when the antenna is broadside to the transmitter. Similarly, the signal capture is not critical through the angle of rotation over which the antenna can be moved before losing more than half of its effectiveness. In Fig. 4-19 the concentric circles represent the voltage gain, where unity, or 1.0, is taken as reference for all comparisons.

If a reflector is added to the dipole, the gain and directional characteristics of the antenna are changed and the polar diagram will take the form indicated in Fig. 4-20. It will be observed from the diagram that the angle is still sufficiently wide, generally at least 80°.

So far, we have considered an antenna operating only on the channel for which it was designed. It is the usual practice to use dimensions that give half-wave dipoles in the middle of the low channels. When used on the high channels, a third harmonic will result, giving the antenna pattern shown in Fig. 4-21.

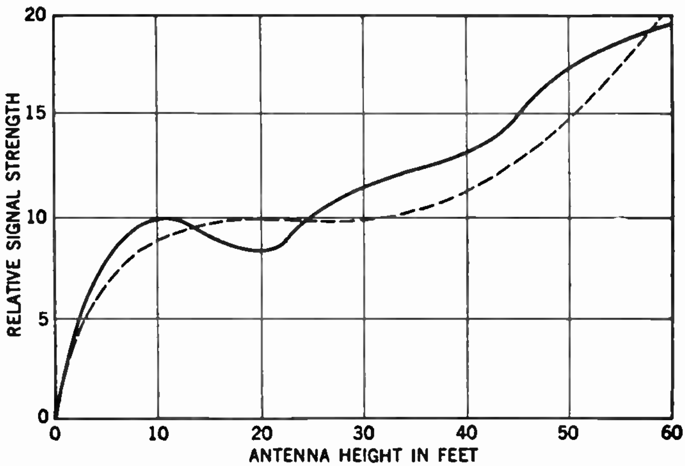
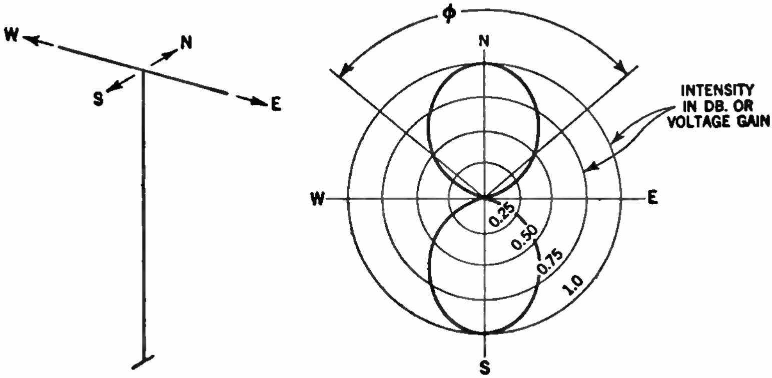


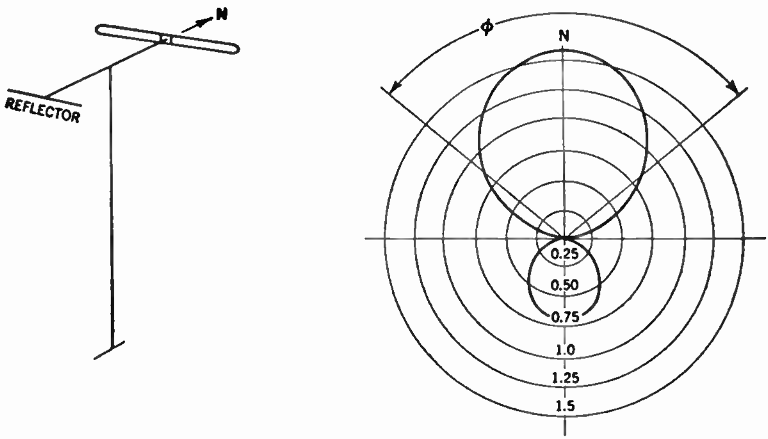
Fig. 4-18. Relative signal strength at antenna per height in feet (applies only at considerable distance from transmitter).

A dipole operated in this way will have six lobes and will be symmetrical and oriented as indicated. With reference to the field pattern, these lobes are too narrow and point in different directions from that previously shown. This will make orientation difficult or even impossible if the stations on the high- and low-band channels are in the same direction. It follows that no reliable antenna manufacturer would sell an antenna with these characteristics without showing the relation of the lobes for each frequency.



(A) Antenna. (B) Polar response.

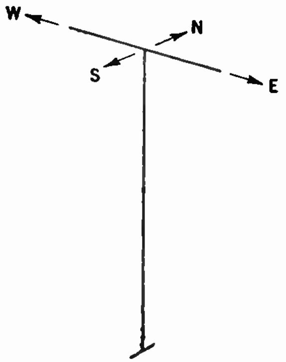
Fig. 4-19. Directional response of a dipole antenna.



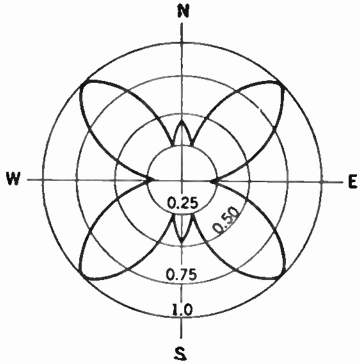
(A) Antenna. (B) Polar response.

Fig. 4-20. Directional-response pattern of a folded-dipole antenna with reflector.

The ratio between maximum and minimum voltage (measured with a voltmeter slid along the transmission line) is called the *voltage standing-wave ratio* (VSWR). It is obtained numerically by dividing the maximum voltage by the minimum voltage; thus



(A) Antenna.



(B) Polar response.

Fig. 4-21. Directional-response pattern at a frequency other than the one the antenna is cut for.

maximum and minimum values of 15 and 5 would mean a SWR of 3.

If the SWR is plotted on a logarithmic scale against percent loss, the curve will take the form shown in Fig. 4-22. Here it will be observed that a SWR of 2 will cause a loss of only 10 percent, while a SWR of 3 will cause a loss of 25 percent.

ANTENNA IMPEDANCE MATCHING

Impedance matching is a very important factor in antenna installations. When the receiver input matches the impedance of the transmission line, the transmitted signal is completely absorbed; as a result, there are no reflections or standing waves on the transmission line and consequently no ghost images. It should be observed that the antenna impedance is important only from the standpoint of power transfer. It is only when the antenna impedance matches that of the transmission line that maximum power transfer takes place. A condition that may easily arise is the mismatch of 300 ohms to 75 ohms; this produces an SWR of 4 and a loss of 37 percent.

A method of matching impedance employs a commercial device called a *balun* (from "balanced-unbalanced"). A balun

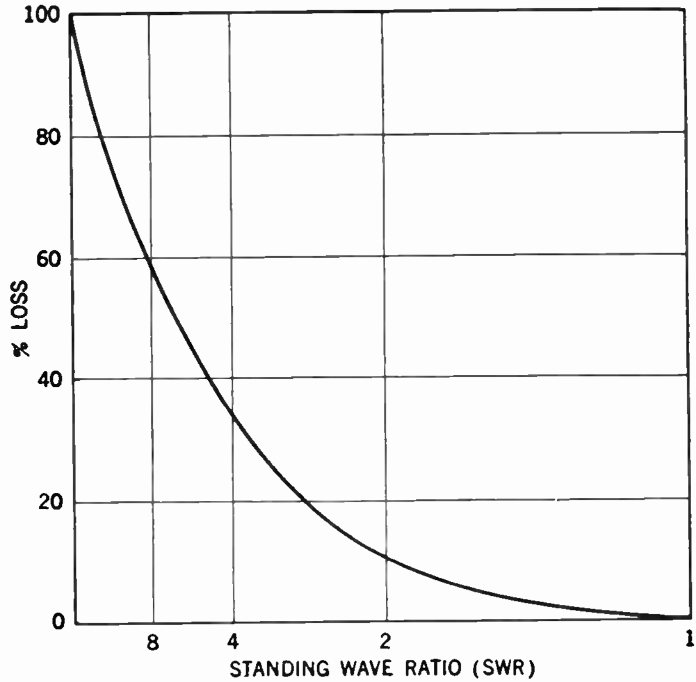
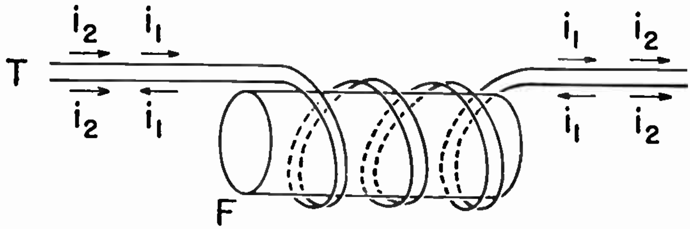


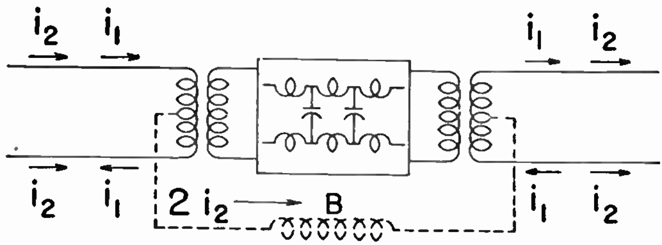
Fig. 4-22. Relationship between voltage SWR and percent of loss due to mismatch.

consists of two coils, each of which can be considered as a transmission line having a surge impedance of 150 ohms and a length of approximately one-quarter wave at the lowest operation frequency. The two transmission lines, or coils, are connected in parallel on one end, forming the 75-ohm impedance, and in series on the other end, producing the 300-ohm impedance.

A transmission-line coil and equivalent diagram are shown in Fig. 4-23. The transmission line T, having a surge impedance of 150 ohms, is wound on the coil for F. The magnetic fields produced by the symmetrical, or push-pull, current neutralize each other to the closely spaced conductors of the transmission line. The magnetic fields produced by the unsymmetrical, or push-push, current are added together and would pass through the transmission line if it were not wrapped to form a coil.



(A) Transmission lines.



(B) Equivalent diagram.

Fig. 4-23. Transmission-line coil and equivalent diagram for a balun.

The mutual inductance between the individual turns of the coil acts like a conventional choke coil B, which offers a high impedance to the push-push currents. The transmission-line coil therefore acts as an ideal transformer, which passes the push-pull currents and eliminates the push-push currents.

YAGI ANTENNAS

Generally, there is no benefit to be gained by adding additional reflectors. However, additional directors can be added. When more than one director is used with the folded dipole and reflector, the antenna is called a *Yagi* (named after Hidetsugu Yaga, the Japanese physicist who discovered it). Two types of Yagi antennas are shown in Fig. 4-24.

The Yagi antenna provides a very high gain. However, its principle disadvantage is that it is highly directive (see Fig. 4-25) and covers a very narrow band of frequencies. Both of these factors

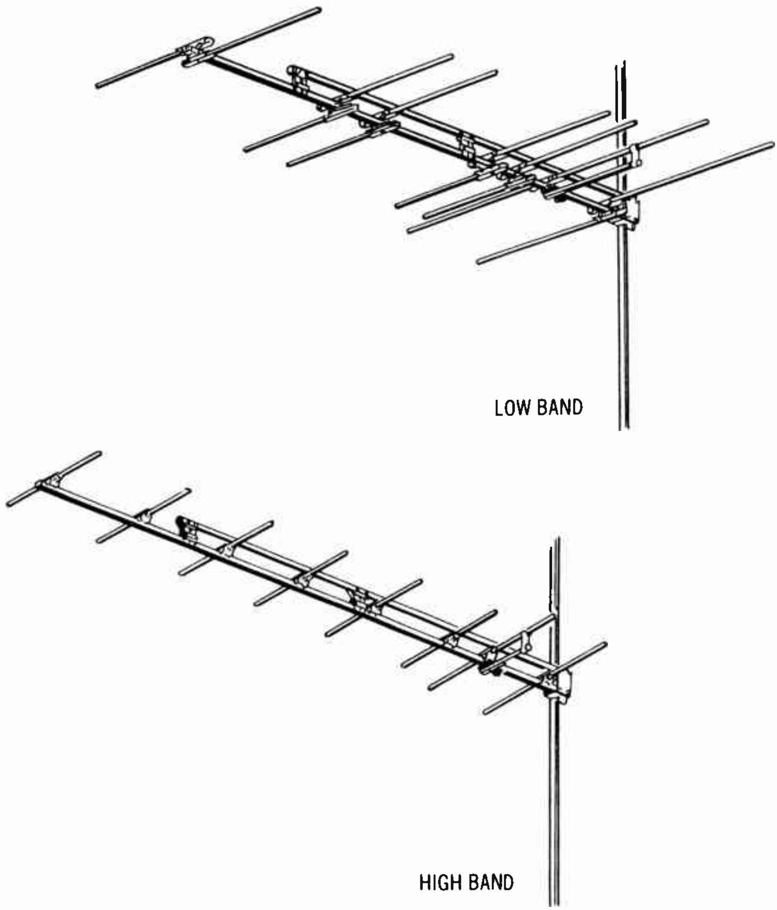


Fig. 4-24. Two commercial Yagi antennas.

and its high gain make it highly desirable for fringe-area use. As more directors are added, the gain is increased; but the bandwidth is narrowed, and the directivity pattern becomes sharper. For VHF applications, Yagi antennas with up to 10 elements are employed; for UHF applications, even more elements may be used.

Optimum operation at VHF frequencies can be obtained for only one channel with a Yagi antenna; however, satisfactory

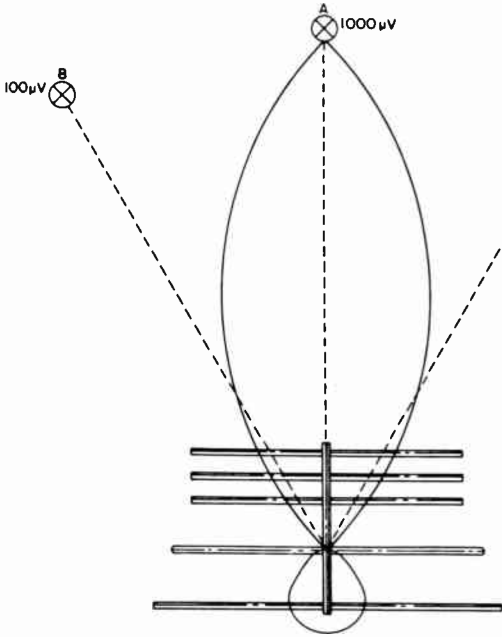


Fig. 4-25. Response pattern of a Yagi antenna to signal from three different angles.

operation may be obtained for two, three, or even more adjacent channels. For UHF operation, several adjacent channels can usually be received from a single Yagi antenna. For even greater gain, two Yagi antennas can be stacked one above the other.

CORNER-REFLECTOR ANTENNA

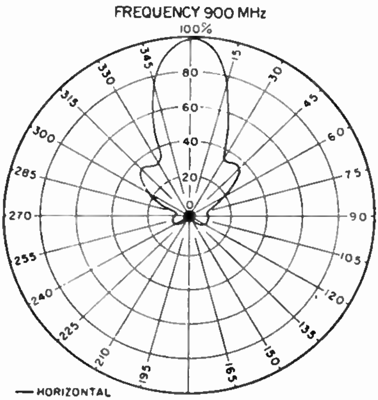
The parabolic-reflector type of UHF antenna has found increased use in weak-signal areas. A more familiar application of the parabolic-reflector principle is found as a well-known part of many light fixtures, where it is employed for concentration of light beams. This useful property, when utilized for concentration of UHF television signals, has provided several antennas of various design for both transmission and reception.

Because of the somewhat difficult design principles involved in the construction of a parabolic antenna, tests have shown that, instead of using curved surfaces, it is possible to use two flat surfaces that are placed so as to intersect each other at some suitable angle, forming a corner. An antenna of this type, known as the *corner reflector*, is shown in Fig. 4-26.

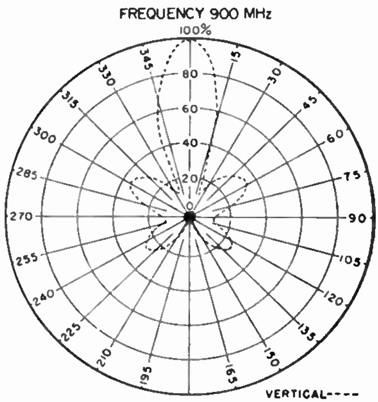
Fig. 4-26. UHF corner-reflector antenna.

The reflector grids have an included angle of 90° and are made from hard aluminum tubes; other materials, such as wire fencing, can be used if desired, providing the wire spacing is small in comparison to a wavelength. The driven element, usually a dipole antenna, is placed at the center of this corner angle and at some distance from the vertex of the angle. The elements are supported near their centers with ceramic insulators in order to minimize the effect of rain, snow, and ice.

The response pattern of the antenna depends not only on the corner angle, but also on the distance between the antenna and the vertex of the reflector corner. When this distance is large, that is, in comparison to the wavelength used, a pattern containing more than one main lobe is obtained, as shown in Fig. 4-27. Moving the antenna too close will affect the vertical response of the array and make it more susceptible to ground-reflected signals. Since neither of the foregoing conditions is desirable, the exact positioning of the dipole must be obtained.



(A) Spacing too small.



(B) Spacing too great.

Fig. 4-27. Effect of spacing between dipole elements and reflector on directivity.

The corner angle of a commercial array is 90°. A similar bend is included in the dipole element. The reflector-bar spacing must be controlled within one-fifth of a wavelength at the highest frequency at which the corner-reflector antenna is to be used.

ANTENNA SELECTION

The selection of the proper antenna for a given location is dependent on many factors. Perhaps the primary concerns are the distance from the station and the signal strength available. In metropolitan areas, satisfactory reception of VHF and UHF signals can usually be obtained from a built-in, or indoor, antenna. However, a more elaborate antenna system is usually required for color reception than is needed for black-and-white reception. As the distance from the transmitter to the receiver increases, antennas with more gain are necessary.

Another consideration in selecting the proper antenna is the number of channels available. For example, if both VHF and UHF channels are available, an antenna suitable for both bands should be used if sufficient signal strength can be obtained with it. For fringe areas, all-channel Yagis are available. However, in extreme fringe areas, an antenna cut for the channel desired must usually be employed. Sometimes antennas must be stacked to obtain sufficient signal strength. Also, it may be necessary to use separate antennas for each channel.

ANTENNA TROUBLESHOOTING

The most common symptom of trouble produced by an antenna is weak, snowy, or no picture reproduction on some or all channels. Note that sound is often satisfactory even when the picture is very weak or absent. This occurs because the sound signal has a comparatively high level, and the receiver provides high gain in the sound channel. Inspection of the antenna might show, for example, that one or both of the lead-in conductors have broken loose from the antenna or that the lead-in has become damaged at some point. Lightning damage can melt a lead-in conductor, usually at a point where the stroke arcs to grounded objects. Although lead-in that is not connected to the antenna will pick up more or less signal, its response is unpredictable. In most cases, all channels are weakened, but in exceptional cases most channels might be weakened, with stronger reception on one or two channels.

If a folded-dipole construction or the equivalent is used in the antenna, the system can be checked for continuity with an ohmmeter. However, the ohmmeter will not read 300 ohms; only the dc resistance of the conductive path is indicated. An infinite reading shows that there is an open circuit; a very high resistance reading shows that there is a poor connection.

Sometimes an antenna system becomes intermittent, and the picture varies erratically from time to time. In most cases, the symptom is most annoying in windy weather. Intermittents are the most difficult faults to locate, and sometimes it is most expedient to simply replace the lead-in (and the antenna, also, if it is in badly deteriorated condition). It is good practice to install the lead-in securely so that it does not whip or swing in the wind. Not only will this precaution stabilize picture reproduction on the high frequencies, but it will also prevent metal crystallization and eventual failure.

SUMMARY

There are basically four classes, or types, of television antennas. They consist of built-in antennas for primary areas to outdoor antennas for far-fringe areas of 75 miles and over. The quality of the picture that is reproduced on the screen of a television receiver is dependent on many factors, but the antenna plays a very important part in normal television reception.

The transmission of a television picture signal acts quite similarly to rays of light; the signal will not bend around corners and is not reflected by obstacles in its paths. Therefore, television waves do not follow the curvature of the earth, and reliable reception should be anticipated only in the region determined by the line of sight to the horizon in all directions from the antenna tower of the transmitting station.

The United States uses a positive transmission signal. Various foreign countries transmit TV signals with more lines than the United States in some instances and fewer lines in other instances.

Impedance matching of the antenna is a very important factor. When the receiver input matches the impedance of the transmission line, the transmitted signal is completely absorbed; and as a result, there are no reflections, or standing waves, on the transmission line and consequently no ghost. A condition that may easily arise is the mismatch of 300 to 75 ohms. This condition will exist when a 300-ohm antenna is connected to a receiver having a 75-ohm input impedance.

REVIEW QUESTIONS

1. Name the four classes of television antennas.
2. What are echoes or ghosts?
3. Explain the purpose of the transcontinental television transmission system.
4. What are the three factors covering antenna installations?
5. What are the two general types of transmission lines?
6. What are parasitic elements?
7. What is a reflector? A director?
8. Why are VHF stations easier to receive than UHF?

CHAPTER 5

Antenna Installation

The first step in any antenna installation is a survey of the location. Look over the building. Note the type of construction (brick, stone, frame, etc.) and the type of roof. Check the location of the TV receiver(s) to be served by the antenna. Decide on the best location for the antenna and the best route for the lead-in. Sometimes the best location for an antenna will be determined by the availability of a good ground. An example of an antenna grounding arrangement is shown in Fig. 5-1. Observe that the mast is grounded directly, and that the lead-in is connected to the ground. A short and direct connection to an external ground is required by the National Electrical Code and by local electrical codes.

The actual selection of the type of antenna to be installed will depend on many factors. The distance from the transmitting antenna is of prime importance. Another important factor is the number of channels available. As discussed in Chapter 4, some antennas are suitable for strong signal areas, some are suitable for

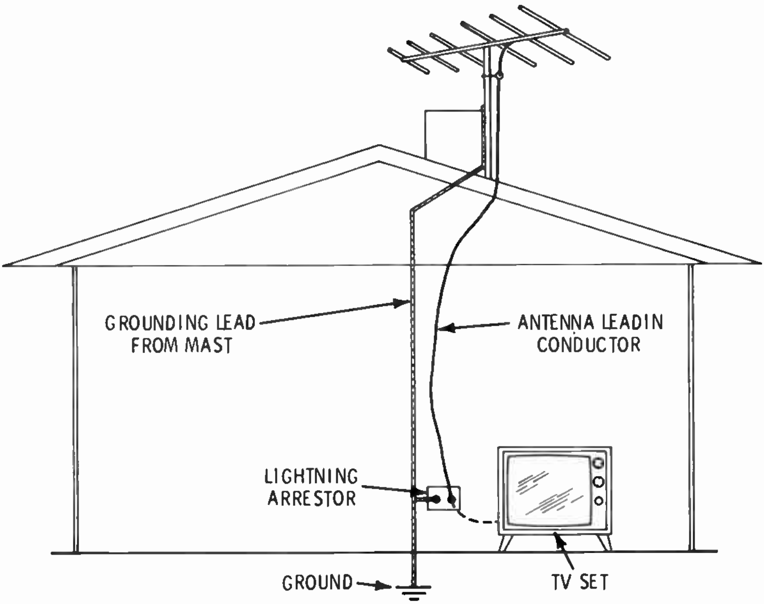


Fig. 5-1. Example of antenna-grounding arrangement.

all-channel reception, and others for only a single channel. Look around and see what types of antennas are used on neighborhood houses; but before installing one of the same type, make sure they are obtaining suitable reception.

Most homes have two or more TV sets. Where it is practical, it is logical to use one antenna to serve every set in the house. Figure 5-2 shows the simplest way in which this is done—by using a multiset coupler. In other cases, people want a TV antenna outlet in every room. This requirement is served best by a home TV system such as depicted in Fig. 5-3. (Technical details are explained later in this chapter.)

TOOLS

Of course, one of the first tools needed in any antenna installation is a ladder. Usually a 20- or 24-foot extension ladder is best.

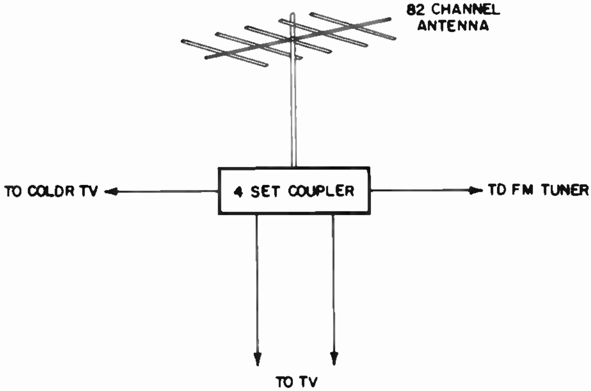


Fig. 5-2. Antenna-coupler splitter.

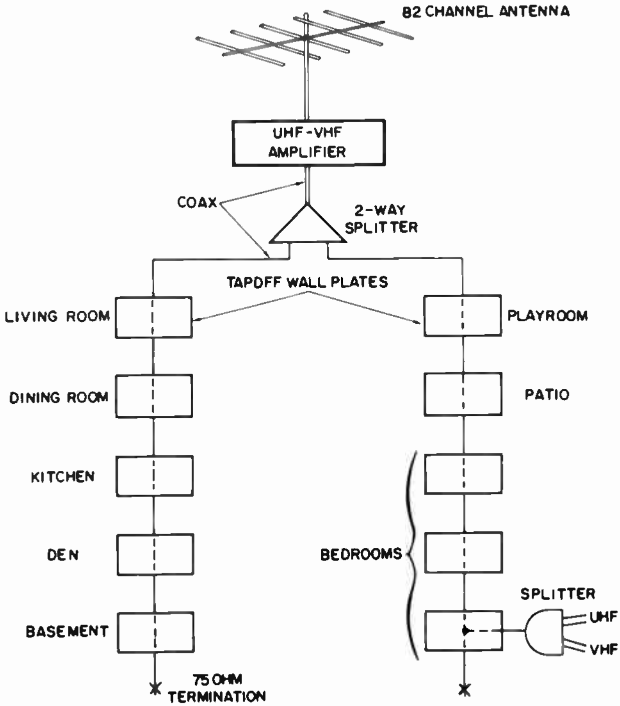


Fig. 5-3. Small master antenna system.

Several hand tools are also necessary. No attempt will be made to list all the possible tools that may be needed. Each installation job varies, and so do the tool requirements. However, the following are considered the basic tools required before any installation is attempted:

1. Assortment of screwdrivers
2. Slip-joint pliers
3. Long-nose pliers
4. Diagonal cutting pliers
5. 6-in. case-hardened cutters (for bolts, guy wire, etc.)
6. Open-end wrenches
7. Nut drivers (1/4, 3/8, 5/16, 7/16, and 1/2 in.)
8. Hammer
9. Assortment of wood bits
10. Bell-hangers bit (3/8 in. by at least 12 in. long)
11. Brace for bits

In addition, there are many other useful tools. Socket wrenches are often handy, as is a small adjustable wrench. Also, a hacksaw and small keyhole saw are often needed. Although not a necessity, a 1/4- or 3/8-in. electric drill is very handy. A long extension cord will be needed for the drill.

If the house is of brick or masonry construction, some means of drilling a hole in the wall must be available. A star drill (Fig. 5-4) can be used. This type of drill is hit with a hammer and rotated slightly after each stroke. A much easier method of drilling a hole is provided by the carbide-tipped masonry drill bit shown in Fig. 5-5. This bit fits in the 1/4-in. electric drill (be sure to get a bit with a 1/4-in. shank). One word of caution: Don't force the bit in the masonry—take your time.

MASTS AND TOWERS

Another decision that must be made in the initial inspection is how to support the antenna. Again, one of the primary factors in determining the selection is the distance from the transmitting antenna. In strong-signal areas almost any type of installation can be used. In fringe areas, tall towers may be necessary.

Fig. 5-4. Two types of star drills.

Fig. 5-5. Carbide-tipped masonry bit.

Masts

The *tubular mast* is the most popular method of supporting an antenna. It can be mounted on a chimney, or the peak of a roof, from a flat roof, attached to the side of the building, or even hung in the attic (see Fig. 5-6). Tubular masts are made of aluminum or steel and are usually sold in 10-ft. lengths. The ends are made so that one end slips into the opposite end of another section to obtain greater heights. If properly guyed, masts up to 50 ft. can be employed.

Telescopic masts are also available. In this type of construction, each section fits inside the next lower section. When a section is extended, a locking mechanism holds it in place. Telescopic masts are available up to 50 ft. in length. (See Fig. 5-7.)

Towers

Where greater heights or a sturdier installation is necessary, the triangular steel tower is used. Towers are available in 6- or 10-ft. sections that are bolted together to obtain the necessary height. A typical fringe-area installation utilizing a tower is shown in Fig. 5-8.

Another type of tower is hinged in the middle and has a built-in winch that is used to tilt the top over to gain access to the antenna. In still a different type of tower, each section gets pro-

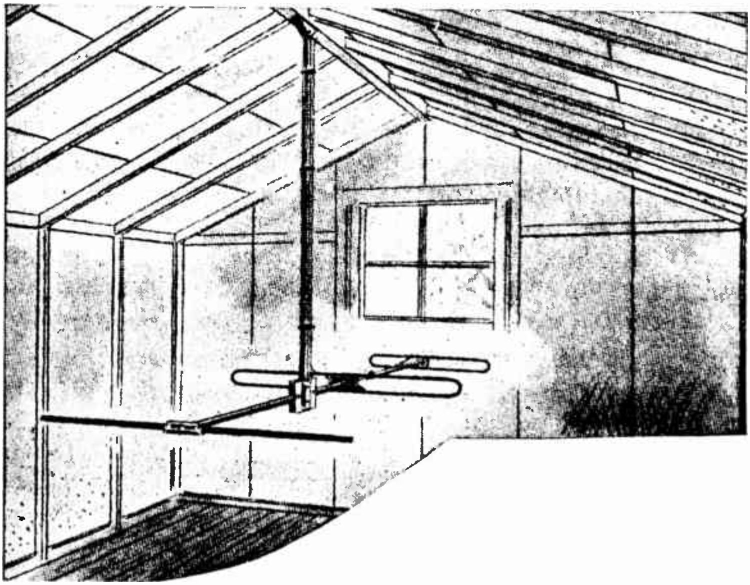


Fig. 5-6. Typical attic installation.

gressively smaller as it approaches the top, and each section fits inside the next lower section. Thus the entire tower is telescoped together and is raised and lowered by a built-in winch at the base.

Locating the Antenna

Before attempting to install the antenna, it is essential to carefully select a position that allows the following conditions to be fulfilled:

1. Absence of obstruction, such as buildings, trees, power lines, other nearby antenna systems, etc., between the proposed antenna site and the transmitting antenna.
2. Maximum distance between proposed antenna sites and sources of electrical noise such as might originate in ignition systems, elevator relays, diathermy and x-ray machines, and arcing from electrical transmit systems. Several of these conditions preclude the possibility of mounting the antenna

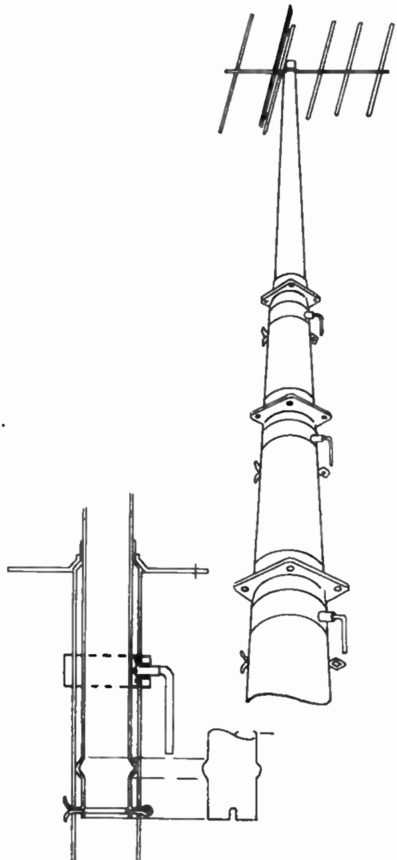


Fig. 5-7. Telescopic mast detail.

Courtesy South River Metal Products

near the edge of a roof adjoining a street with heavy traffic even though this site may be preferable with respect to length of antenna lead-in.

3. Greatest possible height above ground level. In general, this will allow the antenna to overcome such obstructions as mentioned in item 1.

Before the mast or tower is actually installed, a preliminary check of the location choice should be made. Temporarily connect the antenna to a mast, and attach the transmission line. Connect the transmission line to the TV receiver, and hold the

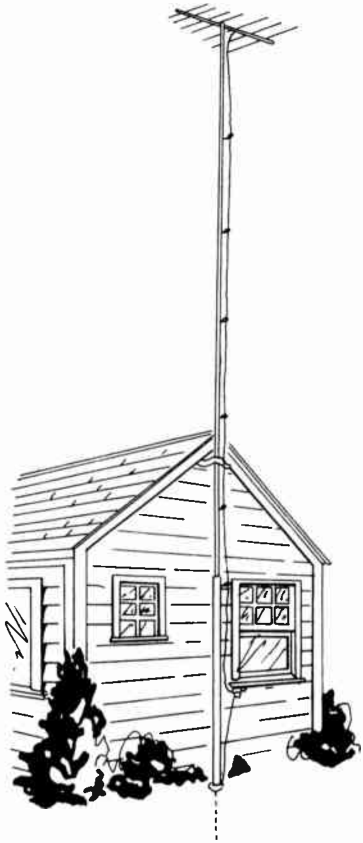


Fig. 5-8. Typical fringe-area antenna installation.

Courtesy South River Metal Products

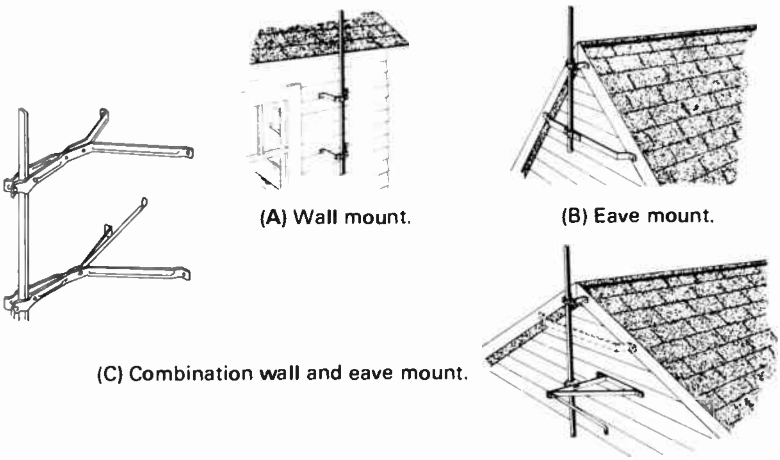
antenna in the chosen location to determine if a suitable signal is obtained.

It is often possible to obtain considerable improvement in performance by moving the antenna location a small distance from the original site. This final test for the most desirable antenna location becomes vitally important in areas where signal strength is low or where reflection from surrounding surfaces produces multiple transmission paths, thereby creating multiple images, or "ghosts," on the screen.

By now it should be obvious that an antenna installation requires two people. One can hold the antenna while the other observes the effect on the screen. Some means of communication between the two is necessary. "Walkie-talkies" or wireless, two-way headset radios are very helpful for this purpose. Lacking this, a third person can stand outside a window or door and relay the message between the person at the antenna and the one observing the receiver.

Mast Installation

Various methods are used for mounting antenna masts. For short masts, brackets can be used to attach the mast to the wall or eave, as shown in Fig. 5-9. In addition, there are many versions of



(A) Wall mount.

(B) Eave mount.

(C) Combination wall and eave mount.

Fig. 5-9. Wall and eave mounts.

the chimney mount (Fig. 5-10). Before the mountings shown in Figs. 5-9 and 5-10 are attempted, be sure to check the wall or chimney. Make sure they are in good condition so that they will be able to withstand the added strain placed on them by the antenna. During a windstorm or in the winter in the northern areas, when the antenna and mast are coated with ice, enormous pressures are exerted on the installation.

The spacing between the brackets should be sufficient to hold the mast rigid. This distance will vary with the mast height. A

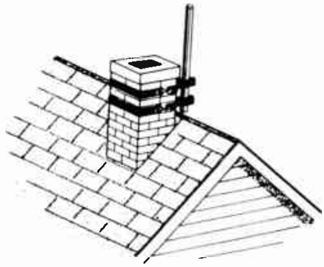


Fig. 5-10. Chimney mount.

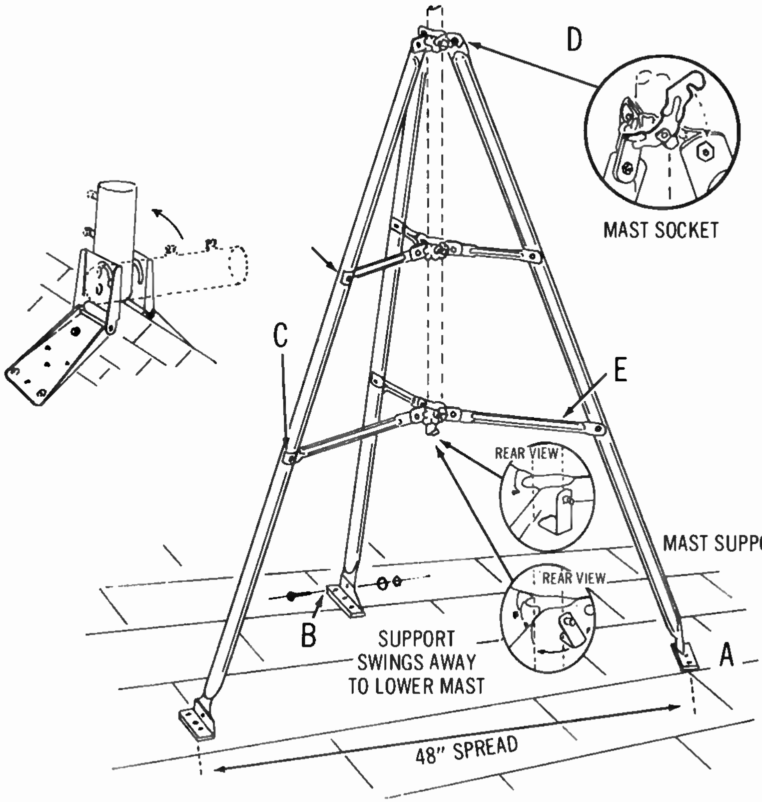
mast support suitable for a peaked roof is shown in Fig. 5-11. Supports very similar to this can also be used for flat roofs.

Masts can also be based on the ground and extended above the roof top. Some method of solid support must be provided at the base. This support can be provided by a cement block, solid board, or even a flat rock. A pipe strap should be placed around the mast at the eave or gable of the house. If the mast does not extend for more than 10 ft. above this point, no additional supports are required. Enough slack should be allowed in the strap to enable the mast to be turned during installation. The strap should exert enough pressure on the mast to prevent the wind from twisting the antenna upon completion. Thus, orientation of the antenna is simplified. This type of installation is popular and easy to make. Telescopic masts, which are available in heights up to 40 ft., are usually employed.

Tower Installation

Like masts, towers can be mounted on the roof or on the ground; however, the ground installation is more popular because of the difficulty in manipulating the tower on a roof. Perhaps the easiest method is to assemble the tower on the ground and attach the antenna and transmission line. Then, with one person on the roof and two on the ground, the antenna is lifted into position.

Sometimes, however, it is necessary to install the tower section while the installer climbs the tower. Guy wires should be installed in their proper locations before the installer attempts to climb the tower (see the following section). *Never* attempt to climb an unsupported tower. A safety belt is a necessity when working on a tower because both hands will be needed for connecting the sections. In addition, some means must be employed to raise the



Courtesy South River Metal Products

Fig. 5-11. Antenna mount suitable for a peaked roof.

sections for the person on the tower. Gin poles (Fig. 5-12) are available for this purpose.

Guy Wires

Guy wires must be attached to practically every antenna installation to support the mast or tower. The only exceptions are self-supporting steel towers set deep in concrete and eave installations, which extend only a few feet above the roof.

The most popular guy wire is 6/20 steel (6 strands of No. 20-gage steel wire). Heavier wires, such as 6/18 and 6/14, are also available; and sometimes aluminum wire is used. Three or four

Fig. 5-12. Safety belt worn while working on a tower.

guy wires should be used at each guying point. In the three-guy system (Fig. 5-13), guy wires are spaced approximately 120° apart; while in the four-guy system (Fig. 5-14), the spacing is approximately 90°. The actual spacing between guy wires must depend upon the physical layout of the location.

In general, separate guy-wire systems should be attached for each 10 ft. of height for masts; for towers, guy wires should be attached for each 10 or 12 ft. of height. In either case, they can be spaced closer if necessary. In areas where high wind velocities or severe winters are expected, extra guy wires are indicated.

Rings that fit over the mast are available for attaching the guy wires. For towers, rings that fit over each leg are used; they should be slipped over the legs as the tower is assembled.

The type of anchor used at the opposite end of the guy wire will depend on the location. Flat steel plates with one end bent

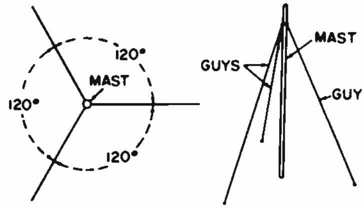


Fig. 5-13. Method of placing three guy wires.

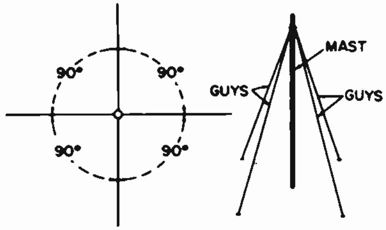


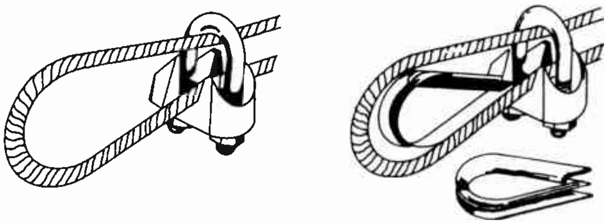
Fig. 5-14. Method of placing four guy wires.

up at approximately a 45° angle should be used for anchoring guy wire on walls or flat surfaces. Screw-in eyes are available for roof installations. Special screw auger stakes are available for use in the ground.

Do not attach the guy wire directly to the ring on the mast or tower or the anchorage. Instead a thimble should be inserted first. The wire is inserted around the thimble and twisted as shown in Fig. 5-15. When the guy wire is attached in this manner, there are no exposed sharp edges to cut into the wire and weaken the installation.

TRANSMISSION LINES

A properly selected and installed transmission line is as important to the quality of the antenna system as the antenna itself. An improperly installed line causes reflection (ghosts) and high losses. Reflections in the line make it impossible to obtain clear pictures; and in severe cases, the reflections cause "smears" so that the picture appears out of focus even though the receiver is perfectly focused. In general, the longer the transmission line, the more care required in installation.



Courtesy South River Metal Products

Fig. 5-15. Use of a guy-wire thimble.

Most television receivers have a 300-ohm input circuit, which is intended for connection to a 300-ohm antenna system. Failure to observe proper impedance match between antenna, transmission line, and receiver will result in less energy delivered to the receiver, and undesirable effects of noise and interference may be accentuated.

Types of Transmission Line

A 75-ohm, shielded coax transmission line is now the accepted installation cable, replacing 300-ohm, low-loss transmission line. Since coaxial cable normally is not available with a 300-ohm impedance, impedance-matching devices should be used.

Length of Line—The length of the transmission line should be kept as short as possible. The longer the line, the greater the opportunity for man-made electrical disturbances to introduce undesirable effects. In addition, attenuation of the line, although low, will reduce the energy fed to the receiver in direct proportion to length.

Splicing the Line—If it becomes necessary to splice on an additional length of coax cable, care should be exercised to avoid a mismatch or short at the splice. The user of F connectors and a female-to-female "barrel" connector is recommended to complete the splice. (See Fig. 5-16.)

Routing and Securing—It is well to carefully consider the best route for the transmission line with respect to length and electrical disturbance shielding. A compromise must usually be made on the length so as to be able to take advantage of the shielding effect of the building against such disturbances as ignition noise

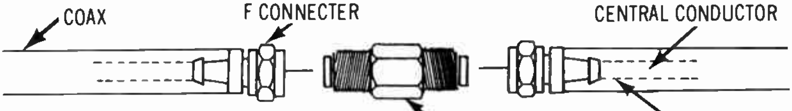


Fig. 5-16. Proper method of splicing coax cable.

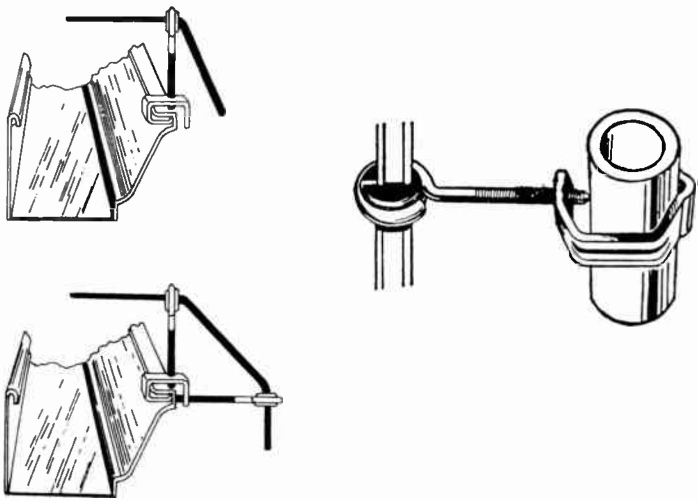
and arcing from electrical transit systems. Whenever possible, the line should be run in a vertical direction so that rain, sleet, and snow will have less tendency to cling to it. If a horizontal run is necessary, it should be made under an eave or other protection.

The standoff insulators shown in Fig. 5-17 are designed for mounting in wood (left) or on the mast (right). Other types of standoffs are constructed for mounting in almost any surface; there is even one for driving into cement walls. Shafts of various lengths are also available to suit any need.

Courtesy South River Metal Products

Fig. 5-17. Standoff insulators.

Standoff insulators should be placed approximately 5 ft. apart along the line. However, the actual locations will depend upon the location of physical obstructions and the route the line must take. The insulator should grip the transmission line and support it in both the vertical and horizontal directions. To attach the line to the standoff, insert the line in the slot and then twist the inner insulating material so that the slot opening is positioned at the rear of the metal eye, as shown in Fig. 5-18. The line should be pulled tight so that a heavy wind will not cause it to swing against surrounding objects, and then the metal eye should be squeezed so that it tightly grips the inner insulator (hence the line), preventing it from moving.



Courtesy South River Metal Products

Fig. 5-18. Method of placing transmission line in standoff insulator.

Other types of mountings are now available, developed by the CATV industry (Fig. 5-19). They include plastic nail-in anchors, siding push clips, and, for wood surfaces, a round crown stapler. Care must be exercised in the selection of these anchors. The anchor diameter must match the diameter of the coax to avoid crushing the dielectric and therefore affecting the characteristics of the coax cable. Direct attachment to the structure below the roof line prevents the danger of protruding obstructions to the occupants of the structure, prevents "wind whipping," and provides a more pleasing appearance.

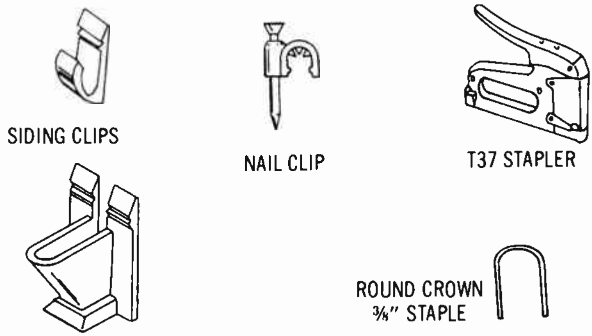


Fig. 5-19. Attachments developed by the CATV industry.

Entering the House

Various methods are employed for entering the house. Of course, the window can be raised, the coax inserted, and the window lowered. However, this method is far from satisfactory. If the window is metal or if metal flashing is employed along the window, the metal will create a short across the conductors of the coax, thus shorting out the antenna. In addition, raising and lowering the window will wear away the insulation and allow moisture to gain access to the cable (not to mention the heat loss to the house).

Special entrance fittings are available. A ½-in. hole is drilled through the wall, and the device inserted. The coax is then inserted through the device, which also seals the hole to prevent cold or rain from entering. Such a device can be installed directly behind the desired location for the receiver. The receiver will hide the entrance fitting from view. Some devices are equipped with a socket at the inside end for attaching the coax to the receiver.

Another method of entering the house is under the floor through a ventilation opening or hole drilled for this purpose. The lead-in is then run under the house to the desired location. When routing the coax inside or under the home, it should be routed by the shortest possible path to the receiver, taking special precaution to avoid contact with pipes, radiators, or other metal objects.

Special wall plugs can be used as a means for connecting the transmission line to the receiver. The lead-in can be run under the floor or in the attic to a point directly below (or above) the desired location. Then a hole is drilled between the walls, and a cutout is made for the wall receptacle. The lead-in is routed through the hole to the receptacle opening. This procedure is commonly used in *prewiring* of a house or commercial structure where exposed wires are not desirable.

In addition to the TV-antenna outlet, antenna receptacles may also provide outlets for rotator cables or an FM antenna. The unit shown in Fig. 5-20 has an outlet for the TV and an FM antenna.

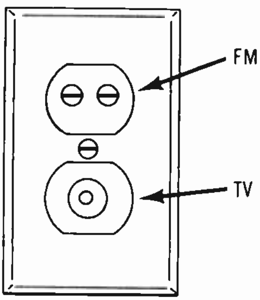


Fig. 5-20. Combination TV- and FM-antenna wall socket.

Outlets can be installed at several locations within the house. However, if more than one receiver is to be operated at once, some means of isolation is usually necessary. A *splitter*, or *tap*, may be used to provide a multiple connection and isolation point. Even when only one receiver is being used at one time, the length of the transmission line to the other outlets may sometimes cause an adverse effect on the signal.

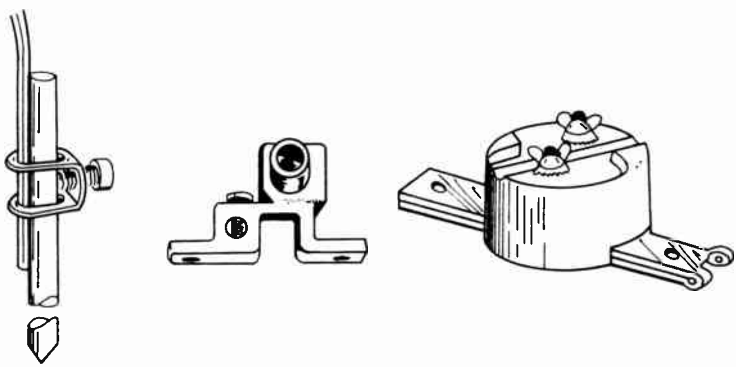
Connecting Line to Receiver

Depending on the year of manufacture, a terminal strip or a female F connector or barrel will be found on the rear of the receiver cabinet. The 300-ohm lead-in may be connected directly to the terminals marked VHF. A 75-ohm coax lead may be connected directly to the female F connector, or a balun may be employed to match the impedance of the terminal strip. If the antenna is an all-channel antenna, a VHF-UHF splitter will be required to feed both the VHF and UHF inputs. When a wall plate is used, a short length of transmission line must be fabricated with a plug or connector that matches the wall plate.

GROUNDING

No antenna installation is complete until it has been properly grounded. Unless the mast or tower is buried in the ground, a ground wire must be run from it to a suitable ground. Cold-water pipes, underground tanks, or other *metallic underground systems* are considered suitable grounds. A ground rod can be driven in the ground and connected to the tower. Such a rod should be a ⅝-in.-diameter, 8-ft.-long, copper-plated steel rod.

In addition, a lightning arrester should be placed at the point where the lead-in enters the building. Numerous approved types are available. All have some means whereby two contacts are placed in close proximity to the line (Fig. 5-21). Then a ground



Courtesy South River Metal Products

Fig. 5-21. Typical lightning arrestors, grounding blocks, and grounding rod.

wire is run from another terminal to the ground rod. The National Electrical Code states that separate grounds should be employed for each portion of the system. However, if the lightning arrester is connected directly to the mast or tower, a single ground can be used. In addition, where separate grounds are employed, each of these separate grounds should be connected together by a separate interconnecting ground wire.

Always leave a loop between the last standoff or lightning arrester and the point where lead-in enters the house, as shown in Fig. 5-22. This loop prevents water from running down the line and inside the house.

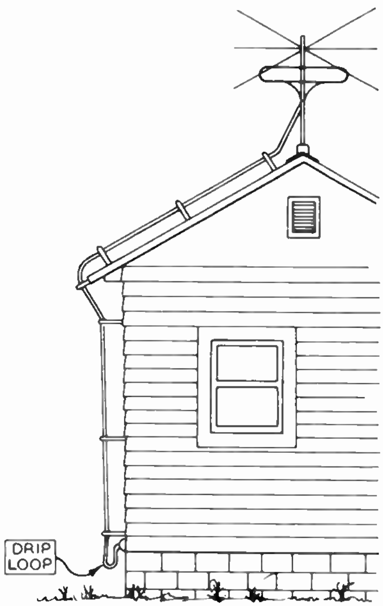


Fig. 5-22. Drip loop in the antenna lead-in.

CODE SPECIFICATIONS

Articles 810 and 820 of the National Electrical Code give the specifications for safe installation of antenna systems for radio and television receivers. Portions of this code are now given.

ARTICLE 810—RADIO AND TELEVISION EQUIPMENT—RECEIVING EQUIPMENT—ANTENNA SYSTEMS

810-11. Material. Antennas and lead-in conductors shall be of hard-drawn copper, bronze, aluminum alloy, copper-clad steel or other high strength, corrosion-resistant material. Soft-drawn or medium-drawn copper may be used for lead-in conductors where the maximum span between points of support is less than 35 feet.

810-12. Support. Outdoor antennas and lead-in conductors shall be securely supported. The antennas shall not be attached to electric service mast. They shall not be attached to poles or similar structures carrying electric light or power wires or trolley wires of more than 250 volts. Insulators supporting the antenna conductors shall have sufficient mechanical strength to safely support the conductors. Lead-in conductors shall be securely attached to the antenna.

810-813. Avoidance of Contacts with Conductors of Other Systems. Outdoor antennas and lead-in conductors from an antenna to building shall not cross over electrical light or power circuits and shall be kept well away from all such circuits so as to avoid the possibility of accidental contact. Where proximity to electric light and power service conductors of less than 250 volts cannot be avoided, the installation shall be such as to provide a clearance of at least 2 feet. Where practicable, antenna conductors shall be so installed as not to cross under electric light or power conductors.

810-14. Splices. Splices and joints in antenna spans shall be made with approved splicing devices or by such other means as will not appreciably weaken conductors. (Soldering may ordinarily be expected to weaken conductors. Therefore, the joint should be mechanically secure before soldering.)

810-15. Grounding. Masts and metal structures supporting antennas shall be grounded in accordance with Section 810-21.

810-16. (b) **Self-Supporting Antennas.** Outdoor antennas, such as vertical rods or dipole structures, shall be of noncorrodible materials and of strength suitable to withstand ice and loading conditions, and shall be located well away from overhead conductors of electric light and power circuits of over 150 volts to ground so as to avoid the possibility of the antenna structure falling into or accidental contact with such circuits.

810-18. Clearances—Receiving Stations. (a) On Outside of Buildings. Lead-in conductors attached to buildings shall be so installed that they cannot swing closer than 2 feet to the conductors of circuits of 250 volts, or less between conductors, or 10 feet to conductors of circuits of more than 250 volts between conductors, where if all conductors involved are supported so as to insure permanent separation, the clearance may be reduced but shall not be less than 4 inches. The clearance between lead-in conductors and any conductor forming a part of a lightning-rod system shall be not less than 6 feet unless the bonding referred to in Section 2586 is accomplished.

(b) Antennas and Lead-Ins—Indoors. Indoor antennas and indoor lead-ins shall not be run nearer than 2 inches to conductors of other winding systems in the premises unless, (1) such other conductors are in metal raceways or cable armor, or, (2) unless permanently separated from such other conductors by a continuous and firmly fixed nonconductor such as porcelain tubes or flexible tubing.

810-20. Antenna Discharge Units (Lightning Arrestor)—Receiving Stations. (a) Where Required. Each conductor of a lead-in from an outdoor antenna shall be provided with a listed antenna discharge unit unless the lead-in conductors are enclosed in a continuous metallic shield that is either permanently and effectively grounded, or is protected by an antenna discharge unit.

(b) Location Antenna discharge units shall be located outside the building, or inside the building between the point of entrance of the lead-in and the television set or transformers, and as near as practicable to the entrance of the conductors to the building. The antenna discharge unit shall not be located near combustible material nor in a hazardous location.

810-21. Grounding Conductors—Receiving Stations. (a) Material. The grounding conductor shall, unless otherwise specified, be of copper, aluminum, copper-clad steel, bronze, or other similar corrosion-resistant material.

(e) Run in Straight Line The grounding conductor for an antenna mast or antenna discharge unit shall be run in as straight a line as practicable from the mast and/or discharge unit to the grounding electrode.

810-27. Grounding Conductors—Receiving Stations. (g) Inside or Outside Building. The grounding conductor may be run either inside or outside the building.

(h) Size. The grounding conductor shall be not smaller than No. 10 copper, No. 8 aluminum, or No. 17 copper-clad steel or bronze.

(i) Common Ground. A single grounding conductor may be used for both protective and operating purposes. (Where a single conductor is so used, the ground terminal of the equipment should be connected to the ground terminal of the protective device.)

It will be noted that a lightning arrester is not required under Section 810-20(a) when the lead-in conductor from an antenna to entrance of a building is protected by a continuous shield that is permanently or effectively grounded. Therefore such a requirement would be met by proper grounding of the outer shield of the regular coaxial cable. Installation men should be particularly cautioned to comply with Section 810-18 and to refrain from the use of insulators or cable clips installed on or in buildings by telephone or lighting companies.

ARTICLE 820—COMMUNITY ANTENNA TELEVISION AND RADIO DISTRIBUTION SYSTEM

A. General

820-1. Scope. This article covers coaxial cable distribution of radio frequency signals typically employed in community antenna television (CATV) systems. Where the wiring system employed is other than coaxial, Article 800 shall apply.

The coaxial cable shall be permitted to deliver low-energy power to equipment directly associated with this radio frequency distribution system if the voltage is not over 60 volts and if the current supply is from a transformer or other device having energy-limiting characteristics.

820-2. Material. Coaxial cable used for radio frequency distribution systems shall be suitable for the application.

B. Protection

820-7. Ground of Outer Conductive Shield of a Coaxial Cable. Where coaxial cable is exposed to lightning or to accidental contact with lightning arrester conductors or power conductors operating at a potential of over 300 volts to ground, the outer conductive shield of the coaxial cable shall be grounded at the building premises as close to the point of cable entry as practicable.

(a) Shield Grounding. Where the outer conductive shield of a coaxial cable is grounded, no other protective devices shall be required.

(b) Shield Protective Devices. Grounding of a coaxial drop cable shield by means of a protective device that does not interrupt the grounding system within the premises shall be permitted.

C. Installation of Cable

820-11. Outside Conductors. Coaxial cables, prior to the point of grounding, as defined in Section 820-7, shall comply with (a) through (e) below.

(a) **On Poles.** Where practicable, conductors on poles shall be located below the light or power conductors and shall not be attached to a cross-arm that carries light or power conductors.

(b) **Lead-in Clearance.** Lead-in or aerial-drop cables from a pole or other support, including the point of initial attachment to a building or structure, shall be kept away from electric light or power circuits so as to avoid the possibility of accidental contact.

Exception: Where proximity to electric light or power service conductors cannot be avoided, the installation shall be such as to provide clearances of not less than 12 inches (305 mm) from light or power service drops.

(c) **Over Roofs.** Cables passing over buildings shall be at least 8 feet (2.44m) above any roof that is accessible for pedestrian traffic.

(d) **Between Buildings.** Cables extending between buildings and also the supports or attachment fixtures shall be acceptable for the purpose and shall have sufficient strength to withstand the loads to which they may be subjected.

Exception: Where a cable does not have sufficient strength to be self-supporting, it shall be attached to a supporting messenger cable that, together with the attachment fixtures or supports, shall be acceptable for the purpose and shall have sufficient strength to withstand the loads to which they may be subjected.

(e) **On Buildings.** Where attached to buildings, cables shall be securely fastened in such a manner that they will be separated from other conductors as follows:

(1) **Light or Power.** The coaxial cable shall have a separation of at least 4 inches (102 mm) from light or power conductors not in conduit or cable, or be permanently separated from conductors of the other system by a continuous and firmly fixed nonconductor in addition to the insulation on the wires.

(2) **Other Communication Systems.** Coaxial cable shall be installed so that there will be no unnecessary interference in the maintenance of the separate systems. In no case shall the conductors, cables, messenger strand, or equipment of one system cause abrasion to the conductors, cable, messenger strand, or equipment of any other system.

(3) **Lightning Conductors.** Where practicable, a separation of at least 6 feet (1.83 m) shall be maintained between any coaxial cable and lightning conductors.

820-13. Conductors Inside Buildings. Beyond the point of grounding, as defined in Section 820-7, the cable installation shall comply with (a) through (d) below.

(a) **Light or Power.** Coaxial cable shall be separated at least 2 inches (50.8 mm) from conductors of any light or power circuits or Class 1 circuits.

Exception No. 1: Where the light or power or Class 1 circuit conductors are in a raceway, or in metal-sheathed, metal-clad, nonmetallic sheathed, or Type UF cables.

Exception No. 2: Where the conductors are permanently separated from the conductors of the other circuit by a continuous and firmly fixed nonconductor, such as porcelain tubes or flexible tuning, in addition to the insulation on the wire.

(b) In Raceways and Boxes. Coaxial cable shall not be placed in any raceway, compartment, outlet box, junction box, or other enclosures with conductors of light or power circuits or Class 1 circuits.

Exception No. 1: Where the conductors of the different systems are separated by a permanent partition.

Exception No. 2: Conductors in outlet boxes, junction boxes, or similar fittings or compartments where such conductors are introduced solely for power supply to the coaxial cable system distribution equipment or for power connection to remote-control equipment.

(c) In Shafts. Coaxial cable installed in the same shaft with conductors for light or power shall be separated from the light or power conductors by not less than 2 inches (50.8 mm).

Exception No. 1: Where the conductors of either system are encased in noncombustible tubing.

Exception No. 2: Where the light or power conductors are in a raceway, or in metal-sheathed, metal-clad, nonmetallic-sheathed, or Type UF cables.

(d) Vertical Runs. Coaxial cables bunched together in a vertical run in a shaft shall have a fire-resistant covering capable of preventing the carrying of flame from floor to floor.

Exception: Where cables are encased in noncombustible tubing or are located in a fireproof shaft having fire stops at each floor.

There is no specific separation requirement between Class 2 or Class 3 circuits, wired distribution system cables, and communication cables or conductors, other than the clearance necessary to prevent conflict or abrasion.

820-14. Spread of Fire or Products of Combustion. Installations in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be so made that the possible spread of fire or products of combustion will not be substantially increased. Openings around penetrations through fire resistance rated walls, partitions, floors, or ceilings shall be firestopped using approved methods.

820-15. Location. Circuits and equipment installed in ducts and plenums shall also comply with Section 300-22 as to wiring methods.

Exception: Coaxial cables listed as having adequate fire-resistant and low-smoke producing characteristics shall be permitted for ducts, hollow spaces used as ducts, and plenums other than those described in Section 300-22(a).

RF AMPLIFIERS

Where the signal obtained from the antenna is insufficient to provide a suitable picture, *boosters* are often employed. As their name implies, boosters are nothing more than RF amplifiers placed between the antenna and the TV receiver. The additional amplification provided by the booster raises the signal strength to the point where it is sufficient to drive the TV receiver.

There are many types of amplifiers available. Some are tuned to a single channel (strip amps), while some provide all-channel VHF amplification (broadband amps). Two types of mountings are employed for amplifiers. Some are fixed-tuned and are mounted on the mast near the antenna. These may be for single or all-channel (VHF) operation. Some antennas incorporate boosters as part of their design. Such boosters may use transistors, and power must be supplied to the unit via either the lead-in or separate leads.

Tunable amplifiers are usually housed in a wood or plastic cabinet and placed on top of the TV receiver. Then, when the TV receiver is switched to select a given channel, the booster is also set to the same channel.

The actual design depends upon the application intended for the particular unit; the more elaborate the design, the more gain obtained.

MASTER ANTENNA SYSTEM

The primary purpose of a master antenna system (MATV) is to provide individual antenna outlets to two or more locations. For example, hotels, motels, and apartment buildings often use a single antenna system to supply the TV signal to all tenants. In addition, two or more TV receivers are often used in single-family dwellings.

Installing separate antennas for each TV receiver not only creates a maze of antennas on the roof, but also would be very expensive. All TV receivers cannot be connected to a single lead-in because of interaction between sets, and one antenna will not provide sufficient signal to drive all the TV receivers in some buildings. Therefore, some means must be provided for connecting receivers.

In another application of the MATV, a whole town may be supplied. This is known as a community antenna system (CATV). The antennas are located on a high tower or nearby mountain. Separate antennas are usually employed for each available channel. The signals are amplified and sent to the various subscribers' houses via a transmission line. Other amplifiers may be located at various points along the line.

Presently three types of master-antenna installations are employed in multiple dwellings:

1. Divider network system
2. Distribution amplifier system
3. Separate antenna system

Divider Network Antenna System

This system operates from a high-gain antenna able to provide sufficient signal strength for connection to a considerable number of receivers. Since no amplifiers are used and no power is required, a multiple-antenna system of this type is low in maintenance and first cost. Multiset couplers are often employed in houses where it is desired to operate more than one receiver. They can also be used for operating a TV set and an FM receiver from the same antenna. The schematic for a typical divider network, four-set coupler is shown in Fig. 5-23.

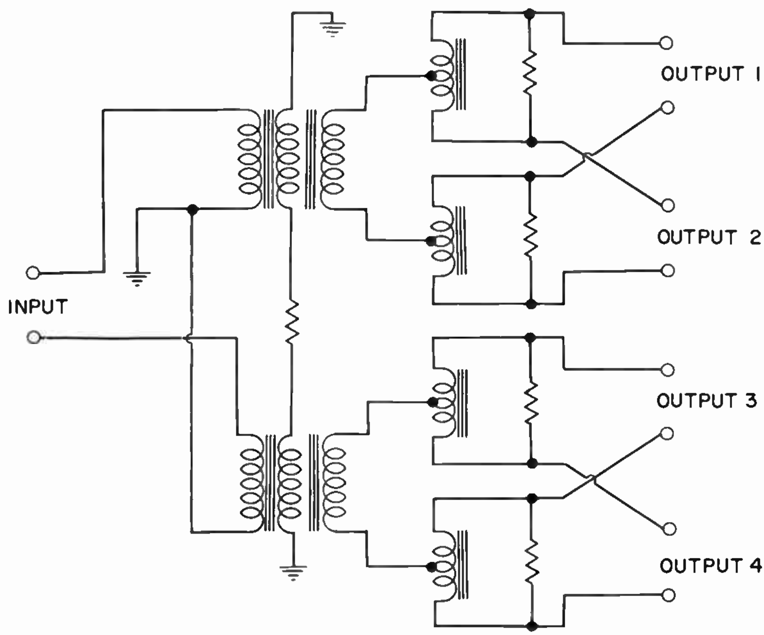


Fig. 5-23. Schematic of a four-set coupler.

Distribution Amplifiers

Where several receivers must be connected to an antenna, the set couplers described previously may not supply sufficient signal. For example, hotels, motels, and apartment buildings often require several outlets. In installations such as these, some amplification must also be provided. This amplification is provided by distribution amplifiers. Essentially, a distribution amplifier is a booster with multiple outlets. The antenna is connected to the distribution amplifier, and the TV receivers are connected to the outlets. In elaborate systems, divider networks may be employed in each leg to provide more outlets. Still more distribution amplifier systems may be inserted in the line to provide still more outlets.

Separate Antenna System

This system (Fig. 5-24) differs from the multiple antenna systems mainly in that a separate antenna is provided for each individual channel to be received. A group of pretuned amplifiers, one for each channel, is supplied to provide interference-free signals to each receiver outlet. In addition, individual resistance pads at the input of each channel amplifier are provided to enable the antenna technician to compensate for varying signal levels in any location.

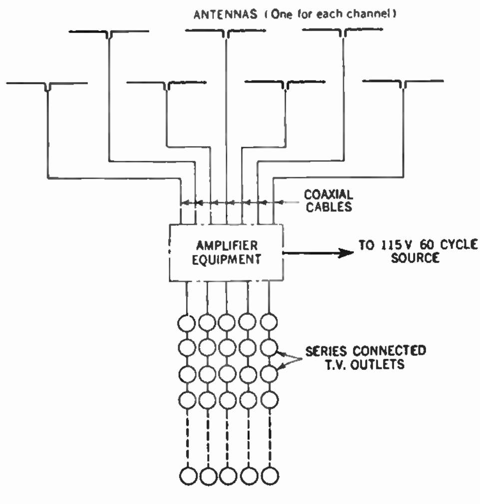


Fig. 5-24. Schematic of a multiple-outlet system with separate antenna for each channel.

In an installation of this type, it is important to separate the different channel antennas by a distance of 10 ft. or more to prevent any mutual coupling between them that may form a distorted picture. Coaxial cables are used to connect the antennas to the amplifiers in order to prevent noise pickup and match the input impedance of the amplifiers.

Troubleshooting MATV Systems

It is not always necessary to go through an entire troubleshooting procedure to pinpoint MATV troubles. A knowledge of what is a probable system malfunction can often provide helpful shortcuts. The following are the common causes of trouble symptoms in MATV systems.

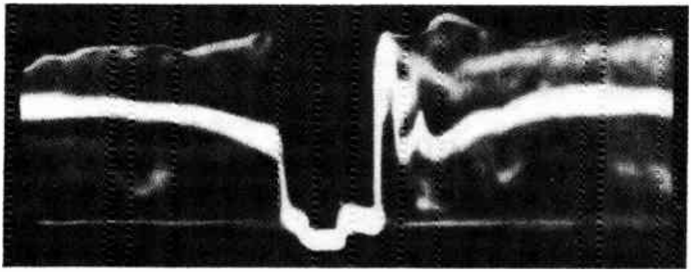
AC Hum—Hum interference appears as one or two stationary or rolling dark bars on the picture-tube screen. The technician should check with a portable-TV receiver to make sure that the hum isn't originating from a defective filter or circuit fault in the tenant's receiver. Then, if it is found that the hum is originating in the MATV system, it is most likely to be caused by a defective filter in the MATV amplifier.

Picture Rolling—When this symptom appears on one channel only, it is usually caused by sync compression in a single-channel amplifier. (See Fig. 5-25.) As an amplifier ages, tuning shifts can cause an AGC shift to produce increased gain, causing overload. The remedy is to troubleshoot the amplifier.

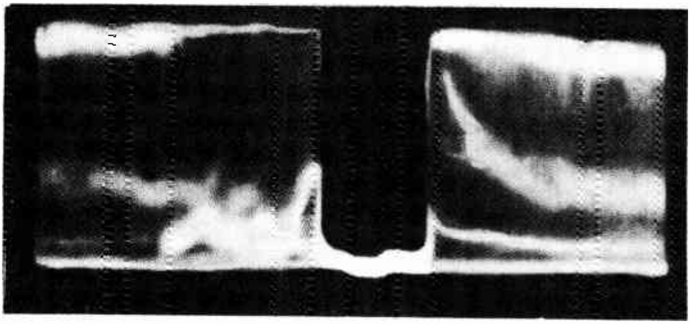
Cross Modulation in Broadband Systems—When this malfunction occurs, suspect first that signal levels may have been set in the past but the maintenance man or some tenant may have changed the amplifier gain setting.

Ghosts—Sometimes a tenant will attempt to compensate for receiver deterioration by taking more signal out of the MATV system. For example, a tenant might short-circuit the isolation arrangement in the tapoff unit. Although increased signal is obtained, the resulting impedance mismatch often causes ghosts along the trunk line. In some cases, ghosts occur because a tenant has extended the line and added more outlets. Since few tenants understand the principles of impedance matching, ghosts are usually produced as a result.

Snow—If snow is observed throughout the entire MATV system, the amplifier is immediately suspect. On the other hand, snow in a particular branch run is often caused by water entering a splitter or a tapoff unit. However, snow can also be caused by anything from a new building structure to a defective cable, faulty coax connector, or deteriorated TV receiver.



(A) Sync tip partially compressed.



(B) Sync tip completely compressed.

Fig. 5-25. Sync-tip compression due to nonlinear amplification.

SUMMARY

The actual selection of the type of antenna to be installed will depend on many factors. The first step in any antenna installation is a survey of the location. Look over the house to note the type of construction, such as brick, stone, frame, etc., and the type of roof. The distance from the transmitting antenna is also an important factor.

Another important decision that must be made in the initial installation is how to support the antenna. Again, one of the primary factors in the determining the selection is the distance from the transmitting antenna. In areas where the signal is strong, any installation can be used; in fringe areas, tall towers are usually necessary.

Guy wires must be attached to practically every antenna installation to support the mast or tower. The only exceptions are self-supporting steel towers, which are set deep in concrete, or eave and roof installations, which extend only a few feet above the roof. In general, separate guy-wire systems should be attached for each 10 ft. in height for masts.

Most television receivers have a 300-ohm input circuit, which must be connected to a 300-ohm antenna system. Failure to observe proper impedance match between antenna and receiver will result in the undesirable effects of noise and interference. Where interference may be picked up by the antenna lead-in itself, shielded coaxial cable should be used. Since coaxial cable is normally not available with a 300-ohm impedance, impedance-matching transformers should be used.

REVIEW QUESTIONS

1. What should be the first step to consider when planning an outside antenna system?
2. What determines the type of antenna to use?
3. What determines the type of antenna mast?
4. Can one outside antenna serve more than one TV receiver? If so, how?
5. When should guy wires be used?
6. What is the purpose of the lightning arrester?
7. What is a master antenna system (MATV)? CATV?

CHAPTER 6

Television-Receiver Placement and Adjustment

The proper placement of a television receiver, of course, depends upon such factors as the layout of the house, number and size of the individual rooms, lighting arrangement, location of power outlet, and antenna lead-in. In some cases, the type of power outlet is a matter of importance. For example, most receivers may be plugged into switched outlets. Some receivers provide digital readout, with channel number and the time displayed on the screen when so commanded (see Fig. 6-1). The digital clock should always be operated from an unswitched outlet; otherwise, the indicated time is likely to be in error.

Courtesy the Heath Co.

Fig. 6-1. TV receiver with digital clock and channel indicator.

The following points should be taken into consideration:

1. Do not place the receiver in such a position that direct illumination, such as light from a window, falls on the face of the screen. A certain amount of background illumination is desirable when viewing over long periods of time to reduce eyestrain.
2. Do not place the cabinet directly against the wall. Leave a 2-in. air space so that adequate ventilation will be ensured. In addition, the receiver must be installed a sufficient distance from any heating device, such as vents and radiators, as the effect of heat will impair its operation or even damage the receiver.
3. It is desirable to locate the receiver as far as possible away from sparking or gaseous electrical discharge devices, such as neon display signs and electrically operated cash registers.
4. If the receiver is to be connected to an outside antenna, proper attention should be given to the location of the antenna lead-in and the power outlet to prevent excessive length of these connector leads. A typical receiver location is shown in Fig. 6-2.

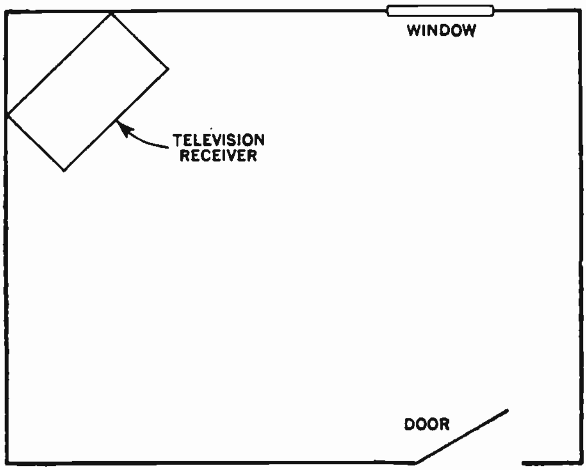


Fig. 6-2. Typical receiver location.

With respect to the decorative scheme of the home, most decorative authorities agree on the following points:

1. The room containing the television receiver should be so planned that viewers can enjoy a program without first upsetting and rearranging the room.
2. Lighting should be arranged so as to prevent the light from shining directly on the screen or into the viewer's face.
3. The television receiver should not be so dominant in design or location that viewers have to sit and face it when not in use.

Other factors, such as seating arrangements, type of chairs, use of stools or hassocks, and their individual characteristics of comfort and convenience must be left to individual taste and suitability. Some owners prefer to have their principal television receiver placed in a corner of the living room, while others prefer to have it or a second receiver in the family room, den, library, or study if such are available.

In recent years, a second or third television receiver has been added to many homes. Children's rooms, basement recreation rooms, and kitchens are popular locations for an additional receiver—often a portable receiver (Fig. 6-3), which can be rolled or carried anywhere in the house or even outdoors wherever power is available. All portable receivers are completely transistorized (except for the picture tube, of course), and some even operate on self-contained batteries that can be carried anywhere.

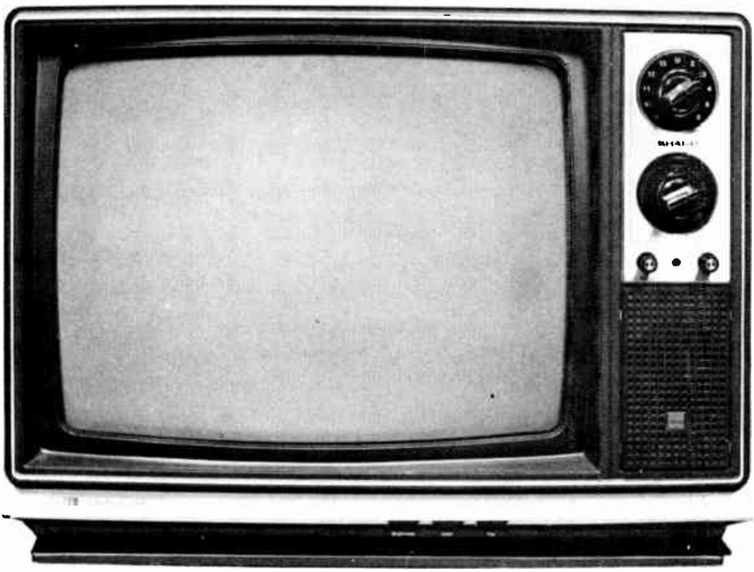


Fig. 6-3. Typical portable television.

Television Lighting—In the early days of television, many people would turn out all the lights and sit in the dark watching the bright spot of the television receiver on the other side of the room. Soon, the eyestrain from such a setup became apparent, and all types of special TV viewing lights made their appearance. Improvement in the viewing screen of television picture tubes and education of the viewing public soon made all of this unnecessary. All that is necessary is to make sure that the lighting (either sunlight or artificial) does not cause a glare on the screen or shine in the viewers' eyes while they are watching the receiver.

TELEVISION CONTROLS

Any piece of electronic equipment must have provisions for adjustment before proper operation can be obtained. The television receiver is no exception—every television receiver contains several controls that are varied to obtain the proper reproduction of the picture and sound transmitted by the station.

Some adjustments must be varied more often than others; hence manufacturers place some controls on the front side or top of the the TV cabinet, where they are readily accessible to the operator. Other controls require less frequent adjustments, and so they are located on the rear panel of the chassis, the chassis itself, or on the neck of the picture tube. The readily accessible controls are termed *operator controls*, while the others are called *service adjustments.*

Manufacturers differ, however, in the number and type of controls they include for operating controls and the ones they make service adjustments. In addition, depending on the chassis design, some receivers will contain controls that are not on others. Also, the terms used to identify the same control vary. Typical service adjustments are shown in Fig. 6-4.

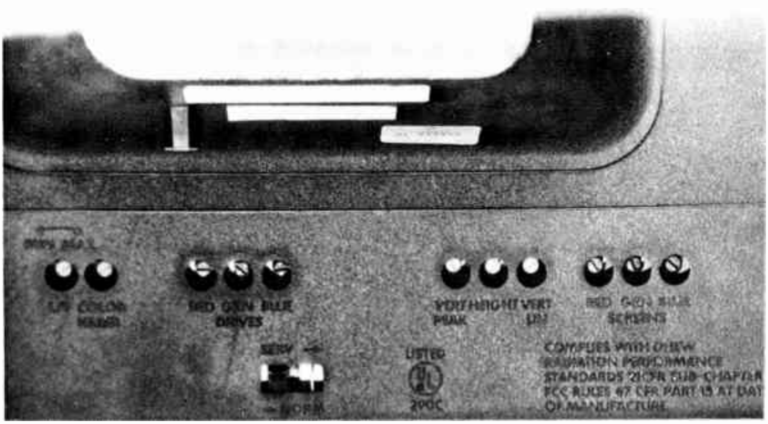


Fig. 6-4. Typical service adjustments.

In general, however, the operating controls affect the program selection and the picture and sound quality, while the service adjustments (also called *preset controls*) affect picture quality, position, or spacing.

The following controls are most often placed as operating controls; however, as mentioned previously, all these controls will not be accessible in all receivers:

1. On-off switch and volume control
2. Channel selector
3. Fine-tuning control
4. Contrast control
5. Brightness control
6. Horizontal-hold control
7. Vertical-hold control

Most of these controls will not need adjustment during normal reception; however, they require more frequent adjustment than the other controls. As receiver design improves, these controls require less frequent adjustment, and so they may be moved to the rear of the chassis. For example, the last two controls listed are not included as operator controls by many manufacturers.

Dual Controls—In order to simplify the operation to improve the appearance of the cabinet, dual controls, with concentric knobs, are often employed. That is, the controls are arranged in pairs of two: a small inner knob and a larger outer knob, each affecting only one-half of the dual control. For example, the channel-selector and fine-tuning controls are commonly dual knobs; also, contrast and brightness controls are often similarly arranged.

Some manufacturers arrange some of the controls behind a hinge panel (Fig. 6-5). Controls that are included behind covers do not need to be reset each time the receiver is operated, and so their lack of accessibility is more than compensated for by the improvement in appearance.

THE TEST PATTERN

Before the operation and proper adjustment of the various controls can be understood, the test pattern and the part it plays

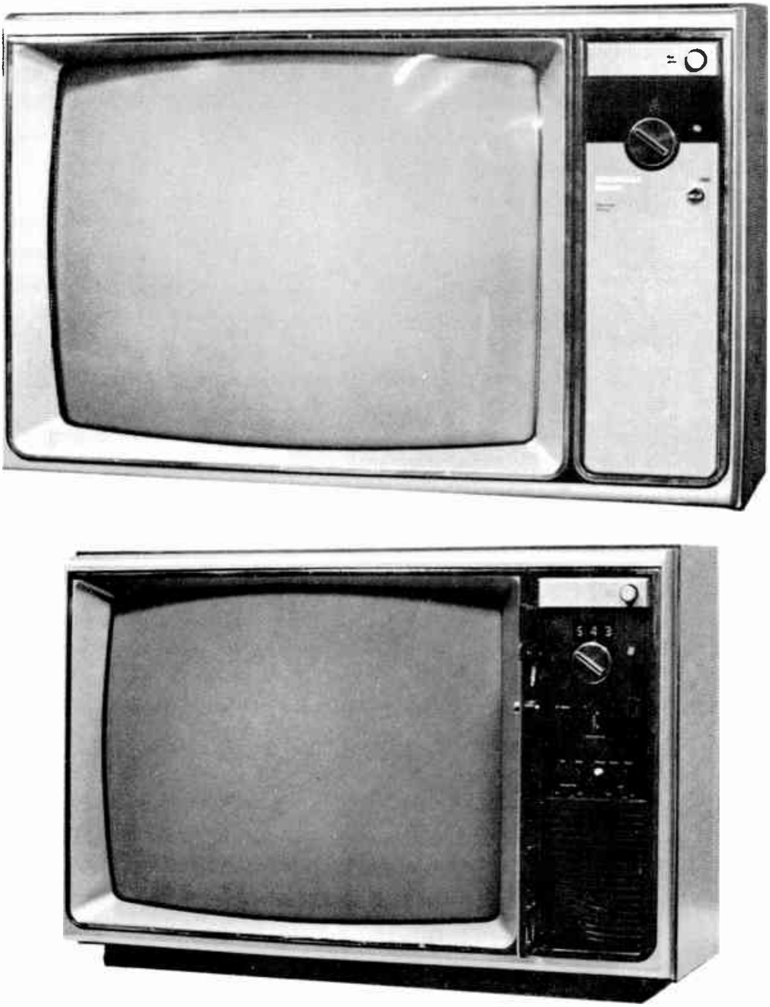


Fig. 6-5. Controls hidden behind swing-out panel.

in adjustments must be understood. Figure 6-6 shows standard test patterns. Many TV stations transmit patterns similar to these before they begin transmitting regular programs for the day. Such patterns are also available from pattern generators—a piece of test equipment (see Fig. 6-7).

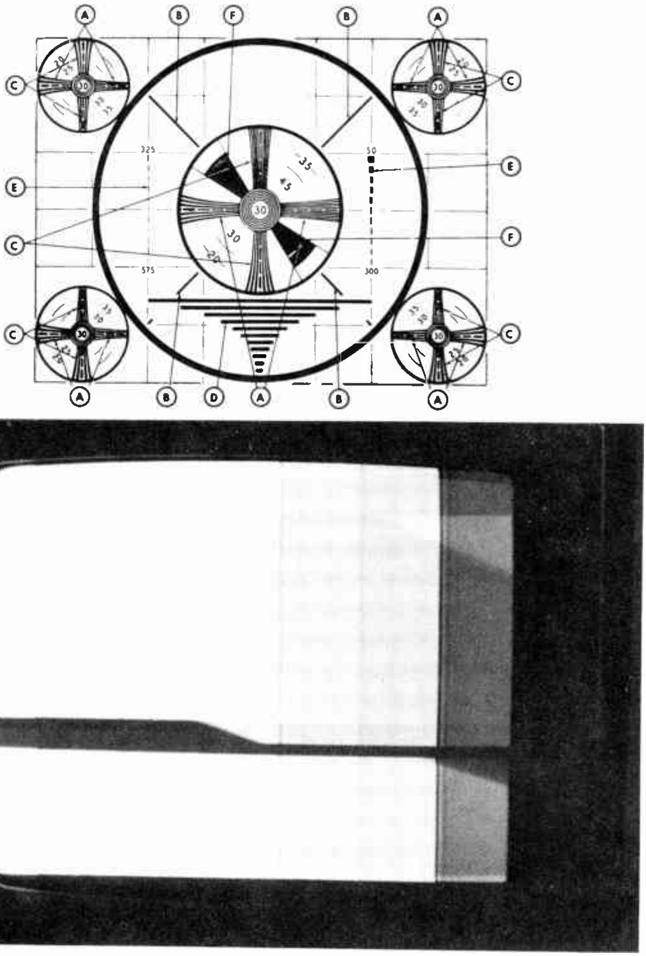


Fig. 6-6. Typical test patterns.

Station test patterns usually will not include all the features shown in Fig. 6-6, but they will include station identification. When a station is transmitting a test pattern, the sound will consist of a single tone transmitted continuously. Many stations begin their programs so early in the day that they do not transmit test patterns.

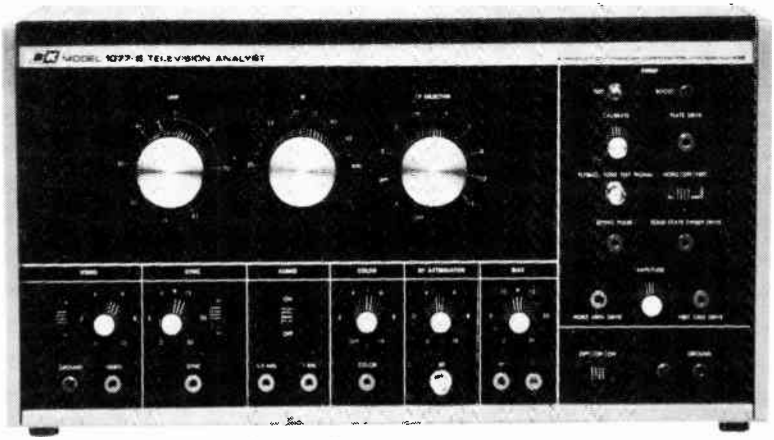


Fig. 6-7. Service-type pattern generator.

The function of a test pattern is to furnish an accurate means of comparing the picture that appears on the picture tube with that set by the television camera. If the two are identical, it would indicate completely perfect transmission and reception throughout the entire system. Such a condition, of course, is impossible to accomplish; however, it can be closely approximated. In addition, such factors as aspect ratio, resolution, linearity, contrast, brightness, and focus can be easily checked using the patterns in Fig. 6-6.

Aspect Ratio

The *aspect ratio* of a picture determines its proportions. The television standards followed by all United States television stations state that the aspect ratio shall be 3:4, which means that the height is ¾ times the width of the picture. The faint vertical and horizontal lines across the pattern in Fig. 6-6 can be used to determine the aspect ratio. Note that there are 6 horizontal lines and 8 vertical lines. Thus, the picture is divided in 6 parts vertically and 8 horizontally, giving an aspect ratio of 6:8, or 3:4.

Resolution

The term *resolution* means the extent to which the details of the televised picture are separated. *Vertical resolution* is determined by the number of separate and distinct horizontal lines that the system can reproduce. It depends largely on the following:

1. Number of scanning lines employed
2. Size of the scanning beams in both the camera tube and picture tube
3. Sensitivity of the camera tube and other elements of the transmitting apparatus

Vertical resolution is determined by the number of separate individual horizontal lines that the system is capable of reproducing from the top to the bottom of the screen. To determine the vertical resolution, look at the horizontal wedges (A) and note the point where the lines are no longer separate and distinct. The breaks in the center line of the wedge indicate 50-line intervals. These 50-line intervals are indicated by the numbers placed diagonally within the circle, except that the last zero is omitted. For example, if the lines tend to merge together at the break opposite 35, the vertical resolution would be 350 lines.

To check *horizontal resolution*, or detail, the vertical wedges at the center and each corner (indicated by the letter C) are used. The amount of detail is determined by the number of separate and distinct vertical lines that can be reproduced side by side. The horizontal detail at each break in the center line is shown at 50 line intervals, as explained for the horizontal wedge.

Linearity

Linearity refers to the uniformity of distribution of the pattern on the screen. When the conditions of the electron beam in the picture tube are such that the beam does not move at constant speed, the objects in the picture will be distorted in shape. As a result, the picture is said to have poor linearity.

Both vertical and horizontal linearity can be checked by observing the black circles in the pattern. If perfect linearity is present, the circle is geometrically flawless. If it is distorted at the top or bottom, vertical nonlinearity is present; if the sides are distorted, horizontal nonlinearity is present.

Brightness and Contrast

Brightness and contrast must be present in suitable proportions for a pleasing picture. Brightness without adequate contrast actually reduces the clarity of the picture. Contrast depends upon the amount of change of the video voltage applied to the picture-tube grid, that is, its peak-to-peak swing. The contrast control affects the picture in the same manner as the volume control affects the sound. Brightness of the picture depends upon the direct current or average value of the video signal at the picture tube.

The correctness of the contrast and brightness control setting can be checked by the shaded wedges that extend diagonally from the upper left to the lower right near the center of the test pattern (labeled F in Fig. 6-6). The wedges contain different shades, ranging from light gray to black. When the brightness and contrast control are properly set, distinct differences in shading should be noted for each step.

Focus

The test pattern can also be used to check for correct focus. Observe the pattern to see if the image is sharply defined. If each element of the pattern is sharp and crisp, the focus is correct; however, if the image appears blurred and the lines are fuzzy, improper focus is indicated.

Interlace

Proper interlace is determined by observing the diagonal black lines labeled B in Fig. 6-6. Poor interlace causes these lines to become jagged. When interlace is proper, the lines are sharp and straight.

OPERATOR CONTROLS

The operator controls for two typical modern television receivers are shown in Figs. 6-3 and 6-4. The receiver shown in

Fig. 6-3 is typical of VHF-UHF receivers. It has separate knobs for tuning the VHF and UHF channels. In addition, volume and contrast controls, as well as the on-off switch, are included as operator controls. The number of operator controls on other receivers will vary from those in Fig. 6-3. For example, the one shown in Fig. 6-4 includes many controls that are normally service adjustments.

As mentioned previously, the operator control may require adjustment each time the TV set is turned on, although most will not. The most popular operator controls and their functions are as follows:

On-Off Switch and Volume Control

The purpose of the on-off switch and volume control is to turn the receiver on and off and to adjust the sound volume to the desired level. The on-off switch is usually included with the volume control.

Channel Selector

The channel-selector control consists of a simple selector switch by means of which the correct channel number of the desired station can be selected. The channels presently employed are Nos. 2 to 83. Some receivers tune only the VHF channels (2 to 13), and others have a separate tuning knob for the UHF channels (14 to 83), as shown in Fig. 6-3.

Fine-Tuning Control

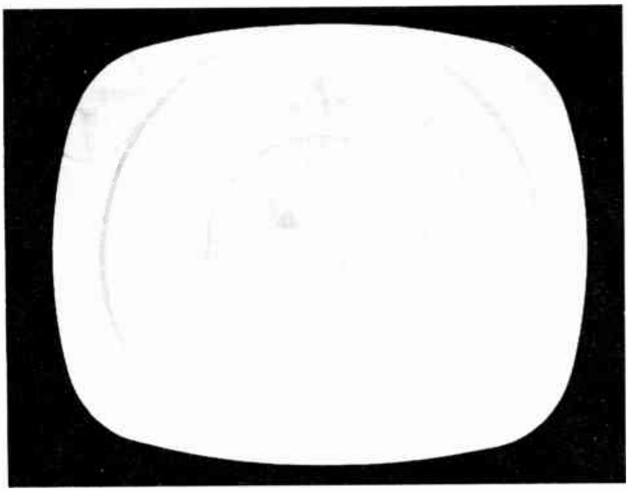
This control tunes the receiver for the best sound and picture. After the proper channel is selected, adjust the fine-tuning control to obtain the best picture quality. In sets employing preset fine tuning, this control can be set for each channel when the set is installed and will seldom need readjustment.

Contrast Control

A variation in the amount of background light or picture shading is provided by the contrast control. Adjust for correct contrast between light and dark areas of the picture.

Brightness Control

The brightness control sets the picture brilliance, or overall brightness of the screen. If the brightness control is set too high, the picture appears "washed out" and bright diagonal retrace lines may appear on the screen, as shown in Fig. 6-8. The contrast control should be used with the brightness control to obtain the best contrast and brightness ratio.



Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 6-8. Test pattern showing effect when brightness control is set too high.

Horizontal-Hold Control

The horizontal-hold control is an adjustment of the horizontal synchronization circuits. Misadjustment of this control will cause the picture to move either right or left, or, in extreme cases, it will cause black-and-white horizontal bars to appear on the screen, as shown in Fig. 6-9. This control should be adjusted until the picture appears, is centered, and there is no horizontal movement.

Vertical-Hold Control

When switching from a strong to a weaker station, sometimes it may be necessary to readjust the vertical-hold control. Misad-

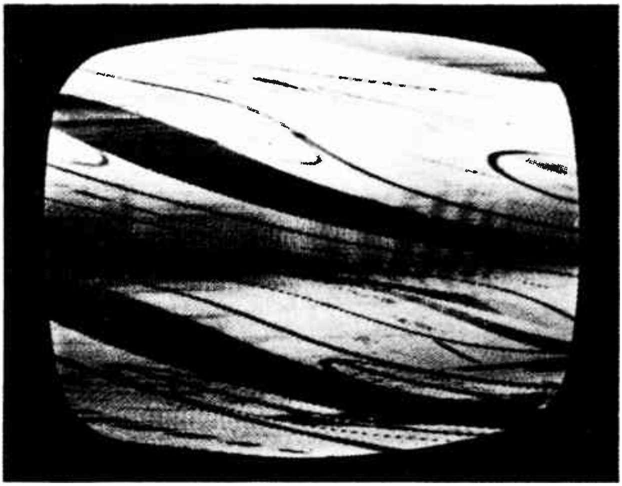


Fig. 6-9. Test pattern showing misadjusted horizontal-hold control. The more the horizontal-hold control is misadjusted, the more diagonal bars appear; as correct adjustment is approached, fewer bars appear.

justment of this control will cause the picture to roll up or down, as shown in Fig. 6-10. This control should be adjusted so that there is no vertical movement in the picture.

STEP-BY-STEP TUNING PROCEDURE

In order to select a particular station and adjust the various controls for correct picture and sound reception, proceed as follows:

1. Turn the volume control about one-half turn clockwise; this supplies power to the receiver.
2. Turn the channel selector so that it indicates the number of the desired station channel.
3. Turn the fine-tuning control for best detail of the picture and good sound.
4. If necessary, adjust the horizontal- and/or vertical-hold controls to properly synchronize the picture.

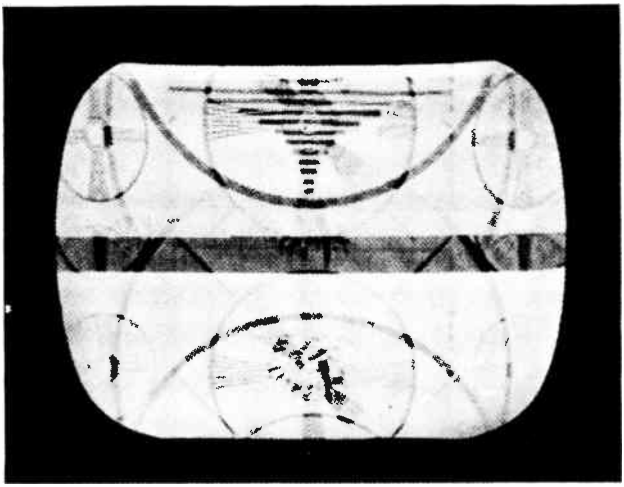


Fig. 6-10. Test pattern showing misadjusted vertical-hold control. As correct adjustment is approached, the pattern moves slower and slower until it locks in position.

5. Adjust the contrast and brightness controls to obtain the proper shading and overall brightness in the picture; that is, it should have good deep blacks, whites, and intermediate shades of gray.
6. Readjust the volume for the most pleasing reproduction.

After the receiver has been adjusted as indicated, the volume control should by used only to turn the receiver on or off between the desired programs unless some other station is to be tuned in.

PRESET, OR SERVICE, ADJUSTMENT CONTROLS

The preset, or service, adjustments are factory adjusted for optimum performance; however, it is usually necessary to make some adjustments at the time of installation. The service adjustment controls usually consist of the following:

1. Focus control
2. Vertical size (height)
3. Vertical linearity
4. Horizontal size (width)
5. Horizontal linearity
6. AGC

Depending upon the design of the receiver, some of these controls may be located at the front or side of the cabinet, whereas others may be located in the rear of the chassis. In addition, all the controls may not be included in all receiver designs, and other receivers may include controls not listed in the foregoing. Three arrangements for service controls are shown in Figs. 6-11 and 6-12. In other receivers, other arrangements will be employed.

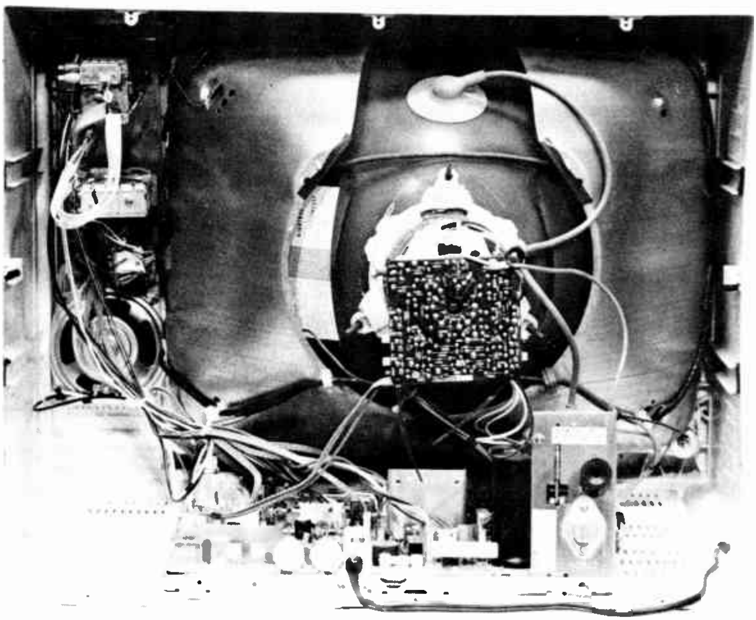


Fig. 6-11. Rear view of a television with the cover removed.

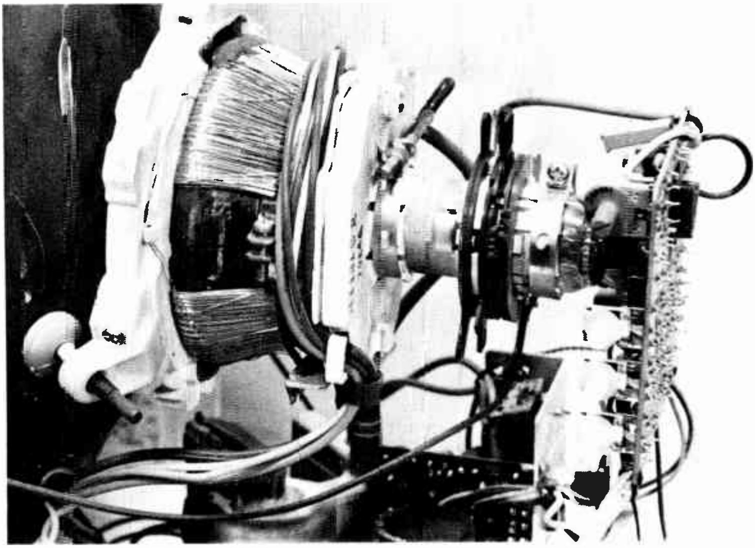


Fig. 6-12. Service controls mounted on the neck of the picture tube.

Focus Adjustment

If the various elements in the picture are not sharp and crisp but appear blurred and printing is difficult to read, the focus should be adjusted. Proper focus is obtained by looking at the horizontal scanning lines that make up the picture and adjusting for minimum width of the lines.

Various means are employed for adjusting the focus. In some receivers, a control on the rear panel is rotated until the best focus is obtained. In others, a screwdriver adjustment or flexible shaft extending from the focus unit around the neck of the tube is adjusted until proper focus is obtained. In still another arrangement, a terminal strip that provides a choice of three or four different voltages is located on the chassis. A lead from the picture-tube socket is connected to the terminal that gives the best focus. Usually a clip arrangement is provided to facilitate this connection. The result of an improperly adjusted focus control is shown in Fig. 6-13.

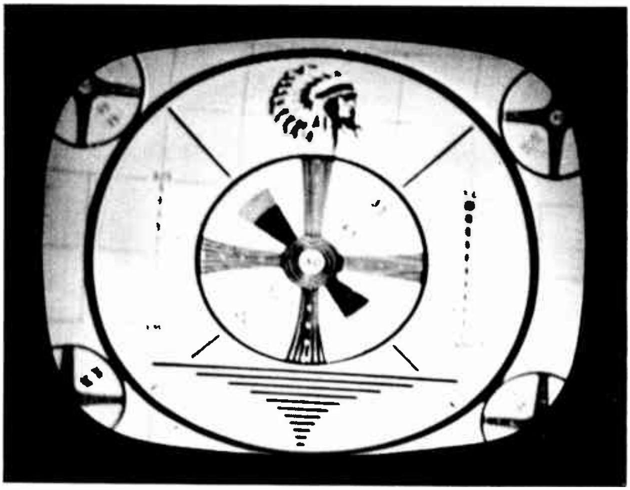


Fig. 6-13. Test pattern showing effect of misadjusted focus control.

Height and Vertical-Linearity Control

These controls should both be adjusted at the same time, preferably while a test is being transmitted. The linearity control affects the upper portion of the picture (Fig. 6-14), while the height (size) control affects primarily the lower portion but also the overall picture (Fig. 6-15). Adjust both controls simultaneously until the test pattern is symmetrical and fills the entire screen vertically. Readjust the vertical-hold control if necessary.

Width Control

Control of picture size in the horizontal direction is accomplished by means of the width control. If the picture does not fill the screen horizontally (Fig. 6-16), adjust the control until the picture fills the screen. If an abnormally low line voltage makes it difficult to obtain sufficient picture width using the width control, changing the horizontal-drive control (if present) may prove helpful. Note that although the width control may be an ordinary variable-resistance control, it is often the slug in a variable inductance. In other receivers, a plastic sleeve with a piece of copper

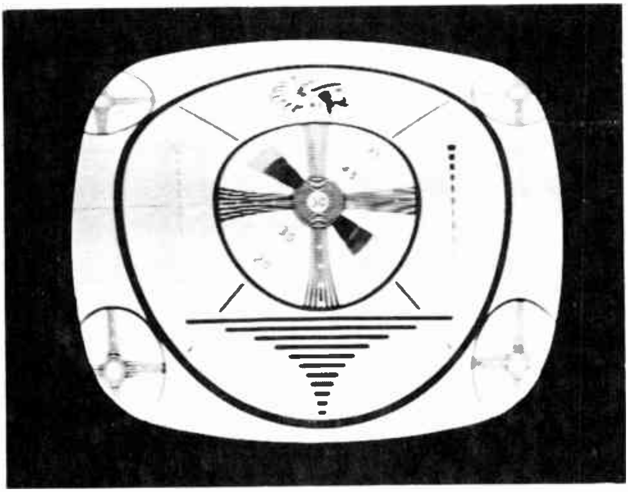


Fig. 6-14. Test pattern showing effect of misadjusted vertical-linearity control.

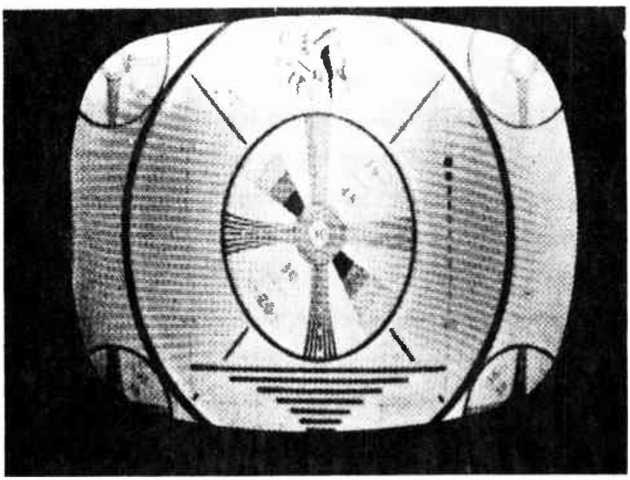


Fig. 6-15. Test pattern showing effect of misadjusted height control.

embedded in it is inserted between the neck of the picture tube and the deflection yoke. The width is varied by sliding the sleeve in and out on the neck. In still other receivers, no width control is included.

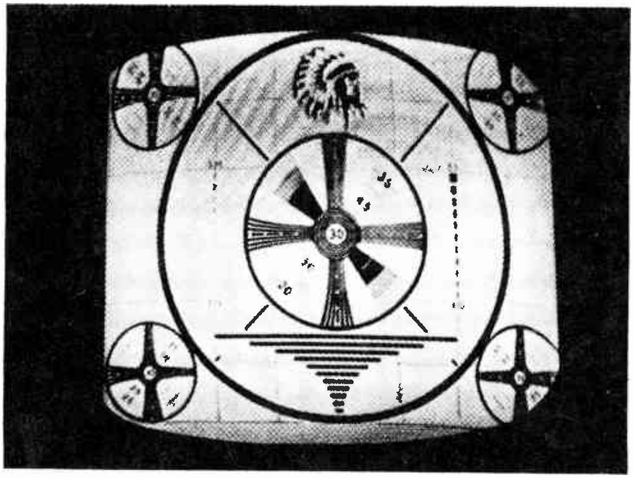


Fig. 6-16. Test pattern showing effect of misadjusted width control.

Horizontal Linearity Control

This control should be adjusted for best possible horizontal linearity. In the event that proper horizontal linearity (Fig. 6-17) cannot be obtained by adjusting this control, then change the setting of the horizontal-drive and/or-width control. Like the width control, the linearity control is most often the slug of a variable inductance. In other systems, no control, as such, is included, but linearity is adjusted by changing the position of small magnets that extend from the neck of the picture tube. In still other receivers, no provisions are included for adjusting the linearity.

Horizontal-Drive Control

Misadjustment of the horizontal-drive control (not included in many chassis) results in the symptoms shown in Fig. 6-18. If white vertical bars, black beaded lines, or foldover appears in the picture, the drive control should be adjusted.

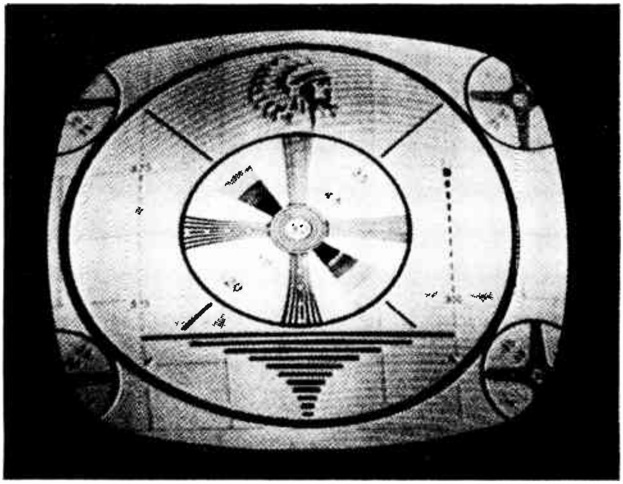


Fig. 6-17. Test pattern showing effect of misadjusted horizontal-linearity control.

AGC Control

Many receivers contain some type of AGC control. Many names are used for these controls, but all perform essentially the same function. In some receivers, a variable-resistance control may be employed. When the AGC control is misadjusted, the symptoms can range from a weak, snowy picture to an overloaded one. (In an overloaded picture, everything is much darker than normal, and partial or complete loss of horizontal or vertical sync may occur. Often, these symptoms are accompanied by a buzz in the sound.) The AGC control should be set to produce the best picture quality. Correct setting may change with picture strength.

Tilted Raster

A tilted raster condition (Fig. 6-19) makes the test pattern or picture appear in a slightly tilted position. The remedy consists of rotating the yoke until the situation is corrected. In some receiv-

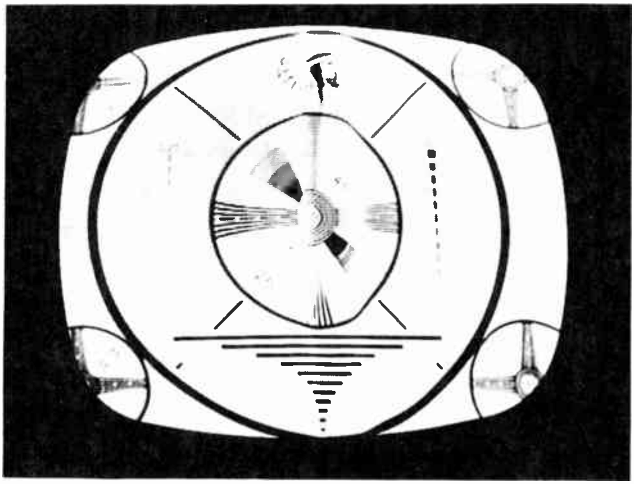


Fig. 6-18. Test pattern showing effect of misadjusted horizontal-drive control.

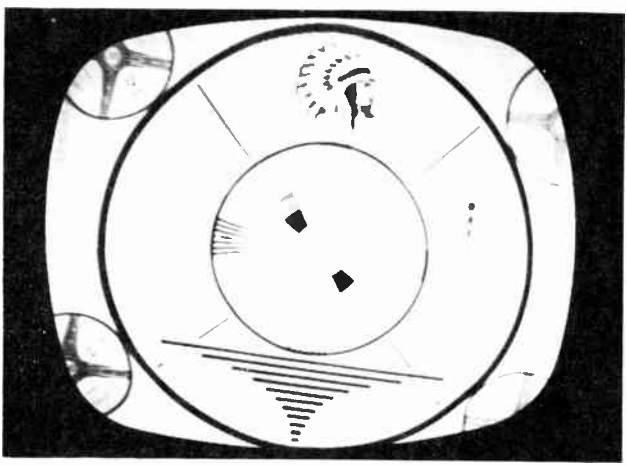


Fig. 6-19. Test pattern showing effect of misadjusted deflection yoke.

ers (Fig. 6-20) a thumbscrew must be loosened before the deflection yoke can be rotated. This locking screw should be retightened after the operation. In others (Fig. 6-21) no locking screw is employed.

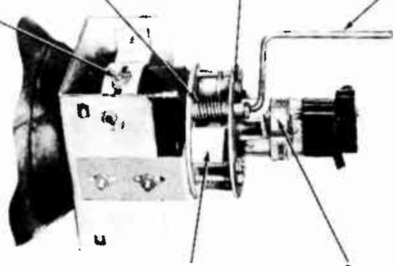


Fig. 6-20. Neck of a picture tube in a TV receiver that employs a deflection yoke with a retaining screw and a permanent-magnet-focus device with positioning lever.

Centering

Figure 6-22 shows a test pattern with the horizontal centering misadjusted. A similar condition will exist when the vertical centering is misadjusted except, of course, the blank space will be at the top or bottom of the screen (Fig. 6-23). The centering adjustments will be located on the rear panel of the chassis or on the neck of the picture tube. In some early receivers, two control—labeled *vertical centering* and *horizontal centering*—were located on the rear of the chassis. These controls are rotated until the picture is properly centered. (*Note:* The width and height controls may need readjustment after the picture is properly centered.)

In another method, centering is accomplished by moving a positioning lever attached to a magnetic shunt in the focus coil (Fig. 6-20). This lever is used for both horizontal and vertical adjustments. Still another method employs a tab that extends from the top of the focus coil and is secured with a thumbscrew. To adjust this type of arrangement, loosen the thumbscrew and move the tab up and down and to the right and left until the picture is properly centered.

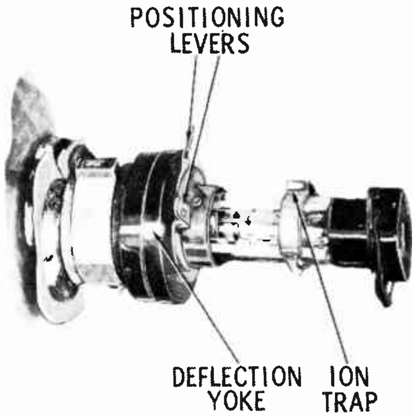


Fig. 6-21. Neck of a picture tube in a TV receiver that employs an unsecured deflection yoke and two magnetized for a centering device.

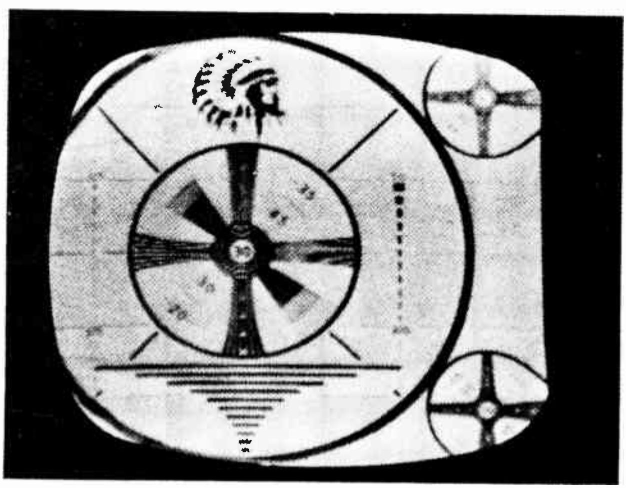


Fig. 6-22. Test pattern showing incorrect horizontal centering.

In most popular centering arrangements for modern TV receivers, two magnetized rings are included on the neck of the tube, as shown in Fig. 6-21. Attached to these rings are tabs which are rotated until the picture is properly centered.

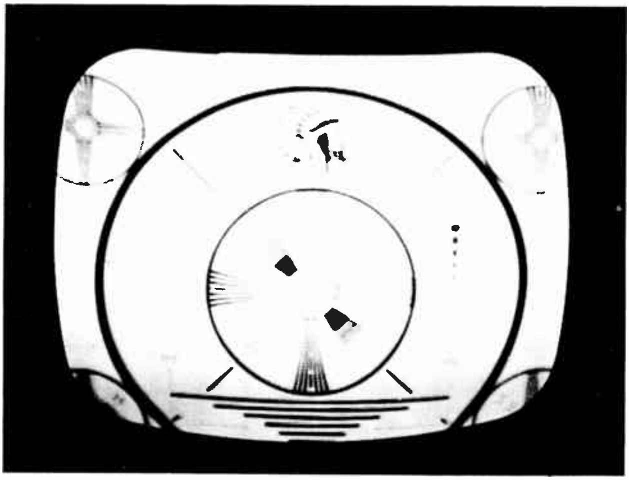


Fig. 6-23. Test pattern showing incorrect vertical centering.

In each of the centering methods employing adjustments on the neck of the tube, there is a certain amount of interaction between the adjustments. Work slowly and carefully until you "get the feel" of the adjustment. Extreme care should be employed to be sure that you do not place undue strain on the neck of the picture tube.

Eliminating Semicircular Shadows

Semicircular shadows (Fig. 6-24) are caused by the electron stream striking the neck of the tube. If the condition cannot be corrected by adjusting the centering controls, it can usually be corrected by applying one or a combination of the following procedures:

1. Make sure that the deflection yoke is positioned as far forward as possible.
2. Reposition the focus coil by readjusting the holding nuts to shift the coil forward.
3. In the event the neck shadow cannot be eliminated by the foregoing procedure, raise or lower the entire yoke and focus-coil assembly so that the focus coil can be repositioned vertically with respect to the tube neck.

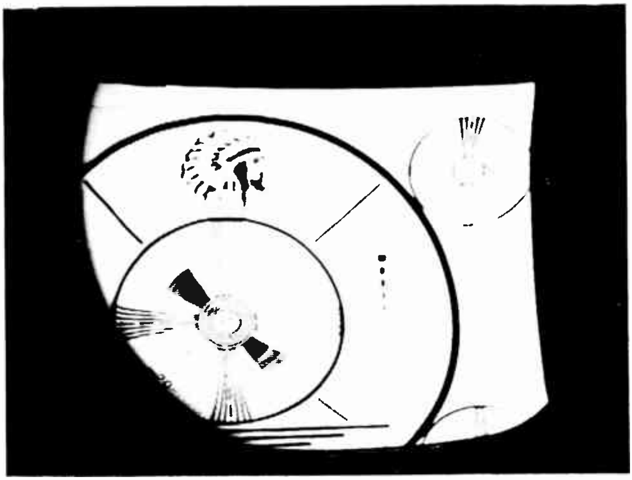


Fig. 6-24. Test pattern showing neck shadow caused by an improperly adjusted centering control.

SUMMARY

The proper placement of a television depends on many factors, such as room layout, size of rooms, lighting arrangements, power outlets, and antenna lead-in. In choosing a location for the TV receiver, remember to keep direct sunlight from windows from falling on the face of the screen. Naturally, heat is always a problem, and so the cabinet should never be set directly against the wall or close to a heat vent or radiator, etc.; the effect of the heat will impair its operation or even damage the receiver.

Every television receiver contains several controls that are varied to obtain proper picture contrast and sound transmission. Some adjustments must be varied more often than others; hence, manufacturers place some controls on the front, sides, top, or other convenient place on the cabinet where they are readily accessible. These controls are called operator controls.

Other controls, called service adjustments, are located on rear panels of the chassis, the chassis itself, or, in some cases, the neck of the picture tube. Most of these controls are needed as adjustments during normal reception. These controls, or adjustments, generally include focus, vertical height (size), vertical linearity, horizontal width (size), horizontal linearity, and AGC.

REVIEW QUESTIONS

1. What is the difference between operator controls and service adjustments?
2. What adjustments are considered to be operator controls?
3. What is meant by resolution?
4. What is meant by aspect ratio?
5. What is the purpose of the deflection-yoke adjustments?

CHAPTER 7

Television Interference

After all the necessary adjustments have been made, the picture may have certain defects altogether different from those described in Chapter 6. A multitude of patterns may be superimposed upon the normal picture. These patterns are produced by man-made disturbances usually termed *interference*.

As an illustration, when two receivers are operated directly from the same antenna, it may happen that mutual interference occurs, as shown in Fig. 7-1. This type of interference is caused by front-end radiation, and the reception on both receivers will usually be substantially normal on certain channels. On other channels, it can happen that receiver A interferes with receiver B; while on still other channels, receiver B interferes with receiver A. The cure for this trouble is to use a two-set coupler that provides ample isolation between the receivers.

As evidenced in radio-broadcast reception, interference is recognized by a burst of noise or continuous background noise. In television reception, interference is evidenced by a burst of light

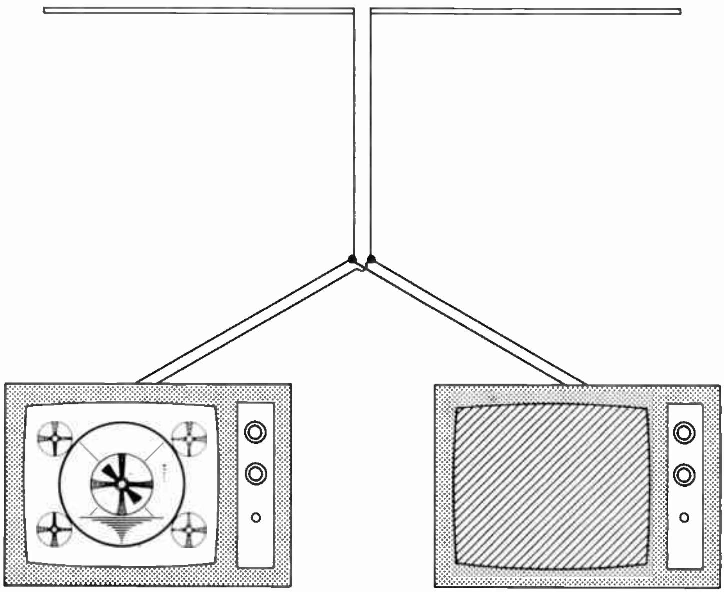


Fig. 7-1. Two receivers operated directly from the same antenna, which can result in mutual interference.

upon the picture screen, momentary "tear out" of the picture, formation of various patterns on the screen, or small spots of light in the picture. Fig. 7-2 shows the appearance of "snow" on a picture-tube screen.

Since television receivers are designed to operate at much higher frequencies than broadcast-band radio receivers, the sources of interference are not the same for the two types of receivers. A television receiver is almost immune to weather-produced interference, which is most common in radio reception.

Some forms of interference are easily identified by an analysis of the interference patterns formed on the screen. After they are identified, corrective measures can be applied to eliminate them. Other types of interference, however, are not so easily identified; and, in some cases, there are no known corrective measures.

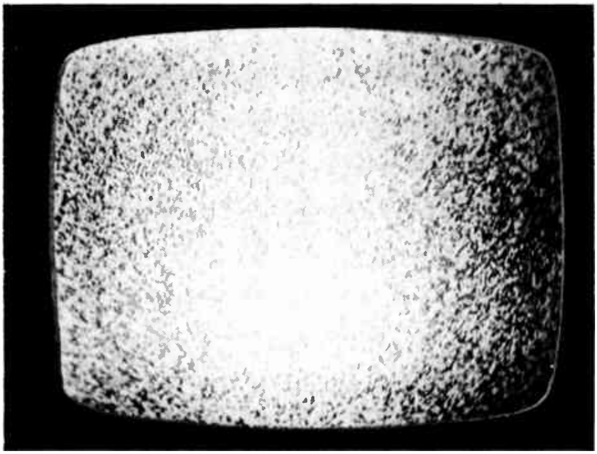


Fig. 7-2. "Snow" pattern on picture-tube screen.

It is of paramount importance, therefore, that every service technician be thoroughly acquainted with the various forms of interference affecting television reception and know how to identify each type. Proper identification may mean success or failure in correcting the trouble because if there is no clue as to what is causing a particular type of interference, no corrective measure can be applied to it. Figure 7-3 shows the appearance of a 60-hertz hum bar in the picture.

To anticipate subsequent discussion, it will be observed that interference may be either external or internal. In other words, if one receiver is interfered with by another receiver, the source of interference is external. On the other hand, a snow pattern exemplifies internal interference; receiver circuit noise is the source of the snow in most cases. Again, if a 60-hertz hum bar appears in the picture, the source of the interference is usually internal. Another example is shown in Fig. 7-4, where Barkhausen oscillation produces the vertical black line at the left of the screen. The source of this type of interference is in the horizontal-output stage of the receiver.

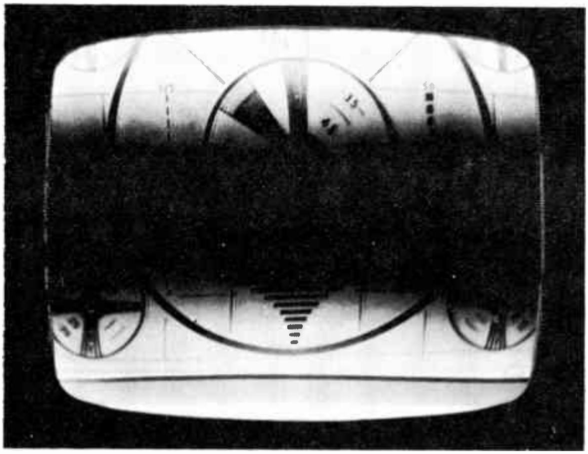


Fig. 7-3. Appearance of 60-hertz hum bar in the picture.

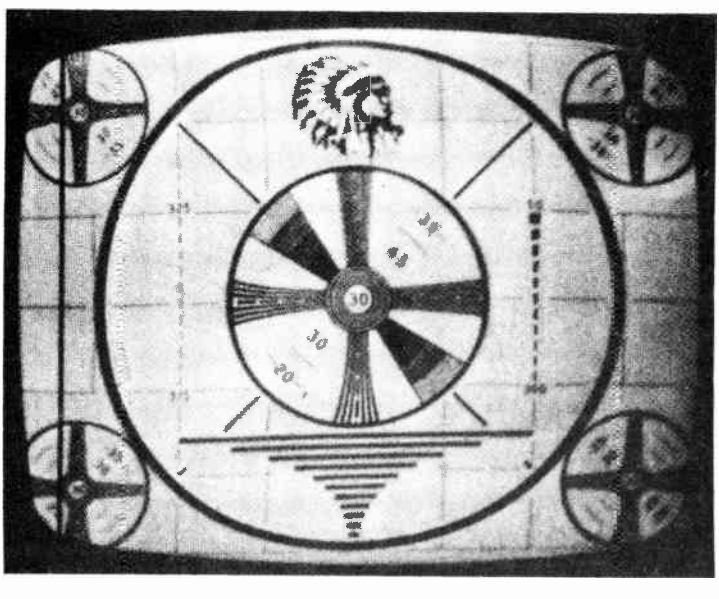


Fig. 7-4. Barkhausen oscillation.

COMMON TYPES OF INTERFERENCE

Television receivers are greatly affected by man-made noise arising from various types of electrical apparatus. Some types of interference frequently encountered by television service technicians are listed below. (They are not necessarily listed in order of their importance or frequency of occurrence.)

1. Ignition or spark
2. Diathermy
3. Germicidal-lamp radiation
4. 4.5-MHz sound-beat pattern
5. Police, amateur, and other stations
6. Two or more nonsynchronized TV carriers on same channel
7. FM transmitter heterodyning with local oscillator in receiver
8. Radiation from local oscillator in a neighboring FM or TV receiver
9. Oscillation in video IF amplifier
10. Barkhausen oscillation from the horizontal-deflection generator
11. Reflections or ghosts

Ignition Interference

Ignition interference from trucks, automobiles, and aircraft may be identified by streaks and splashes on the picture. The ignition system of trucks will produce the most intense interference pattern. It usually consists of a series of broken horizontal dark lines, as shown in Fig. 7-5, the number or spacing of which depends on the frequency of the offending spark.

Aircraft in the vicinity may also produce interference that is usually identified by a temporarily fluctuating picture, usually lasting only a few seconds. Since the noise from the aircraft is usually heard at the time the fluctuation of the picture occurs, identification of this type of interference is comparatively easy.

Interference of this same type can occur from high-voltage and corona discharge in the high-voltage supply of the receiver, as well as in high-tension lines near the receiver location. In addition, electric motors, doorbells, buzzers, and signaling systems, such as teletype machines, usually generate an interference pattern similar to that made by ignition systems.

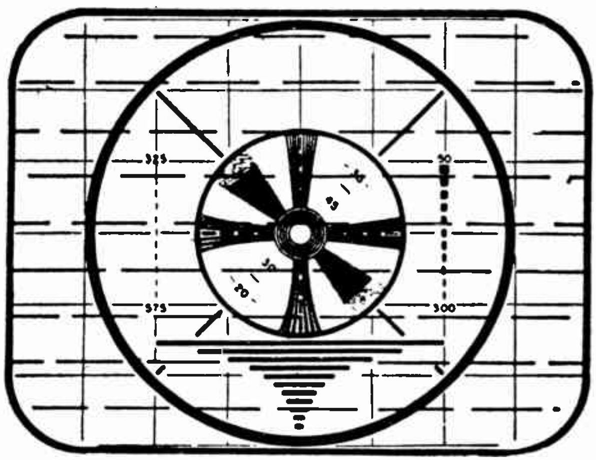


Fig. 7-5. Test pattern showing effect of automobile ignition interference.

Corrective Measures—At the outset, it should be emphasized that there is no clear-cut method whereby all interference problems due to ignition or other causes may be solved. About the only corrective measure with respect to ignition interference is to ascertain that a good antenna is used, that is, one that will result in the best possible pickup of the signal.

At the time of installation, checks should be made to determine the type of interference, if any, which is present at the particular location. The antenna should then be located as far as possible from the suspected source of interference. For example, if the receiver is located near a heavily traveled arterial highway or street intersection, the antenna should always be installed as far from the traffic as possible, and the twin-lead twisted once every 5 ft. After this has been accomplished, an effort should be made to eliminate the remainder of the interference by manipulating the antenna, perhaps by increasing the antenna height by several feet.

In locations plagued by interference, shielded twin-conductor cable or coaxial transmission lines should be used. The use of the shield will prevent most of the noise pulses from reaching the transmission line. For a shielded line to be completely effective, however, the shield must be properly grounded.

In cases where a coaxial cable (single conductor) is used, be sure proper impedance-matching devices are used; otherwise, the problems produced by the mismatch may be greater than those of the original problem. Figure 7-6 illustrates the appearance of RF interference in the picture.

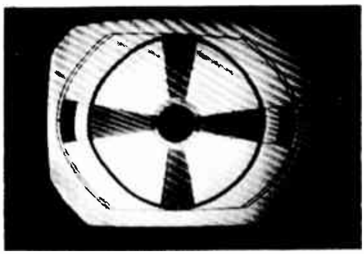


Fig. 7-6. Appearance of RF interference in the picture.

Diathermy

Diathermy interference (Fig. 7-7) is caused by unshielded medical diathermy machines and x-ray equipment. It manifests itself in a herringbone pattern or one of two dark bars moving slowly up and down the picture. If the disturbance is extremely strong, the interference pattern will remain stationary while the picture floats in the background.

Many diathermy machines consist of oscillators using raw 60-hertz ac on the plates. Distribution of the pattern relative to picture height is usually similar to a 60-hertz hum bar due to the strong ac ripple in the signal. This "strip," or bar, pattern will vary in position relative to the top and bottom of the picture, depending on the phase relation between the power lines supplying the diathermy machine and the vertical scanning frequency of the receiver.

Sometimes if this bar happens to be so phased as to occur near the vertical-blanking interval, it will show up as two split narrow "strips"—one at the top of the picture and one at the bottom. The fine-line pattern within the "strip" will vary in spacing, depending on the frequency of the diathermy oscillator; and, as these oscillators are not crystal-controlled, the fine-line pattern will usually vary, assuming various positions between horizontal and vertical.

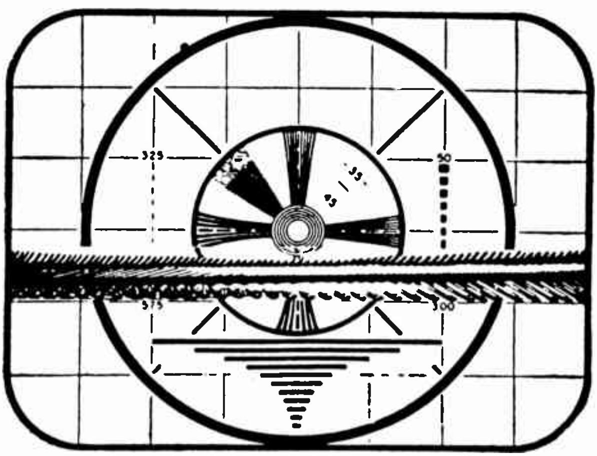


Fig. 7-7. Test-pattern showing effect of diathermy interference.

Corrective Measures—In the case of diathermy interference, corrective measures are practically nonexistent since the signal from a diathermy "transmitter" behaves very much the same as television signals; that is, it is picked up by the receiver antenna.

It is evident that the only permanent remedy against television interference of this sort is to incorporate preventive measures at the source, that is, by proper shielding and filtering of the diathermy machines, by shielding of the room(s) in which they are operated, or both. Fortunately, modern diathermy machines now operate on different frequencies and do not produce the interference previously encountered.

4.5-MHz Sound-Beat Pattern

A 4.5-MHz sound-beat pattern may be recognized by a stationary, very fine herringbone pattern independent of sound modulation and extending over the whole picture. This is caused by the intercarrier sound-IF signal being coupled to the picture tube and heterodyning between the sound and video-IF carriers. Figure 7-8 shows a 4.5-MHz beat pattern.

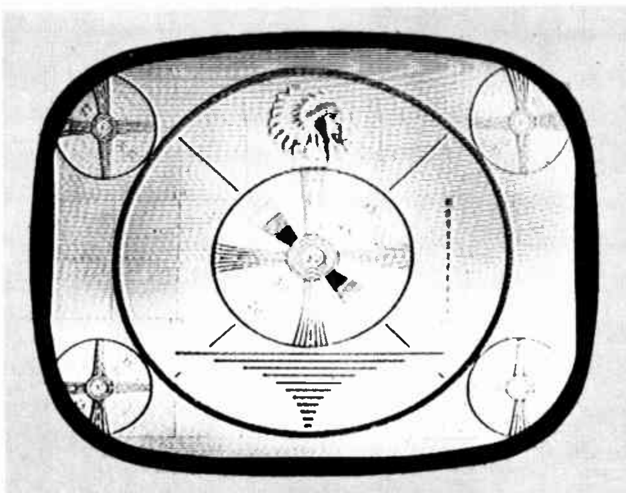


Fig. 7-8. 4.5-MHz beat pattern.

Corrective Measures—Most receivers employ a fairly high-Q trap, tuned to 4.5 MHz and installed either in series with the cathode-ray-tube grid or in the video-amplifier chain somewhere between the point of sound takeoff and the cathode-ray-tube grid. This trap may need readjustment. In extreme cases, it may be necessary to install an additional trap at some other point in the circuit.

Police, Amateur, and Other Stations

Interference from police, amateur, and other stations usually emanates from transmitters being located in close proximity to television receivers, with the result that a high-signal level is fed into the receiver circuit. The fact should not be overlooked that most video amplifiers will amplify to approximately 4 MHz and consequently will readily amplify the signal from a broadcast station if the receiver happens to be in the high-signal area very close to the transmitter. Figure 7-9 shows a 28-MHz beat produced by an amateur transmitter.

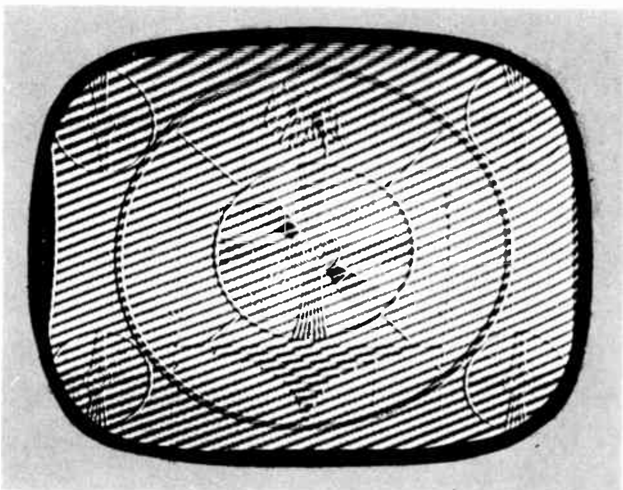


Fig. 7-9. 28-MHz beat produced by amateur transmitter.

Corrective Measures—Corrective measures consist of judicious use of shielding of the affected parts of the receiver and the use of traps tuned to the frequency of the offending transmitter.

Two or More Nonsynchronized TV Carriers on Same Channel

Interference resulting from two or more nonsynchronized TV carriers on the same channel usually affects reception in fringe areas where the television receiver is located equidistant between two or more stations. Sometimes the signals from the different stations are almost equal in strength, and as a consequence the receiver cannot discriminate between the transmitters. This type of interference is called the *windshield-wiper* picture symptom if the receiver locks on one TV signal while the blanking bars of the other signals "wipe" across the screen (Fig. 7-10). But the interference is called the *venetian-blind* picture symptom if the beat frequency between the two signals produces visible horizontal bars on the screen (Fig. 7-11).

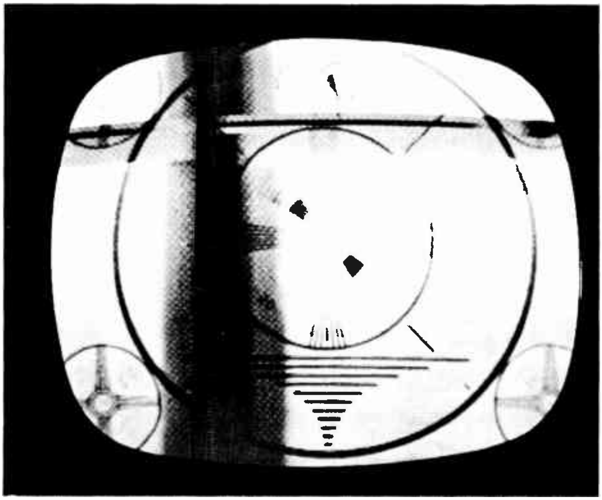


Fig. 7-10. Windshield-wiper effect.

Corrective Measures—The only possible solution to interference problems of this sort is to employ a highly directional antenna and mount it in a rotating mechanism so that it can be precisely aimed at the desired station.

FM Transmitter Heterodyning with Local Oscillator

The heterodyning of an FM transmitter with the local oscillator and the resulting beat coming in on the lower television channels is another cause of interference. Receivers in most of the larger television areas where powerful FM transmitters are located are usually affected by this type of interference.

It is usually recognized on the screen as an ever-changing pattern of parallel lines sometimes assuming a herringbone charac-

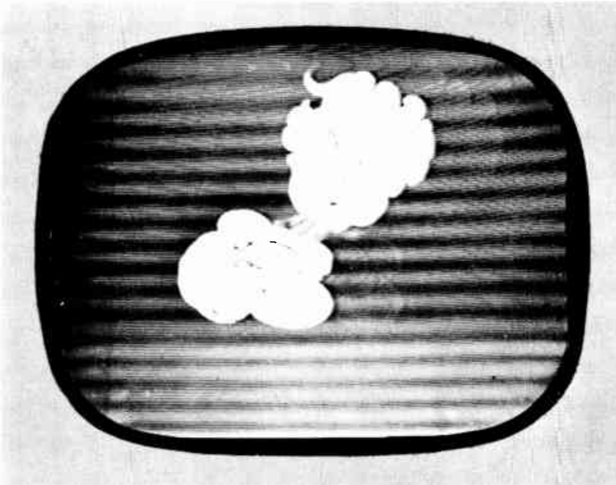


Fig. 7-11. Cochannel interference.

teristic. The pattern will usually change continuously, except when the FM transmitter modulation is off; and the movement of the lines in the pattern will not bear any relation to the accompanying television sound. The number of lines or bars varies according to the modulation of the interfering transmitter.

Corrective Measures—An effective corrective measure in this case consists of fairly high-Q traps at the antenna input to the RF unit of the receiver and tuned to the interfering FM signal.

Radiation from the Local Oscillator in a Neighboring FM or TV Receiver

Interference emanating radiation from a local oscillator in a neighboring FM or TV receiver will vary, depending upon what channel the interfering receiver happens to be tuned to and the nature of the signal it heterodynes with. It will usually result in a fine herringbone pattern, covering the entire picture, although sometimes it will take the form of a ghost picture that seems to float around in the background of a picture tuned in on one of the TV channels.

This trouble is commonly encountered when two or more TV receivers are operated from the same antenna without isolating couplers connected into the lead-in system. It also occurs when individual antennas are used with two or more receivers and the lead-ins are run close together. Even if the lead-ins are well separated, interference sometimes occurs when the antennas are mounted too closely together on the same roof. Figure 7-12 shows the appearance of local oscillator interference.

Corrective Measures—The solution is to install a wave trap tuned to the interfering frequency.

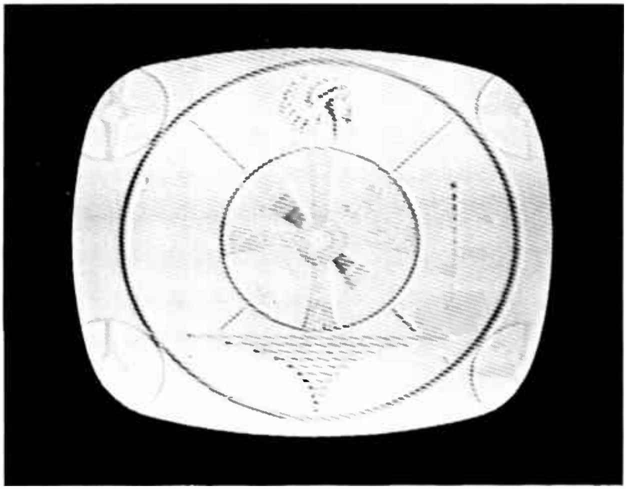


Fig. 7-12. Effect of local-oscillator interference from another TV receiver.

Oscillation in Video IF Amplifier

Interference caused by oscillation in the video IF amplifier will usually be manifested as a pattern of lines that are approximately 3/32 in. apart. This pattern will be noticed on all channels and usually only when the contrast control is advanced near or past the midpoint of its travel. This interference can usually be traced to an open-screen bypass capacitor in one of the video IF amplifier stages; or, in receivers employing stagger-tuned IFs, oscillation can result if several of the stages are peaked too closely together.

Note that the picture symptom can vary considerably, depending on the amount of IF feedback and the incoming signal level. For example, strong signal may be reproduced at low contrast and with ringing of vertical lines with certain spacing, as shown in Fig. 7-13. At a reduced signal level, a negative or partially negative picture may appear. Again, at a slow signal level, the screen becomes blank due to increased IF feedback at low AGC voltages.

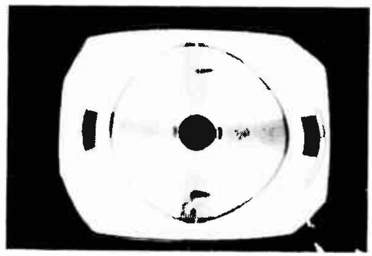


Fig. 7-13. Distorted reproduction with wedge ringing at about 2.5 MHz.

Barkhausen Oscillation

Barkhausen interference originates in the receiver's horizontal-deflection circuit. It will show up as a dark vertical line or series of lines at either side of the picture. If a pattern such as the one described is noticed, a permanent magnet held close to the outside of the horizontal-output tube will have a noticeable effect on the pattern.

Barkhausen effect is a type of high-frequency oscillation that takes place within the electron stream in the tube. The frequency is determined by the distance between the elements and by the velocity of the electrons. It is independent of external tuning circuits.

Corrective Measures—Replacement of the horizontal-deflection tube will usually clear this type of interference. Attaching an ion-trap magnet to the outside of the horizontal-output tube will also usually eliminate Barkhausen oscillations.

Reflections, or Ghosts

Perhaps one of the most prevalent forms of interference is due to reflections of the signal, generally termed *ghosts* (Fig. 7-14).

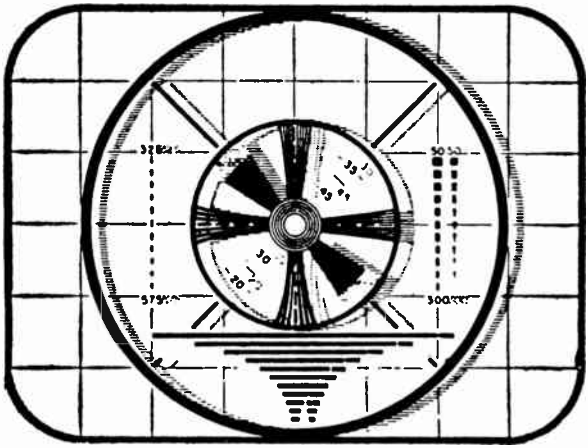


Fig. 7-14. Test pattern showing effect of multiple images, or ghosts.

Since there are numerous forms of this type of interference, they will be treated according to their appearance on the screen.

Trailing Ghost—Probably the most common type of ghost is the *trailing ghost*, which is usually due to a reflection from a building, hill, or other structure that reflects the television signal from the transmitter. This reflected signal, or "echo," which is usually weaker than the direct signal, arrives at the receiving antenna later than the direct signal, and the ghost, or echo, will appear on the right hand, or trailing edge, of the picture.

Sometimes there are locations where several reflected signals from different buildings or structures reach the receiver, resulting in several ghost images in the picture. These are called *multiple ghosts*. Ghost images can be positive or negative, depending on the relative phase of the direct and reflected signal. The relative phase depends on the location of the antenna. If it is located some distance from the transmitter, the relative phase changes, and the direct and reflected signals either aid or oppose, producing a positive or negative ghost. A negative ghost is one where the image is reversed; that is, the white portions are black, and the black portions are white.

Corrective Measures—Where the reflected signal is arriving at the receiver from the rear, a reflector on the antenna will be helpful because it will minimize the rear pickup of the antenna to some extent. If the reflected signal is arriving at the receiver from one side, it can be minimized by orienting the antenna for least pickup in this direction even though the direct signal is reduced slightly. In either case, a highly directional antenna is desirable. Under some conditions, it may be advantageous to orient the directional antenna for maximum pickup of a strong reflected signal and minimum pickup of the direct signal.

Source Ghost—When the reflected signal arrives at the receiving antenna from the same general direction relative to the direct signal from the transmitter, and the angular difference between the two signal paths is very small, it is impossible to differentiate between the two signals resulting in a ghost image, which is called a *source ghost*. So far there is no known corrective measure for reflections of this type.

Fluttering Ghost—Fluttering ghosts due to reflections from aircraft flying in the vicinity of the receiver are sometimes observed. The changing phase of the reflected and direct signals arriving at the receiver as the plane moves along, results in the two signals alternately aiding and opposing each other, producing a flutter in the picture brilliance and in the ghost image. The rate of flutter depends on the position, height, speed, and direction of the plane and changes as the plane progresses in flight. This type of interference is largely overcome by the horizontal-AFC circuit in the television receiver.

Leading Ghosts—Leading ghosts differ from trailing ghosts in this respect: With a trailing ghost, the ghost image is to the right of the direct pickup picture, while with a leading ghost, the ghost image appears to the left of the direct pickup picture. This type of ghost appears under the following conditions:

1. With the receiver located relatively close to the transmitter, considerable signal pickup occurs in the RF or mixer circuits of the receiver, with a long run of transmission line from antenna to receiver. The signal that is picked up directly in the RF or mixer circuit appears ahead of, or to the left of, the picture from the antenna signal, which is delayed in traveling down the long transmission line. In cases of this type, the signal picked up directly by the receiver will usually be affected by the movement of persons about the

room or near the television receiver; and as the signal usually is reflected by objects in the room or nearby structures, multiple ghosts will usually be evident.

2. If a reflected signal is stronger than the direct signal, it will appear as the principal image and the direct signal will appear as a ghost image. Since the direct signal does not travel as far to reach the antenna, it will be reproduced to the left of the reflected signal, producing the predominate picture.

Corrective Measures—If RF or mixer pickup is the cause, it can be corrected by reducing the direct pickup in the receiver by shielding the RF and mixer circuits and possibly the entire chassis. By disconnecting the antenna from the receiver without disturbing the contrast-control setting, it can be determined how much signal the antenna is actually contributing to the picture.

If it is found that multiple-ghost images appear, and that the antenna contributes very little or nothing to the picture, the pickup from the antenna system should be increased; or a defect in the RF-amplifier stage of the receiver may be the cause. It should be obvious that if the RF-amplifier stage of a receiver is inoperative, disconnecting the antenna would not affect the picture because the reproduced image (or images, as the case may be) would be due to direct-signal pickup in the mixer circuit. If the reflected signal is stronger than the direct signal, the ghost can be eliminated by employing a more directional antenna and carefully orienting the antenna.

Tunable Ghost—Tunable ghosts vary in number and intensity as the fine-tuning control of the receiver is adjusted. They are usually caused by incorrect alignment or possibly regeneration in the video-IF stages.

Transmission-Line Ghost—When the transmission line is not correctly terminated at the receiver, a portion of the signal is reflected at the receiver and travels back up the line to the antenna. If the antenna does not correctly terminate the line, a portion of this signal is reflected back and travels down the line to the receiver again, where it produces a *trailing ghost*.

With a normal length of transmission line, the reflected signal takes very little time in traveling up and down the line, and so it is only slightly delayed and does not appear as a separate ghost. It merges with the original picture signal and affects the picture quality by effectively widening the vertical lines so that they appear fuzzy. Only with long runs of transmission line will the reflected signal appear as a distinct and separate ghost.

Corrective Measures—Proper matching of impedance between the antenna and transmission line and between the transmission line and receiver input will reduce or eliminate the problem.

INTERFERENCE TRAPS

In the foregoing discussion of television interference and its corrective measures, mention was made of the insertion of wave traps. These are used in certain instances of interference but should be resorted to only where all other corrective measures have failed to remedy the trouble.

Wave Traps

Various types of interference emanating from FM and amateur transmitters and some commercial or police communication systems, in addition to radiation from local oscillators of neighboring television receivers, can effectively be suppressed by the insertion of wave traps. Interference conditions of this type can be corrected by lowering the amount of signal input to the receiver at the frequency that causes the interference. A wave trap may be inserted in series with the antenna, or it may be built into the receiver as a permanent feature.

A wave trap consists of an LC circuit of fairly high Q, which will resonate at the frequency it is desired to attenuate. It is often series-resonant and inserted in one or both conductors of the transmission line, tuned to the interfering frequency. Fig. 7-15 shows the circuit diagram of a commonly used wave trap. The two traps are wired so that one is in each leg of the antenna circuit, and thus they will not materially unbalance the antenna circuit.

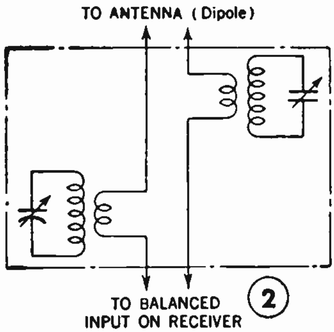


Fig. 7-15. Schematic of typical wavetrap.

Suppression circuits can also take the form of a parallel-resonant circuit, which is inserted in the grid-coupling system between the RF and mixer stages; therefore it curbs the mixing action that produces the interference in the IF system.

To construct an effective wave trap, it is first necessary to calculate the frequency of the interfering signal and construct or purchase a trap that can be inserted and tuned until the interference disappears. Booster amplifiers, because of their added selectivity, are also employed to suppress signal interference. It is for this reason that booster amplifiers are sometimes employed in strong-signal areas. The signal is reduced later with a resistance pad.

Impulse-Noise Suppression

Impulse noise originating in electrical appliances such as electric cash registers, office equipment, and shavers can best be suppressed at the source. This is commonly accomplished by the insertion of a small capacitor shunted across the ac line at the input to the device.

For complete noise suppression from large industrial equipment, electrical signs, etc., there are several types of filters on the market consisting of series-inductor and shunt-capacitor combinations, which prevent RF energy from feeding back to the power line and then radiating or feeding directly into the television or radio receiver.

Because of the tendency of numerous noises to enter the television receiver via the power line, a filter inserted between outlet and receiver, in many instances, will effectively suppress noises emanating from home appliances or industrial equipment operating on the same power line.

It is a well-known fact that neon signs are notorious offenders in television and radio reception disturbances. The flasher device is nothing more than a set of switches, and therefore noise suppression is similar to that employed for other industrial equipment.

Another source of disturbance in neon signs is arcing between connections, particularly in the electrode housing or between cable ends. Again interference may be caused by flickering tubing, an overloaded transformer, faulty insulation, corona discharges between tubing and ground, loose connections, ungrounded transformer case, a broker conductor inside the insulation, etc.

When reception interference has been found to be caused by a neon sign, each of these trouble sources should be investigated. As a general rule, however, it has been found that the employment of filter units across switch contacts and also across the primary winding of the transformer will remedy the trouble. It has also been found effective to install a high-frequency choke properly insulated between the letters of the sign. When filters are installed, it should be remembered that the components employed must be able to withstand the potentials and current that must flow through them.

Perhaps the most important consideration in areas plagued by interference and noise is the choice of antenna and its proper orientation. This consideration, however, has been fully covered in Chapter 4 and needs no further elaboration.

SUMMARY

Television receivers are operated at a much higher frequency than radio receivers, and the sources of interference are not the same. A television receiver is almost immune to weather-produced interference, whereas radio reception is generally affected by such actions.

Many forms of interference can be identified when viewed on the screen. After they are identified, corrective measures can be applied to eliminate most of them. Some types of interference are not so easily identified, and in some cases there are no known corrective measures. Man-made noise arising from various types of electrical apparatus, such as electric motors and automobile ignition noise, can be partially eliminated by using the right antenna, properly placed.

Interference conditions can generally be corrected by lowering the amount of signal input to the receiver at the frequency that causes the interference. A wave trap may be inserted in series with the antenna, or it may be built into the receiver as a permanent feature.

REVIEW QUESTIONS

1. Why are antenna transmission lines twisted?
2. What effects do aircraft have on the TV picture?
3. What are the most common types of TV interference?
4. Explain the Barkhausen oscillator.
5. What is the purpose of the wave trap?
6. What causes local oscillator interference from one TV receiver to another?
7. What causes the venetian-blind effect?

CHAPTER 8

RF Tuners

The RF tuner (or front end, as it is sometimes called) is the first section in the television receiver to receive and act upon the composite video signal. There are many types of tuners, but all perform the same basic functions. The block diagram of a television tuner is given in Fig. 8-1.

As indicated by the block diagram, the tuner in a television receiver essentially performs the same functions as the RF amplifier and converter sections of a conventional broadcast or shortwave radio. In a television receiver, however, there are many problems not encountered in broadcast radio. These problems complicate the design of the television-receiver RF tuner. These problems are:

1. The broad bandwidth of the television channel. Proper television reception requires that a band of frequencies 6 MHz wide be accepted and amplified. For broadcast radio, the required bandwidth is only a few kilohertz.

2. The frequency allocations of TV channels (54–88 MHz, 174–216 MHz, and 470–890 MHz) necessitate special coupling circuits. Component and lead placement are critical. Figure 8-2 shows a typical VHF frequency-response curve, and Fig. 8-3 shows the chief features of a sweep generator.
3. Input circuits must be properly matched to the impedance of the transmission line and antenna and provide the proper match between the transmission-line impedance and RF-amplifier, transistor-input impedance.
4. Even though a wideband response (6 MHz) is desired, many other signals outside the bandwidth of the desired channel must be avoided. Such undesired signals are:
   (a) Adjacent-channel sound carrier
   (b) Adjacent-channel video carrier
   (c) Signals at the intermediate frequency that might be coupled through the RF system
   (d) Signals from other television or FM stations
   (e) Overloading of the RF amplifier by strong signals from any type of station
5. The local oscillator signal must be properly isolated from the antenna. This is one of the principal reasons that all television receivers employ RF amplifiers. If the oscillator signal were allowed in the antenna circuit, the antenna would function as a transmitter and radiate the signal to all nearby television receivers, causing severe interference. The amount of radiation permissible is regulated by the FCC. Without an RF amplifier, it is very difficult to suppress oscillator radiation to permissible limits.

TYPES OF RF TUNERS

RF tuners can be classified in two different ways: (1) by type of RF amplifier, which is the principal circuit difference (the various types of RF amplifier circuits will be discussed later); and (2) by the means employed to accomplish channel selection.

Pushbuttons, continuous (variable inductance or variable capacitance), wafer-switch, turret, and disk tuners have been employed. By far the most popular systems, however, are the switch and turret types. Click-stop tuning is now required for UHF applications. A typical miniaturized VHF tuner is shown in Fig. 8-4, and a miniaturized UHF tuner is shown in Fig. 8-5.

RF tuners can also be classified into tube, transistor, and hybrid types. An all-transistor tuner is solid-state throughout. A typical hybrid tuner employs semiconductor devices in the RF, oscillator, and mixer stages but utilizes a special UHF oscillator tube. These variations with which the technician must contend are explained subsequently.

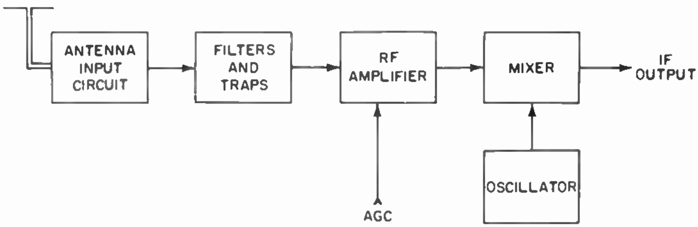


Fig. 8-1. Block diagram of a television RF tuner.

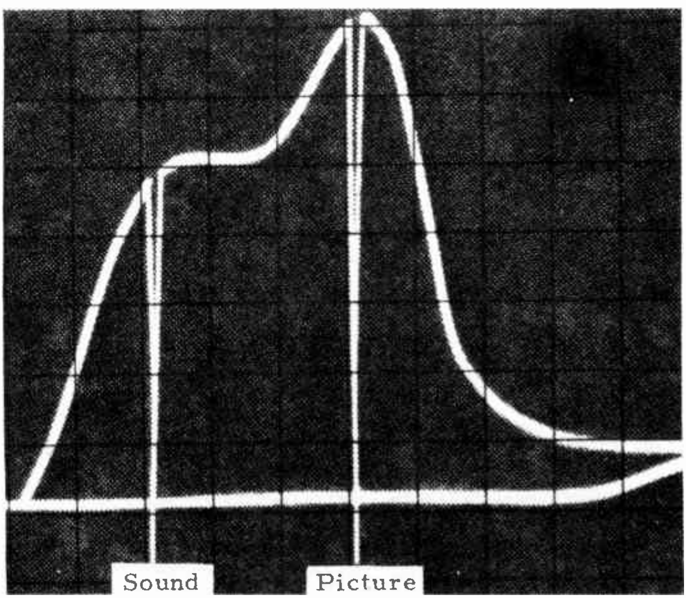


Fig. 8-2. RF response curve with sound- and picture-carrier frequencies marked.

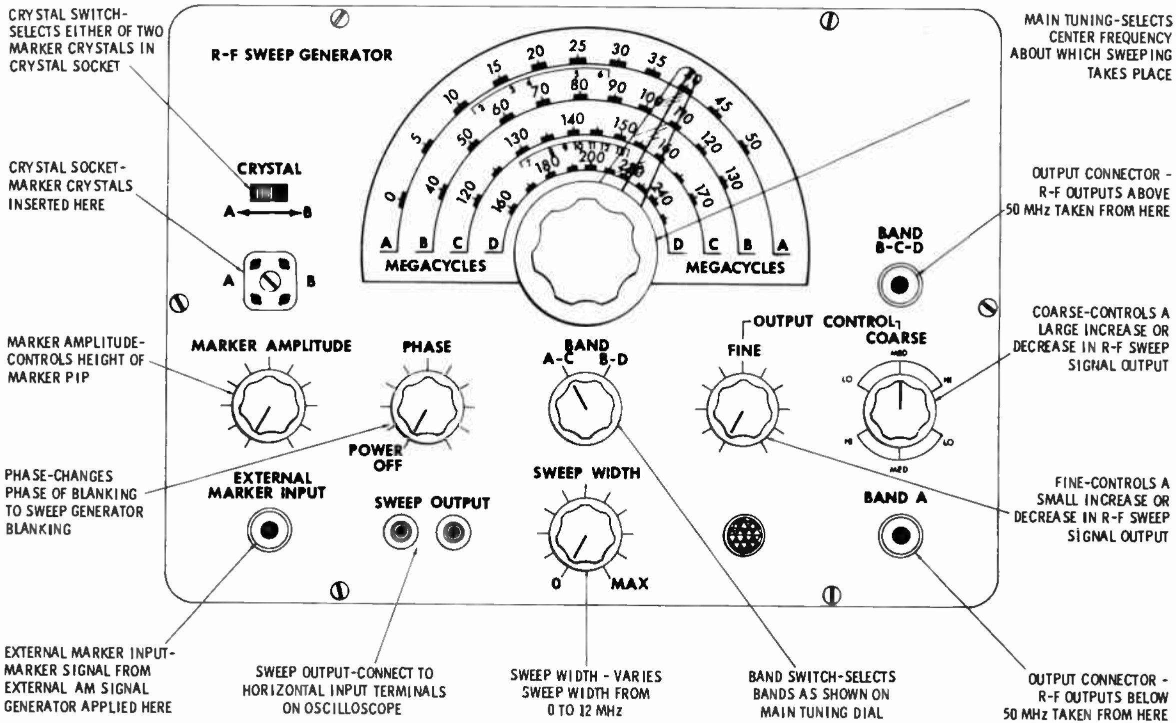


Fig. 8-3. VHF sweep generator used to check frequency-response curves.

Courtesy the Heath Co.

Turret Tuners

A typical tube-type turret tuner is shown in Fig. 8-6. The coils employed to tune the RF amplifier input and output, mixer input, and oscillator input are mounted on the individual strips that form the drum. Each coil is connected to the silver-plated contacts on the outside of the strip. These strips then mate with a set of contacts inside the tuner to complete the circuit. For each channel, a separate set of coils is included. As the channel-selector shaft is rotated, a different set of coils is switched in for each channel.

Most tuners used in transistor TV receivers are of the turret

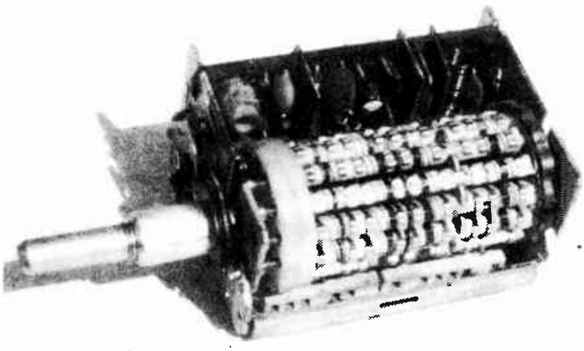


Fig. 8-4. Typical miniaturized VHF tuner.

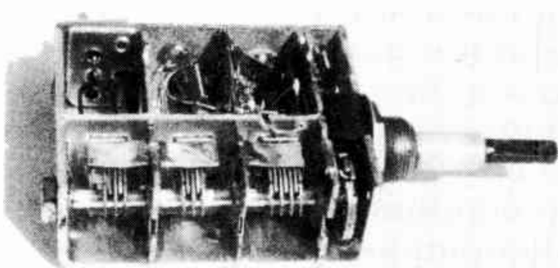


Fig. 8-5. Typical miniaturized UHF tuner.

type. Figure 8-7 depicts the configuration for a VHF transistor tuner. Printed circuitry is often utilized, although metallic chassis construction is employed when optimum low-impedance ground returns are a design goal. A high-pass filter and IF trap are connected in the antenna-input circuit in this example. An alternative interference-rejecting arrangement comprises three tunable traps, as shown in the inset.

Neutralization is accomplished by out-of-phase feedback via C208 in Fig. 8-7. Transistor Q201 operates at an average forward bias of 0.2 volt, subject to AGC variation. Since the mixer transistor operates with emitter and collector circuits tuned to different frequencies, neutralization is not required in this stage. The mixer transistor operates at 0.1 volt forward bias because a nonlinear characteristic is required for heterodyne mixer action. Figure 8-8

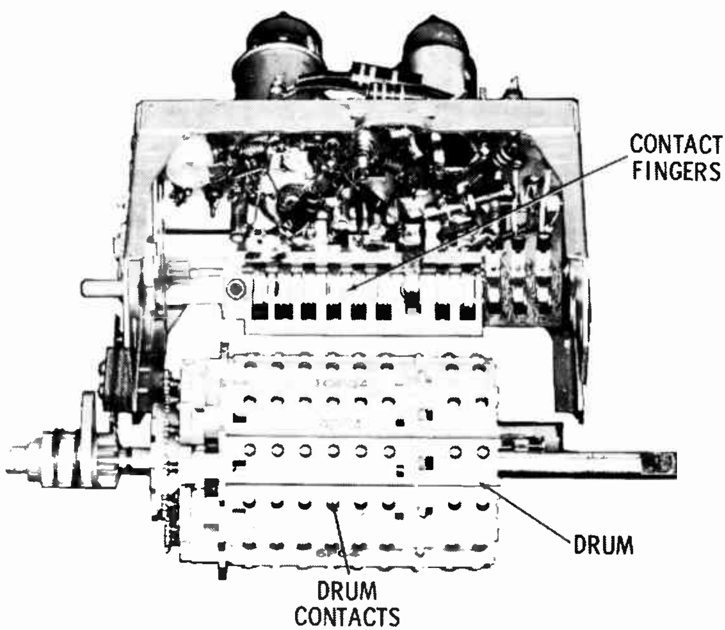


Fig. 8-6. Turret-type tuner.

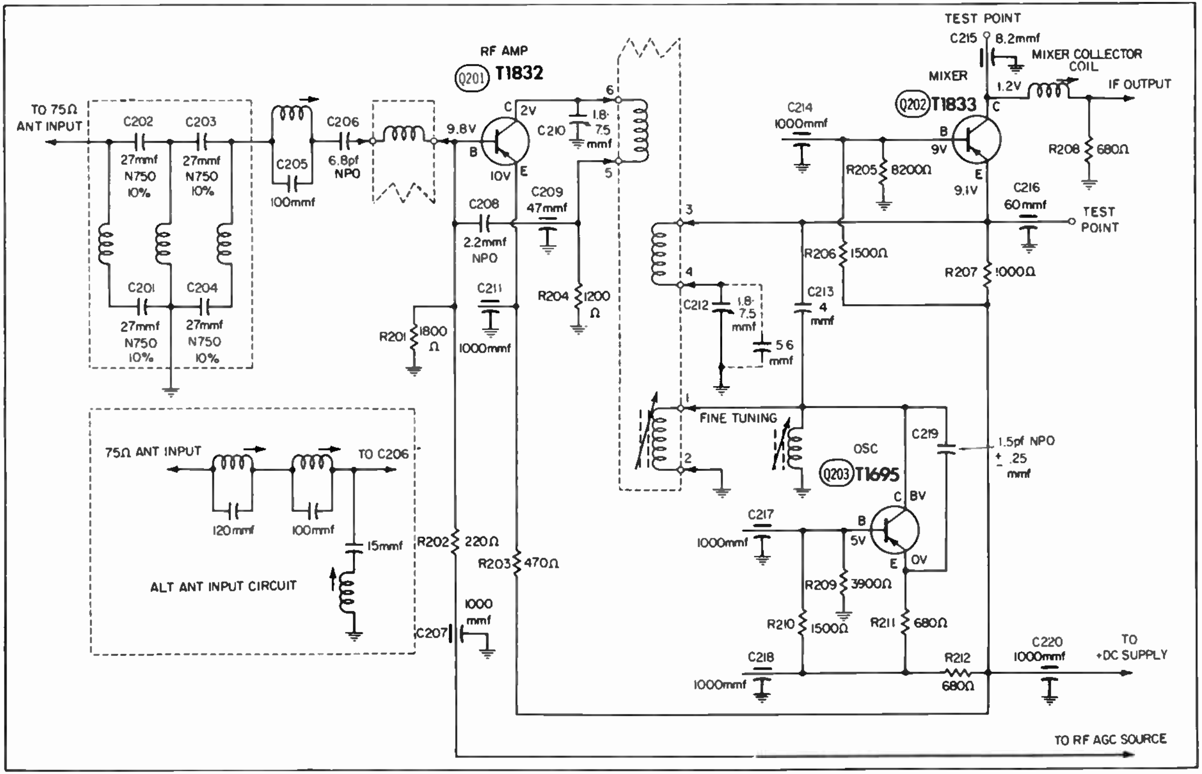


Fig. 8-7. Schematic of a typical turret-type transistor tuner.

shows how the emitter-base characteristic has maximum nonlinearity in the vicinity of 0.1-volt forward bias. Figure 8-9 lists the important characteristics of the three basic bipolar transistor configurations.

Wafer-Switch Tuners

Unlike the turret tuner, individual coils are not employed in wafer-switch tuners (Fig. 8-10). A series of coils are connected between the contacts on each switch deck. As the channel-selector shaft is rotated, the inductances are incrementally added or subtracted to tune the desired band. Thus, this type of tuner is often called an *incremental inductance tuner.* The configuration of a transistor wafer-switch tuner is shown in Fig. 8-11.

Disk Tuners

A disk tuner (Fig. 8-12) combines certain principles of both the turret- and switch-type tuners. Attached to the shaft inside the

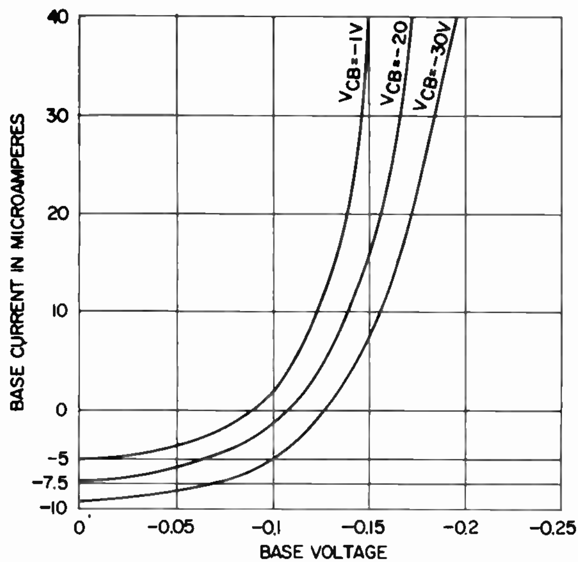


Fig. 8-8. Base family of characteristics.

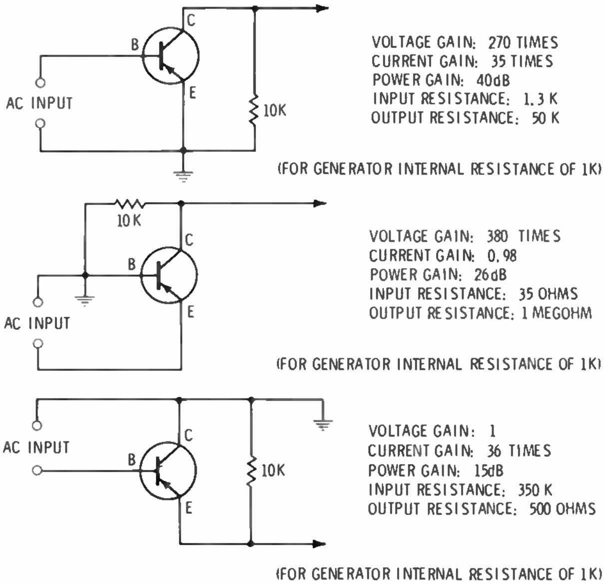


Fig. 8-9. Comparison of typical characteristics of a triode transistor in three basic amplifier configurations.

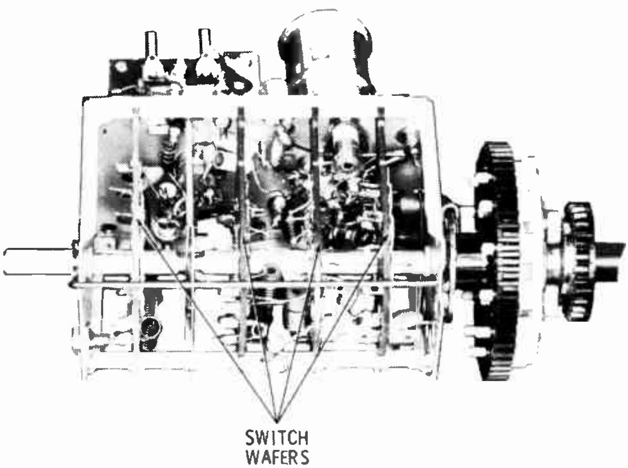


Fig. 8-10. Wafer-switch-type tuner.

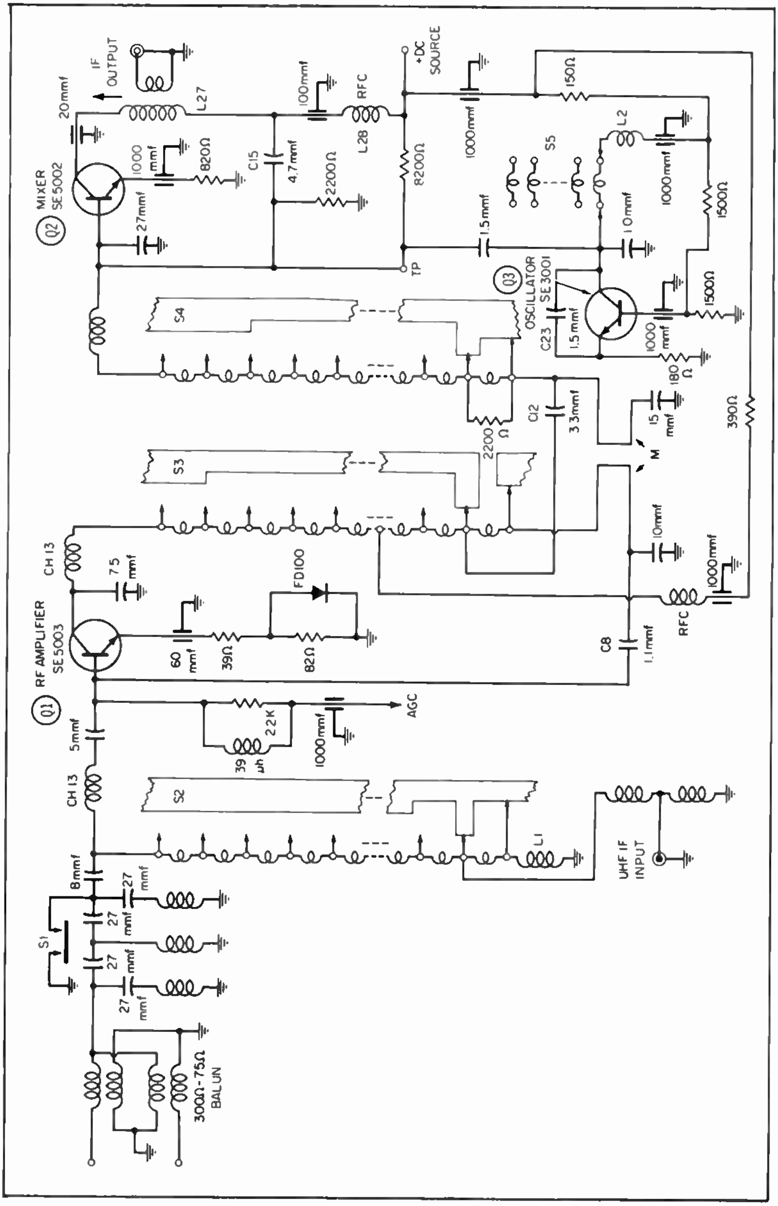


Fig. 8-11. Schematic of typical switch-type tuner.

tuner are two large disks upon which the tuning inductors are arranged. The antenna coils are on the rear disk. A detent mechanism resembling that of the turret tuner is mounted on this disk. Contact buttons and fingers, like those of the turret tuner, connect the disk to the external circuitry.

An important difference between the turret and disk tuners is that the disk tuner does not have a completely separate set of coils for each channel. There are several sets of basic coils plus incremental inductances, which are switched in series with the basic coils to tune certain channels. However, the coils are broken into more separate groups in the disk tuner than in the typical switch tuner described previously.

All the contact buttons on the under side of the upper disk are arranged in six concentric circles. The buttons in the innermost two circles are connected to the plate coils for the RF amplifier; the middle two are connected to the mixer input circuit; and the outer two are connected to the oscillator coils. A 1.5-μf (microfarad) capacitor connects the low-band RF coils to the corresponding mixer coils.

The fine-tuning capacitor is located at the top of the tuner (Fig. 8-12). The movable plate is a strip of metal attached to the tuning shaft, and the fixed plate is printed on a small wiring board.

In still smaller versions of the disk tuner, all coils (antenna, RF, and oscillator) for all 12 VHF channels are mounted on one disk.

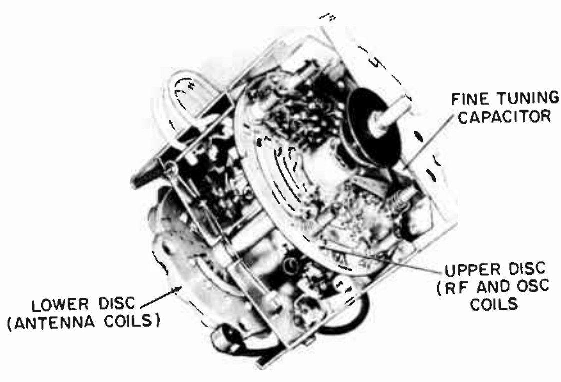


Fig. 8-12. Disk-type tuner.

Connections to the coils are made by spring contacts like those in a turret tuner. Proper positioning of the wheel for each channel is ensured by a detent mechanism like the one in a turret tuner.

A MOSFET-type, VHF-tuner configuration is shown in Fig. 8-13. A dual-gate MOSFET of the *N*-channel depletion type is utilized in the RF stage. The signal voltage is applied to one gate, and the AGC voltage is applied to the other gate. This AGC voltage normally varies from −5 to + 6.7 volts, depending upon the incoming signal strength. A dual-gate amplifier does not require neutralization. The mixer section in Fig. 8-13 uses a pair

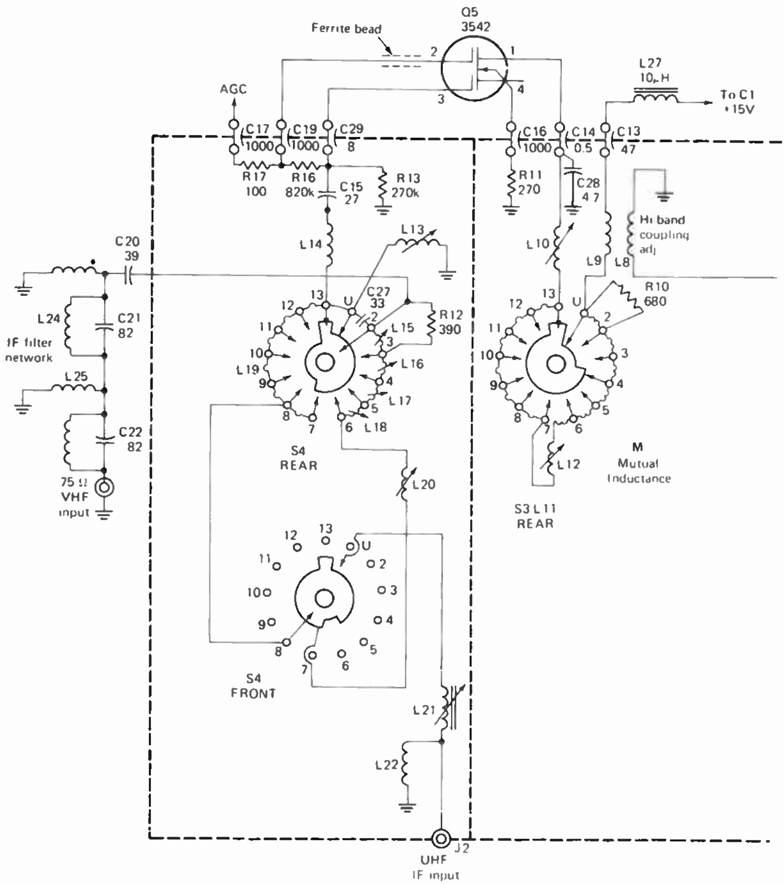
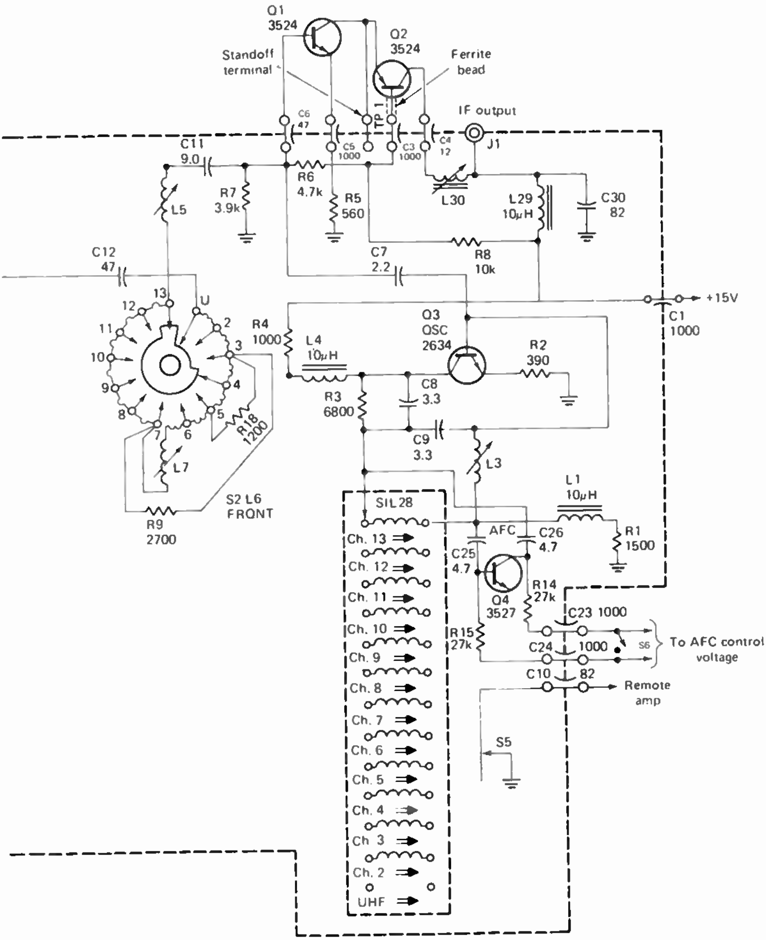


Fig. 8-13. MOSFET-

of bipolar transistors in a standard cascode circuit. Q1 operates in the CE mode and drives Q2, which operates in the CB mode. The oscillator stage uses a bipolar transistor in a Colpitts circuit. Q4 functions as a varactor diode in an AFC circuit to keep the VHF oscillator from drifting off frequency. The oscillator operates at 41.25 MHz above the sound-carrier frequency. Important characteristics of the basic FET amplifier configurations are listed in Fig. 8-14.



VHF-tuner configuration. Courtesy RCA Corp.

ANTENNA INPUT CIRCUITS

As mentioned previously, the primary purpose of the antenna input circuit is to match the impedance of the antenna to the input impedance of the RF amplifier. Normally a balun (for balanced-unbalanced) is used for impedance matching. In addition, most antenna input circuits also include trap circuits for removing unwanted frequencies from other sources, such as amateur radio and commercial communications.

The circuit of a balun designed for matching a 300-ohm balanced antenna to an unbalanced input is given in Fig. 8-15. At first, the balun appears to be a transformer; however, it is actually two sets of parallel-tuned lines, similar to that obtained from ordinary twin-lead line, constructed in a lumped form to conserve space. They are constructed of extremely fine wire and wound on a coil form or on a ceramic core.

The balun coils are precisely tuned by length so that they are connected for the proper input and output impedances, minimum mismatch, and maximum transfer of energy. Another type of balun is shown in Fig. 8-16. This unit is designed for matching a 75-ohm unbalanced coax lead-in to a 300-ohm balanced input.

Usually various trap circuits are also included in the antenna input. Four examples of typical inputs are shown in Fig. 8-17. The inputs in Fig. 8-17A and B are for matching balanced antennas to unbalanced tuner inputs, while the inputs in Fig. 8-17C and D are for matching balanced antennas to balanced tuner inputs. Many other circuits are employed; however, all will resemble those in Fig. 8-17.

RF AMPLIFIER CIRCUITS

Unlike radio receivers where the RF amplifier stage is sometimes omitted, all modern television receivers employ an RF amplifier stage. As mentioned previously, there are two reasons for incorporating an RF amplifier stage. First, the additional gain provided increases the sensitivity of the receiver, which is particularly important where distant stations, which resulting weak signals, must be received. The second reason is that the RF

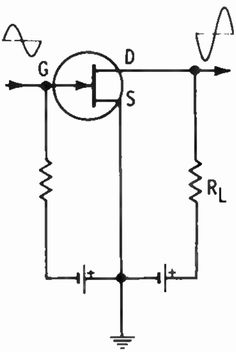
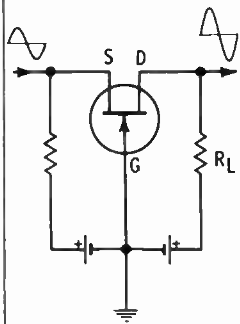
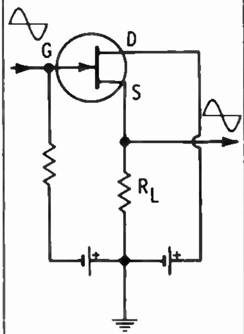
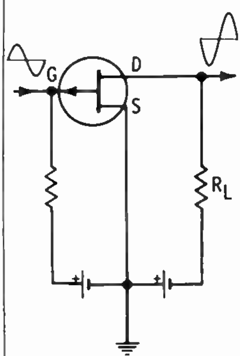
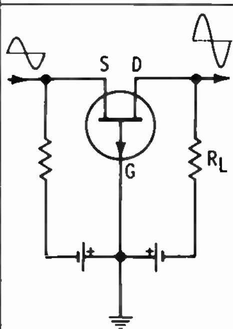
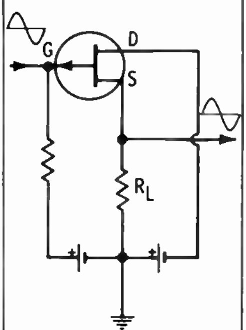
	COMMON SOURCE	COMMON GATE	COMMON DRAIN
N CHANNEL			
FEATURES	High voltage gain High input impedance Moderate output impedance Input and output out of phase	Moderate voltage gain Low input impedance Moderate output impedance Input and output in phase	No voltage gain Good current gain Very high input impedance Low output impedance Input and output in phase
P CHANNEL			

Fig. 8-14. Basic FET circuits.

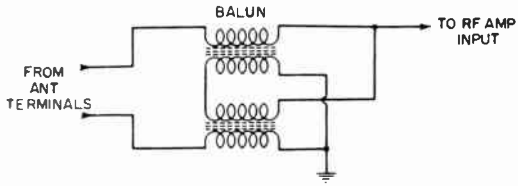


Fig. 8-15. Balum for matching a 300-ohm balanced antenna to a 300-ohm unbalanced input.

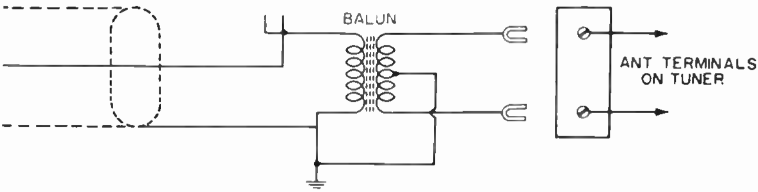
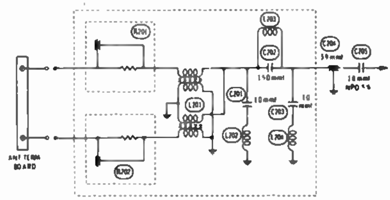


Fig. 8-16. Balun for matching a 75-ohm unbalanced coax lead to a 300-ohm balanced input.

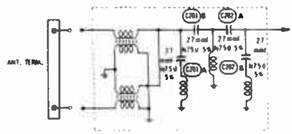
amplifier helps to isolate the oscillator stage from the antenna. Thus radiation of the oscillator signal from the antenna is reduced.

A widely used RF amplifier configuration is shown in Fig. 8-18. An unbypassed emitter resistor is used to optimize the signal-to-noise (SNR) ratio and to reduce the possibility of cross modulation. Capacitor C_N provides neutralization. Forward automatic gain control is used. In other words, as the incoming signal strength increases, the forward bias is increased on the transistor. In turn, the transistor approaches saturation, and its gain decreases. Forward AGC requires that the value of R3 be at least 1,000 ohms, so that the collector voltage on the transistor decreases substantially as the forward bias is increased.

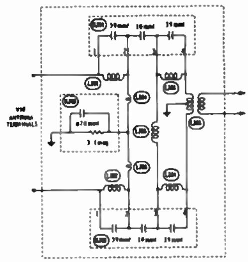
Transistors used in VHF amplifiers must have a suitably high alpha cutoff frequency. For example, the mesa transistor is often used, as shown in Fig. 8-19. The circuit depicted in Fig. 8-20 shows a typical configuration utilizing the mesa transistor. This type of transistor has a better noise figure, has good gain, and is economical. Much of its merit is due to its low interelectrode capacitance. A typical mesa RF amplifier has a gain of 25 db and a noise figure of 7 db on channel 13, with a gain of 35 db and a noise figure of 5 db on channel 2. This is a slightly higher gain and a lower noise figure than found in RF amplifiers using other types of high-frequency transistors.



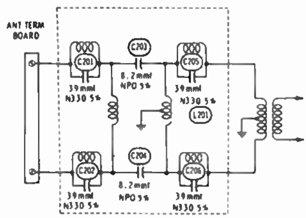
(A) Balanced to unbalanced.



(B) Balanced to unbalanced.



(C) Balanced to balanced.



(D) Balanced to balanced.

Fig. 8-17. Typical antenna-input circuits.

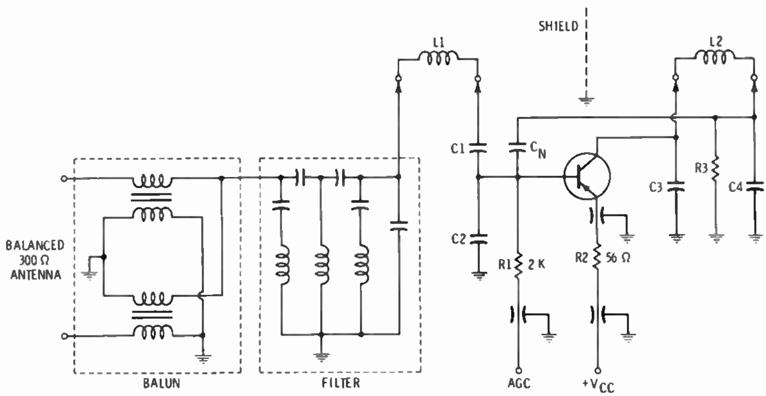


Fig. 8-18. Widely used RF amplifier configuration.

OSCILLATOR CIRCUITS

The purpose of the oscillator is to generate a signal 45.75 MHz above the incoming signal (video) frequency. The incoming signal and the oscillator signal are then mixed to produce the correct IF difference signal.

A typical local oscillator configuration is shown in Fig. 8-21. Since a common-base transistor amplifier is generally regenerative at VHF, this mode of operation is suitable for an oscillator arrangement. Positive feedback is provided via C10 and C11. The value of C7 determines the level of injection voltage to the mixer. About 0.15 volt of oscillator signal into the mixer provides

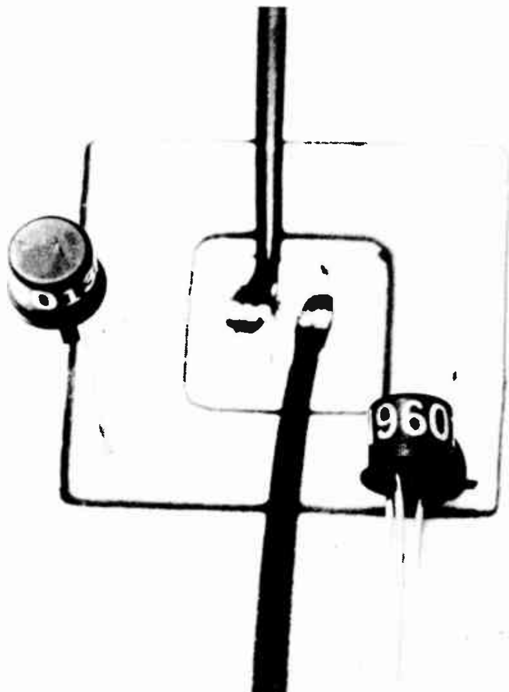
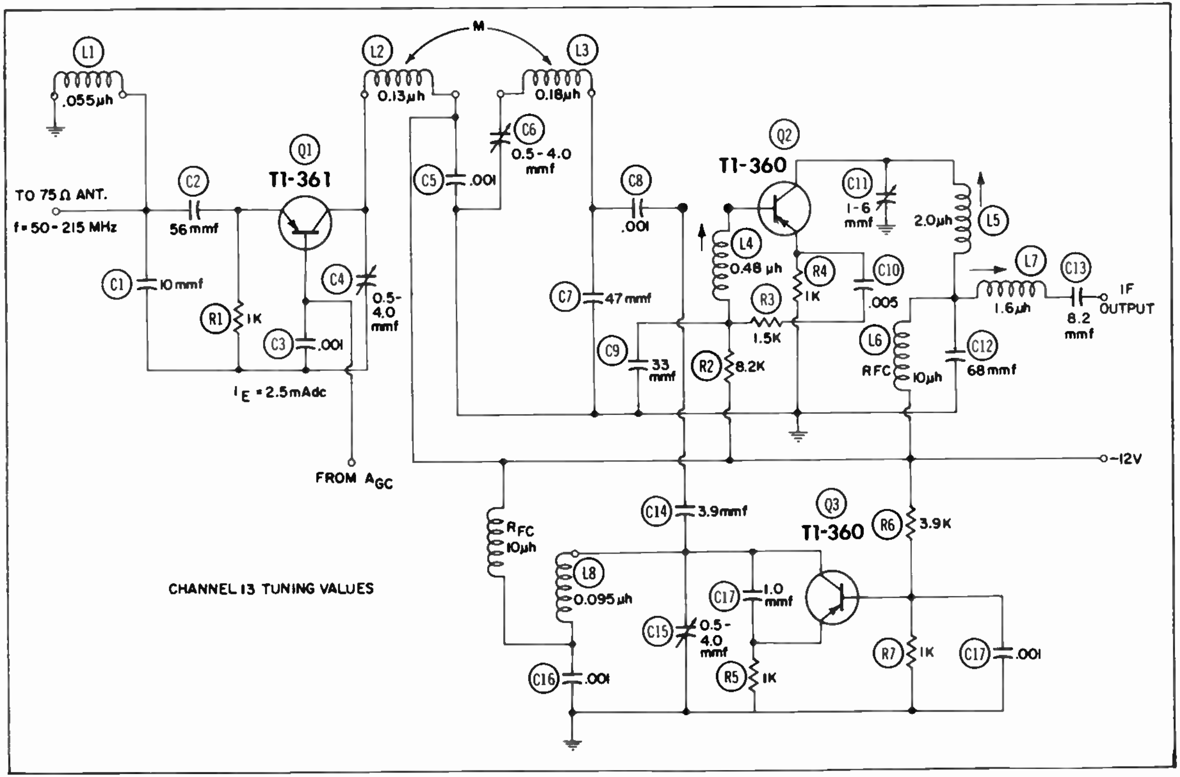


Fig. 8-19. Typical mesa transistor.



Courtesy Motorola Inc.

Fig. 8-20. TV tuner with mesa transistors.

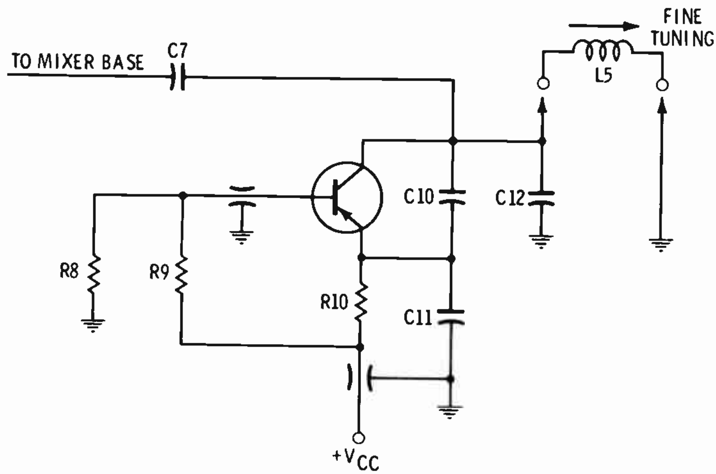


Fig. 8-21. Representative local oscillator configuration.

maximum gain. The fine-tuning slug has a range of greater than ±1.5 MHz. Use of slug tuning in each oscillator coil permits the use of a preset fine-tuning arrangement.

Quite a few RF tuners include an automatic fine-tuning system, which comprises an error sensor and a control device. A typical error sensor consists of a discriminator circuit, as shown in Fig. 8-22. A sample of the IF signal is fed to the discriminator, which has a frequency response as shown in Fig. 8-23. One of the discriminator diodes is forward-biased, and the other is reverse-biased. This provides a push-push action so that both the picture and sound carriers assist in producing a corrective output voltage, which is applied to a varactor diode, as shown in Fig. 8-24. As the correction voltage varies from 1 to 8 volts, the varactor capacitance varies from 15 to 6 pF (picofarads) to return the oscillator to its correct frequency.

MIXER CIRCUITS

A representative mixer configuration is shown in Fig. 8-25. It is similar to an amplifier arrangement, except that the base and emitter of the transistor are at the same dc potential. In other words, the base-emitter junction operates as a rectifying diode,

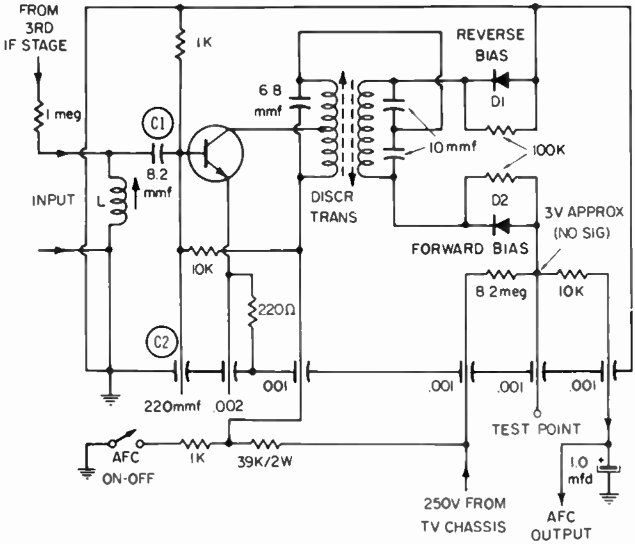


Fig. 8-22. Discriminator circuit used for automatic fine-tuning control.

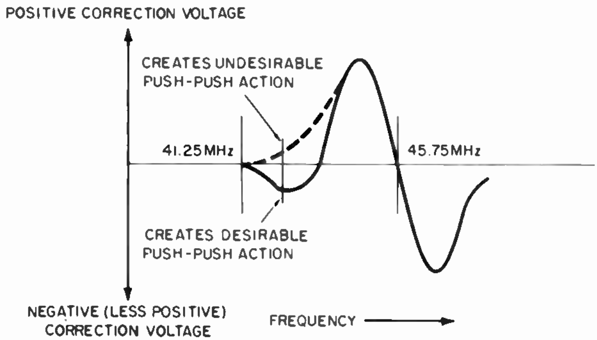


Fig. 8-23. Discriminator diodes in Fig. 8-22, biased to modify the conventional response curve.

thereby obtaining heterodyne action. Neutralization is provided by C_N to ensure operating stability. A 50-ohm output impedance is provided to match a 50-ohm coaxial cable to the IF strip. The dc collector voltage is chosen at a value that provides maximum stage gain.

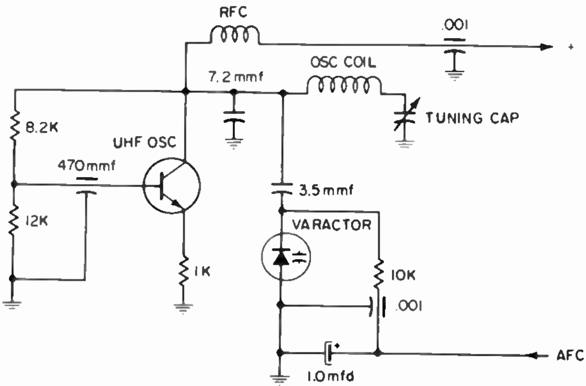


Fig. 8-24. Varactor that operates as a variable capacitor.

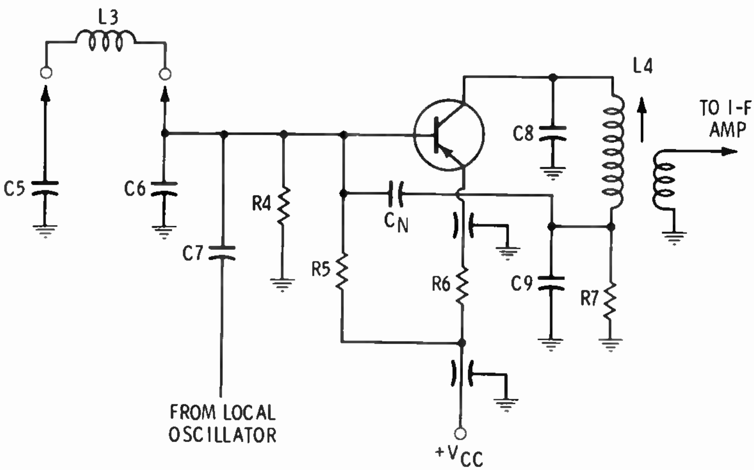


Fig. 8-25. Representative mixer configuration.

Figure 8-26 shows the circuit for a typical transistor mixer stage, with the associated RF and oscillator sections. *Tetrode transistors* are shown in this circuit. A tetrode transistor is also called a *double-base transistor*. The basic arrangement is shown in Fig. 8-27. Bias voltage V_{BB} constricts the base current flow at a comparatively small cross section. In turn, the transit time is shorter through the base, and the transistor is more efficient at very high frequencies. The mixer stage gain in Fig. 8-26 is about 7 db on channel 13.

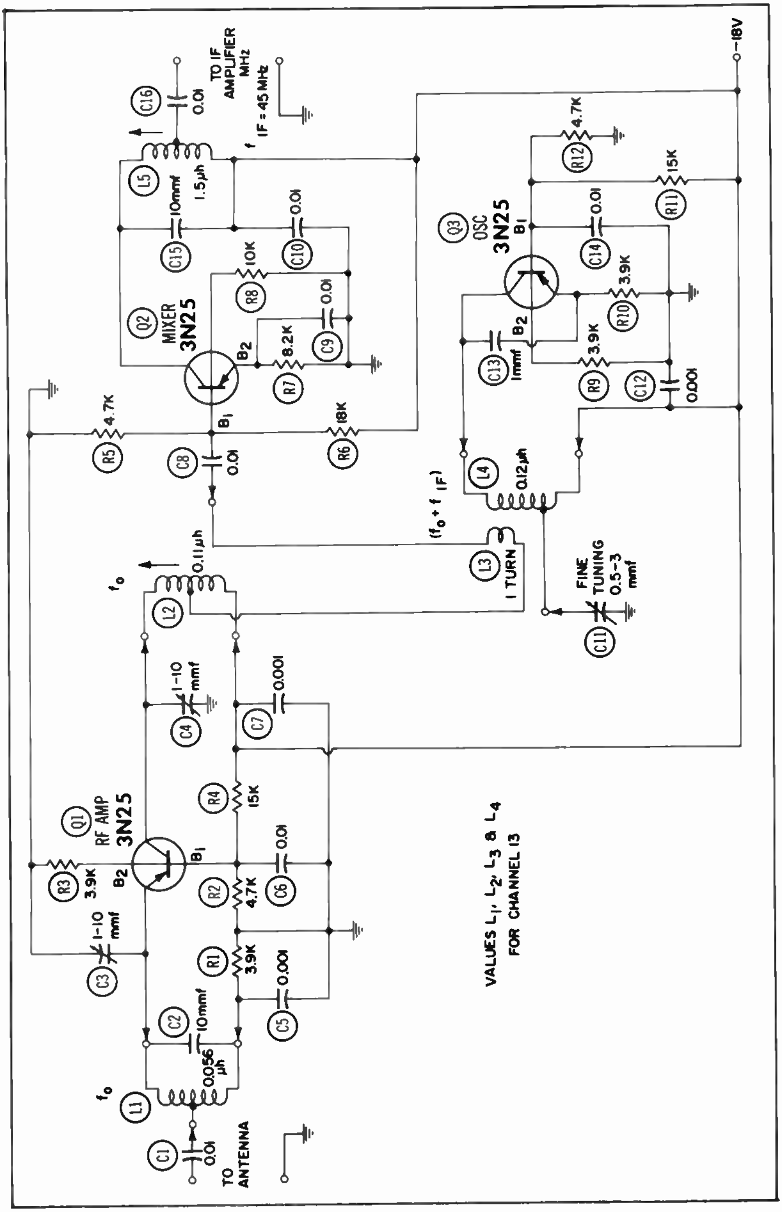


Fig. 8-26. VHF mixer with RF amplifier and oscillator.

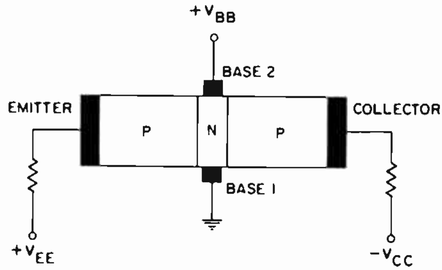


Fig. 8-27. Basic tetrode transistor arrangement.

UHF TUNERS

All the tuners described up to this point will tune only the 12 VHF channels; they will not tune the 70 UHF channels. Therefore some means must be provided to receive these channels. Two methods are employed: the use of two tuners, one for VHF and one for UHF; or the insertion of individual UHF strips in place of unused channels on turret-type tuners.

VHF and UHF Tuners

The most common method of providing reception of all 82 channels is to use a 13-position VHF tuner and a separate UHF tuner. Figure 8-28 shows the arrangement of a transistor UHF tuner employing a semiconductor-diode mixer stage. The output from the mixer is fed to the VHF tuner, which operates as the first IF section in the receiver. About 5 mA are drawn from the dc supply by the UHF oscillator. The mixer output frequency is usually adjusted for operation on channel 6 of the VHF tuner. A special type of silicon transistor is used in the oscillator circuit because the UHF range extends from 470 to 890 MHz.

SUMMARY

RF tuners can be classified in two different ways: by the principal circuit difference and by construction, such as pushbutton, wafer switch, turret, and disk type.

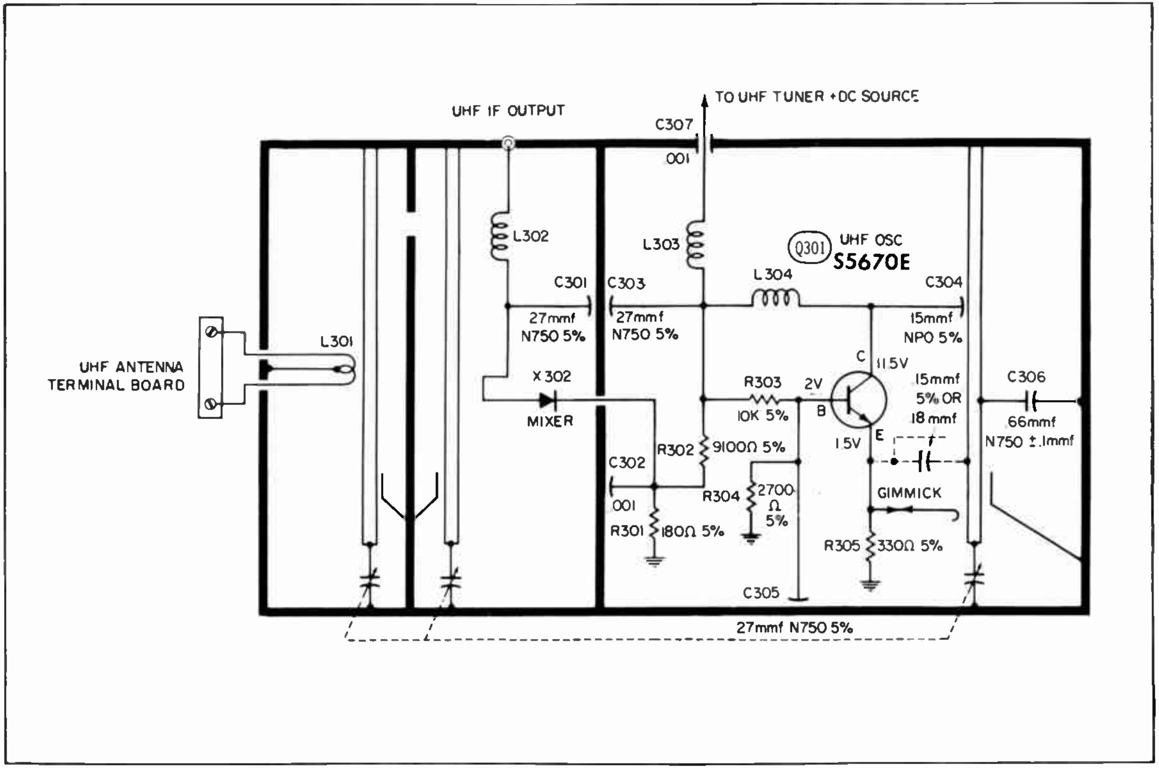


Fig. 8-28. Schematic of typical UHF tuner.

Unlike radio receivers where the RF amplifier stage is sometimes omitted, all television receivers employ an RF amplifier stage (1) to give additional gain, which provides increased sensitivity, and (2) to help isolate the oscillator stage from the antenna.

The purpose of the oscillator is to generate a signal 45.75 MHz above the incoming-signal frequency. The incoming signal and the oscillator signal are then mixed to produce the correct IF difference signal. The mixer stage mixes the signal from the RF amplifier stage and the signal from the mixer stage and combines them. Since these two frequencies are separated by 45.75 MHz, the IF signal, at this 45.75 MHz frequency, appears in the output circuit where it is coupled to the IF amplifier.

REVIEW QUESTIONS

1. What are the frequency allocations for TV channels?
2. Name the various types of television VHF tuners.
3. What purpose does a balun serve in the antenna circuit?
4. What is the purpose of an RF amplifier stage in the television receiver?
5. What is the purpose of the oscillator?
6. What is the purpose of the fine-tuning control?

CHAPTER 9

The Video Channel

The video channel consists of the stages from the tuner to the picture tube—the video IF amplifier, video detector, and the video amplifier. These circuits amplify and process the video signal for application to the picture tube to reproduce the picture.

VIDEO IF AMPLIFIERS

The television receiver is a high-frequency superheterodyne; most of the gain is contributed by the IF amplifiers. IF stage gain is measured as shown in Fig. 9-1. Recall that there are actually two IF signals at the mixer output: the video IF and the sound IF. These two frequencies are separated by the 4.5-MHz difference set by the transmitter. The response of the IF amplifiers is made wide enough that both frequencies are passed. In the video detector, the sound IF and video IF are beat together to produce the 4.5-MHz-intercarrier sound signal.

In early television receivers the sound and video IF signals were separated directly at the mixer output, and separate IF amplifiers were employed for the video and sound. This method was called *split sound*; however, it is not employed in any modern receivers. All modern receivers use the intercarrier principle.

IF Requirements

The requirements of the television IF amplifier system are far more complex than the IF amplifiers in broadcast receivers. In broadcast receivers, the IF amplifiers must pass a band of frequencies only 10 kHz wide. In FM receivers, the bandwidth requirements are only 200 kHz. In a television receiver, however, the IF amplifier must pass a band of frequencies 5 MHz wide. In addition to the requirement of passing the wide band of frequencies, other frequencies must be attenuated so that they cannot cause interference in the desired channel. These frequencies are:

1. Sound carrier of the adjacent lower channel
2. Video carrier with its modulation in the next higher adjacent channel

In addition, the sound IF of the desired channel must be reduced to a level 23 to 26 db below the video carrier within the IF amplifier system. If the sound carrier is not reduced, sound bars (interference) will appear in the picture. Figure 9-2 shows the basic IF and VHF frequency relations.

The number of stages of amplification varies among the different manufacturers and the intended application of the receiver (fringe or local reception). Sets with only one IF amplifier or as many as five stages have been produced. Most receivers, however, employ two or three stages of IF amplification.

In Chapter 8 it was stated that the use of 45.75 MHz as the video IF and 41.25 MHz for the sound IF was practically universal in modern receivers. Formerly, many other frequencies were used as the sound IF. Some of them are as follows:

Video IF Carrier, MHz	Sound IF Carrier, MHz
15.2	10.7
22.9	27.4
25.75	21.25
26.1	21.6
26.2	21.7
26.4	21.9
26.25	21.75
26.6	22.1
26.75	22.25
37.3	32.8

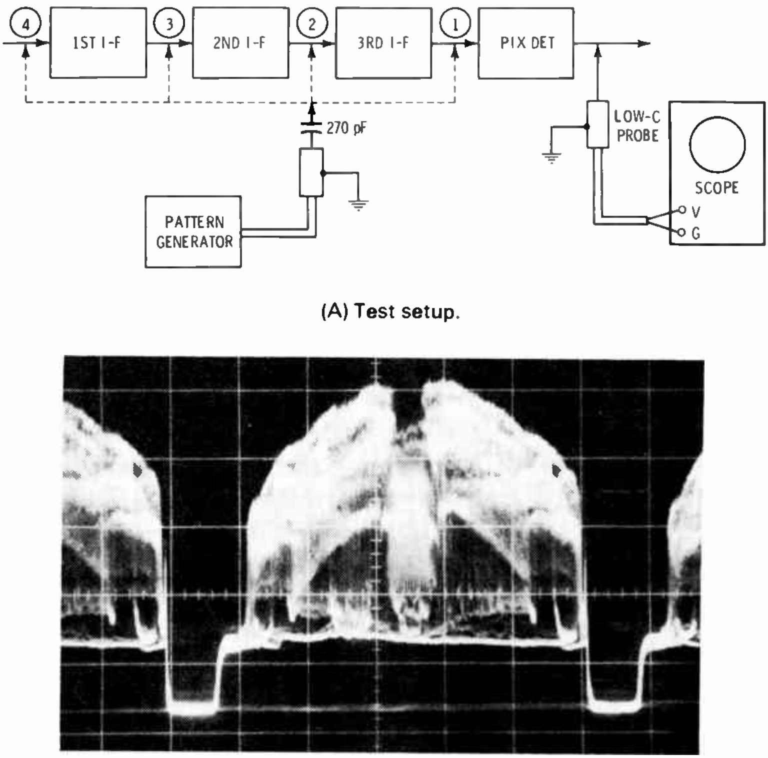
Video IF Response

Recall that in vestigial sideband transmissions (Fig. 9-3A), the amplitude of the transmitted signal is practically constant from approximately 0.75 MHz below the video carrier to 4.0 MHz above the carrier. Also, between 0.75 and 1.25 MHz below the carrier, a portion of the lower sideband is transmitted. Thus, if such a carrier and its sidebands were to be applied to a linear detector, the output would be as pictured in Fig. 9-3B. Obviously, such an output would not give the desired results. With the response of Fig. 9-3B, all objects that result in a video frequency up to 0.75 MHz from the carrier would receive twice the amplification as those from 1.25 to 4.0 MHz. Between 0.75 and 1.25 MHz, the response tapers gradually from 100 to 50 percent.

Some method of compensating for the increased low frequencies due to the double-sideband transmission must be provided in the video IF amplifier. This compensation is provided by reducing the amplification at the carrier frequency and increasing it at the higher frequencies. Thus, the ideal video response should appear as shown by curve B in Fig. 9-4; curve A shows the transmitted carrier.

In curve B, the video carrier is set at the 50 percent point, and the areas between 0.75 MHz above and below the carrier are less than 100 percent of the response. However, by adding the portion of the response between 0.75 MHz below the carrier and the carrier to the response between the carrier and 0.75 MHz above the carrier, the curve at D will result. Thus, these two portions of the curve, when added together, result in an overall 100 percent response between the carrier and the 0.75-MHz point.

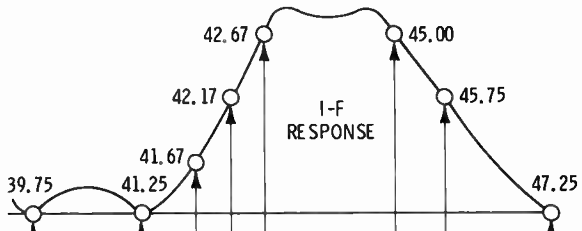
It is impossible to obtain the straight-line response of curve B in Fig. 9-4. Notice, however, the curve at C will also add to the desired response. At the high-frequency end of the response, the ideal curve is depicted by curves A and B. Usually, however, the high-frequency response is tapered off, as shown by curves C and D. This tapering off at the high-frequency end does reduce the fine details in the picture, but it is not noticeable in the average scene. In practice, few receivers provide more than a 3.0-MHz response.



(A) Test setup.

(B) Typical scope pattern.

Fig. 9-1. Measurement of IF stage gain.

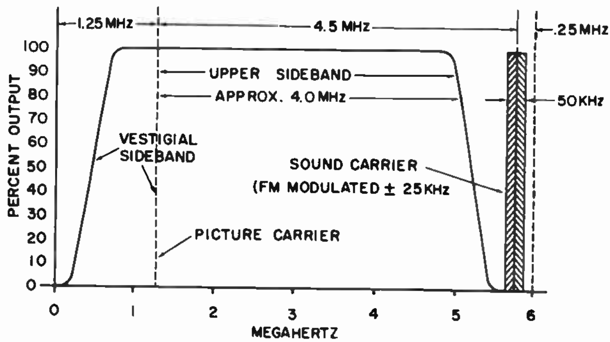


MARKER TITLE	I-F FREQUENCY	CH 4	CH 10	VIDEO/CHROMA
ADJ PIX	39.75 MHz	73.25 MHz	199.25 MHz	6.00 MHz
SOUND	41.25 MHz	71.75 MHz	197.75 MHz	4.50 MHz
CHROMA	41.67 MHz	71.33 MHz	197.33 MHz	4.08 MHz
CHROMA (CARRIER)	42.17 MHz	70.83 MHz	196.83 MHz	3.58 MHz
CHROMA	42.67 MHz	70.33 MHz	196.33 MHz	3.08 MHz
REFERENCE	45.00 MHz	68.00 MHz	194.00 MHz	0.75 MHz
PIX	45.75 MHz	67.25 MHz	193.25 MHz	ZERO
ADJ SND	47.25 MHz	65.75 MHz	191.75 MHz	1.50 MHz

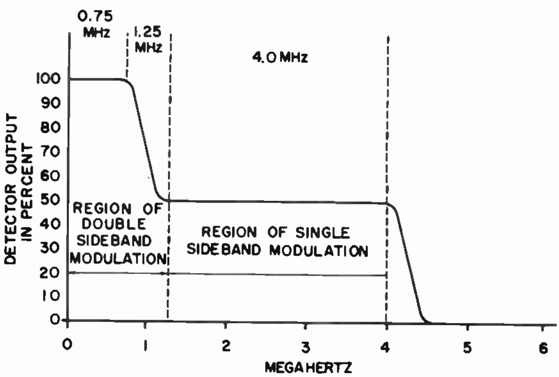
Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 9-2. IF and VHF frequency relations.

Up to this point, we have discussed the frequencies as they are transmitted; that is, the video carrier in Figs. 9-3 and 9-4 is shown at the low end of the response curve, and the sound carrier is shown at the high end. Recall, however, that the receiver local oscillator frequency is higher than the transmitted carrier frequency; therefore, in the IF amplifiers, the sound IF will be located at the low end of the response curve, and the video IF will be at the high-frequency end. Also, in an actual receiver, the ideal response of Fig. 9-4 is seldom obtained. The actual response



(A) Vestigial sideband transmission.



(B) Response obtained by linear detection of (A).

Fig. 9-3. Effect of linear detection of the carrier.

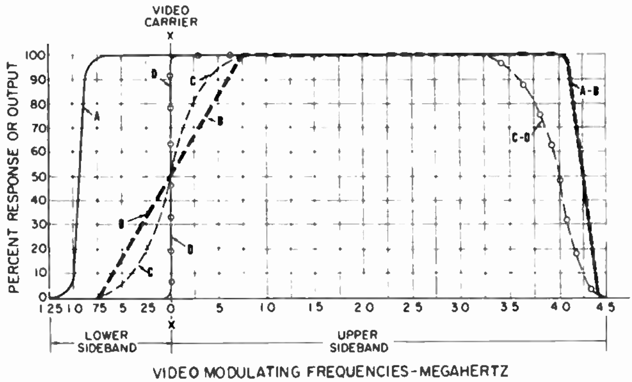


Fig. 9-4. Overall receiver characteristic required to compensate for vestigial sideband modulation.

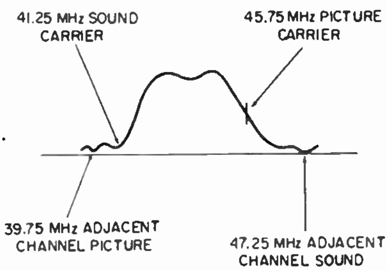
of the IF amplifier section will usually appear similar to the curve of Fig. 9-5.

IF Traps

In addition to providing amplification of the desired frequencies, the video IF amplifiers must also prevent certain undesired frequencies from being amplified and passed on to the following stages. This function is performed by *trap circuits* in the IF amplifier stages.

Based on the 41.25- and 45.75-MHz sound and video IF frequencies, traps are usually included for the following frequencies.

Fig. 9-5. Typical video IF response.



1. 39.75 MHz adjacent-channel sound carrier
2. 41.25-MHz cochannel (desired) sound carrier
3. 45.75-MHz adjacent-channel video carrier

Two types of traps are employed: shunt and absorption traps.The *shunt trap* (Fig. 9-6) consists of a series-resonant tank connected in shunt (parallel) with the input circuit. This circuit presents a low impedance to any signals at the resonant frequency of the coil and capacitor. Thus, any signals at these frequencies will be shunted to ground. The adjustment of the coil permits precise adjustment of the trap to the desired frequency. Either the coil or the capacitor can be made adjustable; however, in actual practice, the coil is usually made adjustable, as shown in Fig. 9-6.

The *absorption trap* (Fig. 9-7) consists of a parallel-resonant circuit inductively coupled to the IF transformer. At the resonant frequency, maximum current flows in the trap circuit. This current must be absorbed from the IF transformer; therefore, any current at the trap resonant frequency present in the IF transformer secondary will be removed.

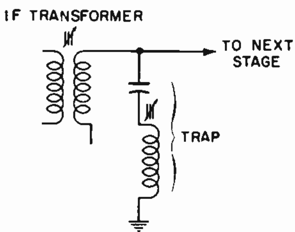


Fig. 9-6. Shunt trap.

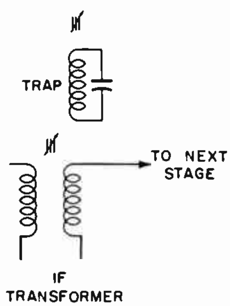


Fig. 9-7. Absorption trap.

IF Amplifier Circuits

As mentioned previously, the IF amplifier circuit must be capable of passing a wide band of frequencies. The video modulation extends approximately 4 MHz from the carrier. In addition, the sound IF carrier, located 4.5 MHz from the video carrier, must be passed.

The sound IF carrier, however, must not be allowed to receive the same amount of amplification as the video carrier if the circuit is to function properly. Usually, the amplitude at the sound IF frequency should be approximately 10 percent of the peak level. For this reason, traps tuned to the sound IF frequency are usually included in the video IF circuit to reduce the sound IF frequencies.

An ordinary amplifier stage would be unable to amplify the wide band of frequencies necessary in the IF system. Therefore, some means must be employed to increase the bandwidth. The following basic circuits are used for video IF amplifiers:

1. Overcoupled amplifiers (see Fig. 9-8)
2. Stagger-tuned amplifiers (see Fig. 9-9)

Stagger-Tuned IF System

In the stagger-tuned IF system, each IF stage is tuned to a different frequency in the passband. Figure 9-9 shows the effect of stagger tuning. Two stages are tuned to two separate frequencies. The response curves of the two individual stages are indicated by the solid lines in Fig. 9-9; however, the overall response of the two stages is indicated by the dotted line. Thus, by proper choice of frequencies and circuits, the response can be widened to obtain the desired response.

Figure 9-10 depicts a basic transistor IF amplifier configuration. The third IF transistor operates at higher power than the first two because the video detector requires appreciable power input. Transistor Q25 operates with a collector voltage of approximately 15 volts and an emitter current of about 15 mA. The collector-load impedance is nominally 1,000 ohms; however, transformer T8 provides some stepup voltage for the video detector. The power gain of this stage is about 18 db. It is neutralized by a 1.5 μf capacitor connected from the base of Q25 to the secondary of the collector output transformer.

The first stage in Fig. 9-10 operates at 15 volts on the collector and an emitter current of 4 mA. Reverse AGC is applied to the base of Q27; this is conventional AGC action in which the transistor is AGC-biased toward cutoff. The minimum collector current of Q27 under strong-signal conditions is approximately 50 μA. Q27 has a dynamic range of 40 db. Diode D12 is a clamp diode that becomes reverse-biased to prevent Q27 from being completely cut off when the AGC voltage reduces the RF tuner gain

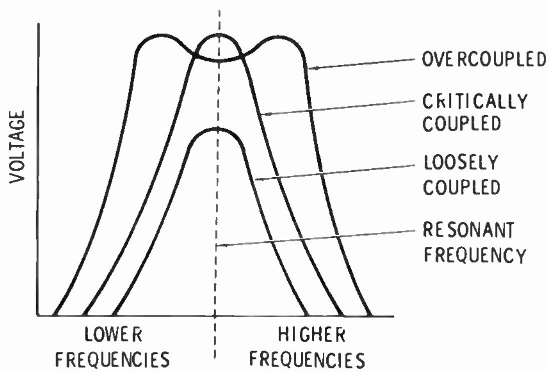


Fig. 9-8. Examples of loose coupling, critical coupling and overcoupling.

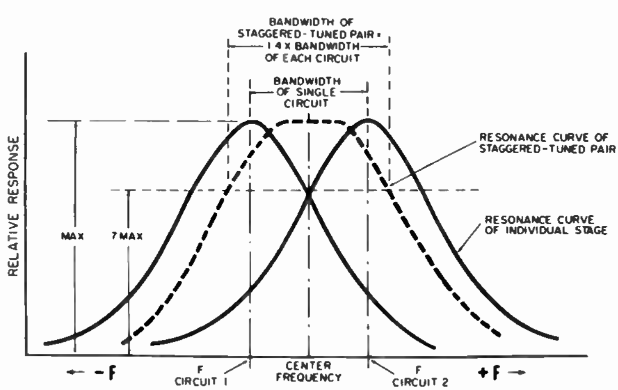


Fig. 9-9. Effect of staggered tuning.

to a very low value. Q27 is neutralized by the 1.5-μf capacitor connected from its base to T6.

Two traps are connected into the input circuit of Q27 in Fig. 9-10: The first is an inductively coupled trap, and the second is a bridged-T configuration. These are the accompanying- and adjacent-sound traps, respectively. The collector load for Q27 is a simple resonant circuit, with a tap to provide an out-of-phase neutralizing signal. Transistor Q26 is base-driven via capacitance coupling. This second stage is not AGC-controlled and operates continuously at maximum gain. The base bias circuit for Q26 provides some negative feedback, which assists in obtaining a properly shaped IF response curve. The collector for Q26 is a bifilar transformer.

Preliminary analysis of IF trouble symptoms requires tests to isolate the defect to a particular stage. This can be done either by signal tracing or by signal substitution. Signal tracing is accomplished by means of an oscilloscope with a demodulator probe. In turn, the progress of the TV signal is checked, stage by stage, through the IF amplifier.

The chief disadvantage of the signal-tracing technique is that heavy loading is imposed on the IF stages by the demodulator probe. In turn, the results of a signal-tracing test are not always conclusive. For this reason, many technicians prefer a signal-substitution procedure, such as outlined in Fig. 9-11. A generator is used as a signal source, and the picture tube serves as an indicator.

VIDEO DETECTORS

The video IF amplifier is followed by the video detector, which is essentially the same as the second detector in AM broadcast or short-wave radio receivers. However, two significant circuit differences in the TV video detector must be taken into consideration: (1) a means of compensation must be used to prevent the loss of the higher video frequencies; and (2) the polarity of the detector output must be considered.

The video signal may be applied to the grid or to the cathode

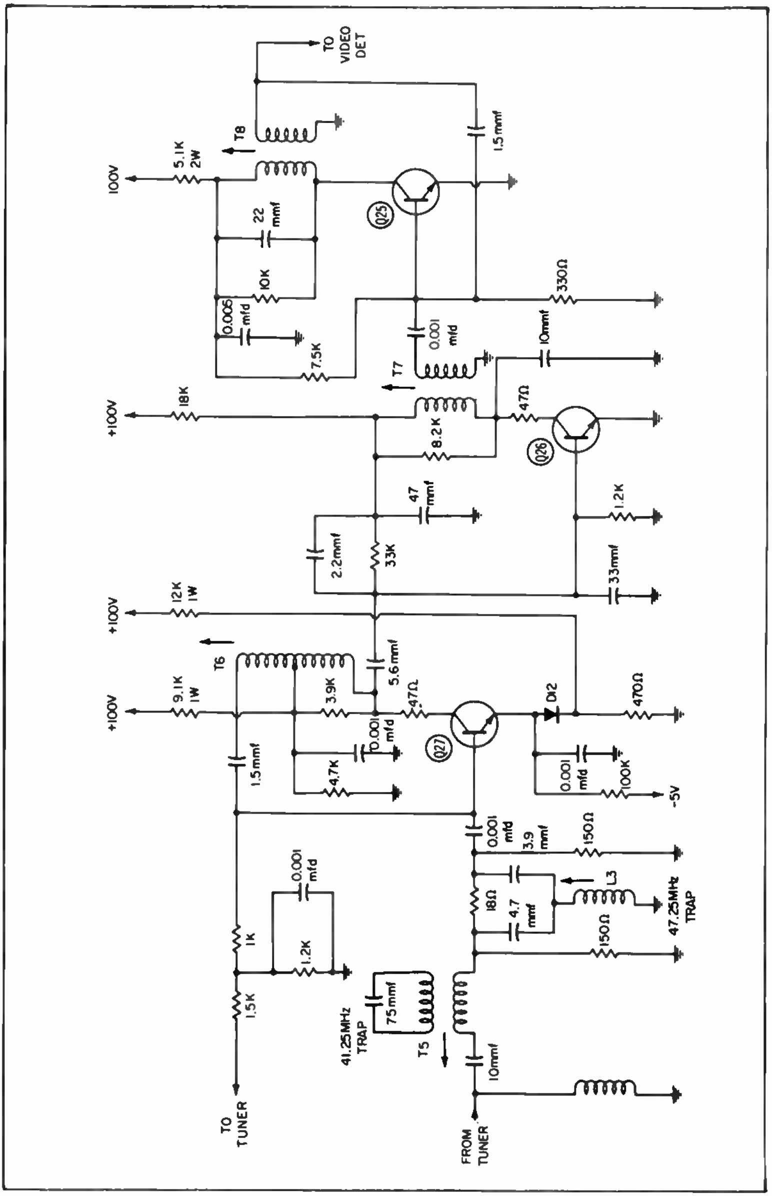


Fig. 9-10. Video IF amplifier circuit.

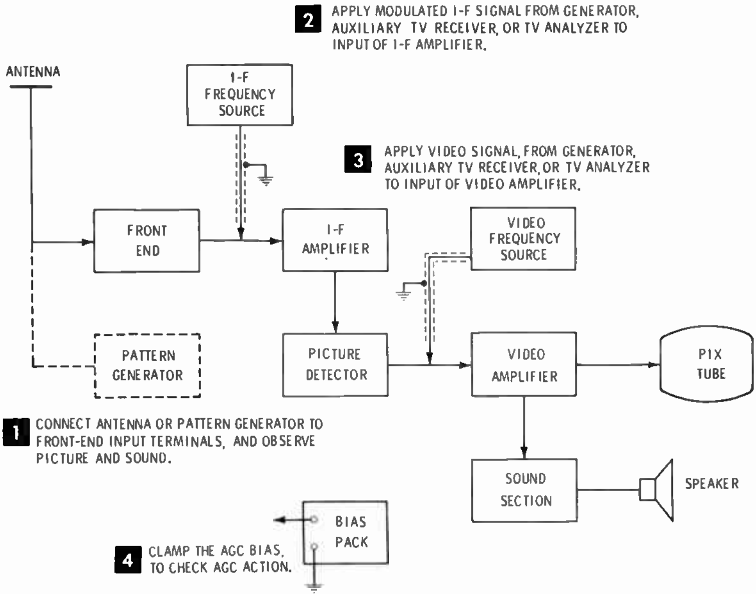
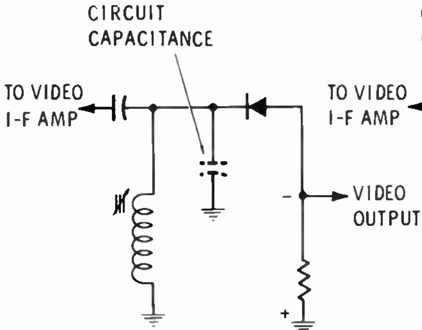


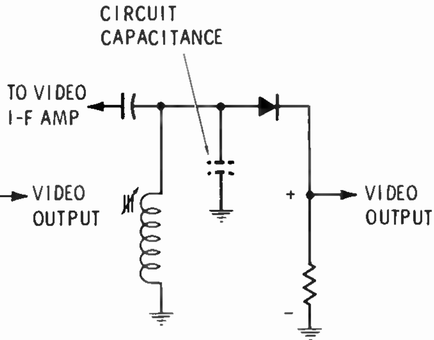
Fig. 9-11. Pointers for isolating defect of IF strip.

of the picture tube. To what element the signal is applied and the number of amplifiers between the detector and the picture tube determine the polarity of the detector-output signal. If there is an even number of video-amplifying stages between the detector and the picture-tube grid, the detector output must be negative-going. In other words, an increase in IF carrier strength at the detector results in a more negative video signal with respect to ground. Figure 9-12A shows a detector that supplies a negative picture polarity.

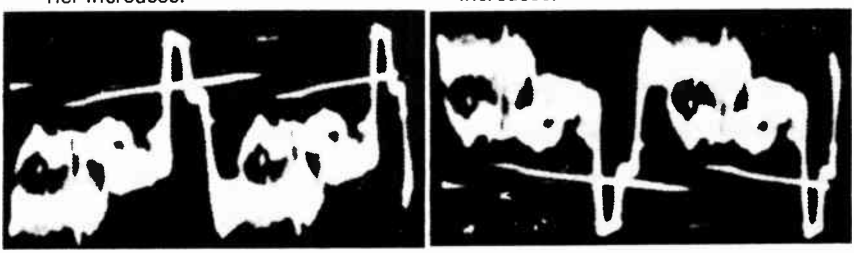
If an odd number of video-amplifying stages are employed (in most instances, this will be a single stage) and the video signal is applied to the grid of the picture tube, the detector must be connected as shown in Fig. 9-12B. This circuit, with the plate of the diode connected to the high side of the video coupling circuit, produces a video output that becomes more positive as the video-carrier strength is increased. Figure 9-13 shows diode polarity identifications.



(A) Video output increases negatively with respect to ground as carrier increases.



(B) Video output increases positively with respect to ground as carrier increases.



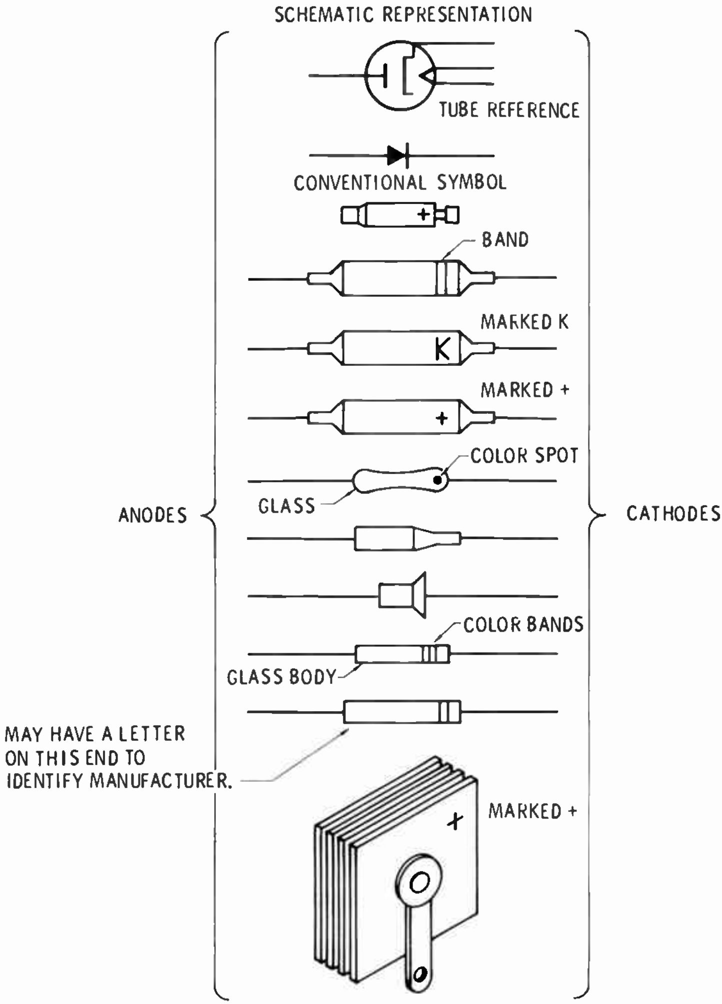
(C) Appearance of positive-going and negative-going video signals on the oscilloscope screen.

Fig. 9-12. Diode video-detector-output polarity.

VIDEO AMPLIFIERS

The output of the video detector seldom exceeds a few volts. Since the picture tube requires a grid swing of approximately 40 volts for its range of black to white, the signal from the video detector must be amplified through one or more stages of video amplication.

In our study of the nature of the video modulating signal, we have seen that the range of frequencies extends from 30 to over 4 million Hz/sec. For an amplifier to provide uniform gain over this extended band, compensating circuits must be used. The basic circuit, to which correction networks are applied, is the familiar resistance- and capacitance-coupled audio amplifier.



Courtesy the Heath Co.

Fig. 9-13. Diode polarity identifications.

Three separate methods of extending the range of a resistance- and capacitance-coupled amplifier for video use are:

1. Low values of collector load or coupling resistance
2. Low-frequency compensation to overcome effects of coupling network, unless direct coupling is used

3. High-frequency compensation to overcome effects of total circuit capacitance

Low Value of Collector Load

Figure 9-14 shows the effect of changing the value of the collector-load resistor. The band of video frequencies over which the output is flat is greatly extended as the coupling resistance is decreased. The choice of load resistor is a compromise between bandwidth and gain. The voltage gain of a video stage is seldom more than 20, whereas in resistance-coupled audio stages gains of as high as 150 are possible. Load resistors of 2,000 to 4,000 ohms are common in video amplifiers. After the value of load resistance is determined, the stage is compensated to raise the gain at frequencies below approximately 100 cycles and above several hundred kilohertz. If direct coupling is used, no LF compensation is required.

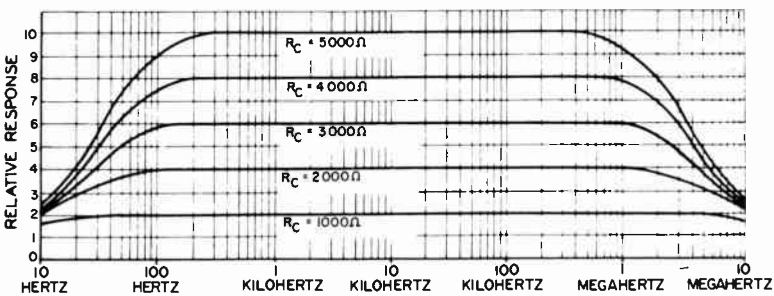


Fig. 9-14. Effect of plate load resistor on gain and bandwidth.

A typical transistor video amplifier is depicted in Fig. 9-15; this amplifier has a nominal gain of 28 db. The video-drive transistor Q204 is connected as an emitter-follower in order to match the comparatively high impedance of the video detector to the input impedance of the video-output transistor Q205. The contrast control is the emitter resistance for the video-driver stage. A 4-μf coupling capacitance is required to obtain good low-frequency response because this capacitor works into a 10-ohm resistance. An *NPN* transistor, especially designed to handle a large-amplitude signal, is used in the video-output stage.

The output-signal voltage provided by the video amplifier in Fig. 9-15 ranges from 25 to 50 volts peak to peak. Note that the collector of the video-output transistor is returned to a 140-volt power supply. With the contrast control turned to maximum, an output-signal amplitude of 100 volts peak to peak can be provided. A light-dependent resistor (LDR201) is used to automatically vary the picture contrast and brightness as the ambient room lighting varies. This device acts to increase or decrease the gain of the video amplifier, thereby automatically controlling the contrast. Since the collector of Q205 is dc-coupled to the cathode of the picture tube, the brightness is also controlled automatically.

Preliminary analysis of trouble symptoms in the video-amplifier section is generally made with an oscilloscope, as depicted in Fig. 9-16. Waveforms are checked for amplitude (peak-to-peak voltage value) and for distortion. Instead of making a frequency-response check, a square-wave test may be used. If a video amplifier is in normal operating condition, it will pass a 100-kHz square wave without substantial distortion.

Measurement of dc voltage and resistance values are basic in pinpointing defective components. These tests apply to solid-state video amplifiers, as well as to tube-type amplifiers. Note that receiver service data often provide resistance charts to facilitate in-circuit resistance measurements. A typical chart is shown in Fig. 9-17. In the case of a solid-state receiver, in-circuit resistance measurements should be made with an ohmmeter that applies less than 0.08 volt across points under test, as noted in the chart.

A "hi/lo-pwr" ohmmeter is provided in the electrical multimeter shown in Fig. 9-18. The advantage of a lo-pwr ohmmeter in solid-state troubleshooting is that normal semiconductor junctions will not be "turned on" during in-circuit resistance measurements. A "turned-on" junction represents an unexpected shunt-resistance path that makes the resistance measure virtually meaningless.

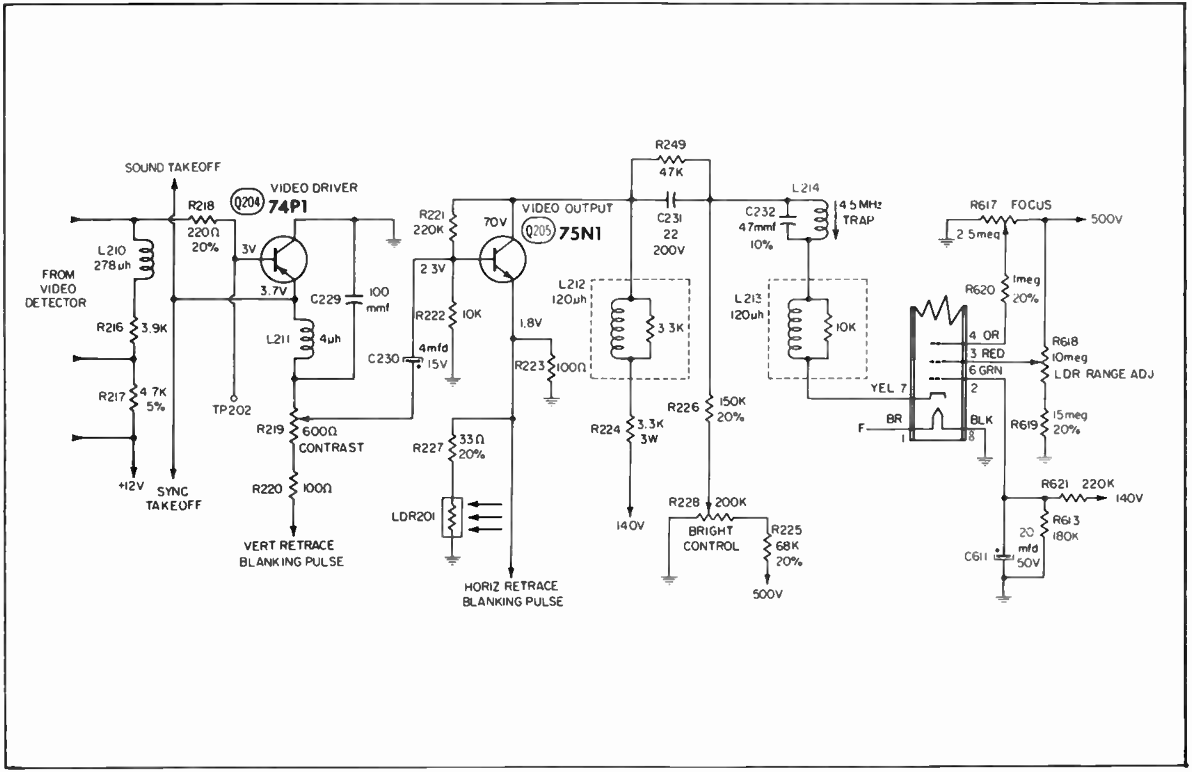


Fig. 9-15. Transistor video-amplifier circuit.

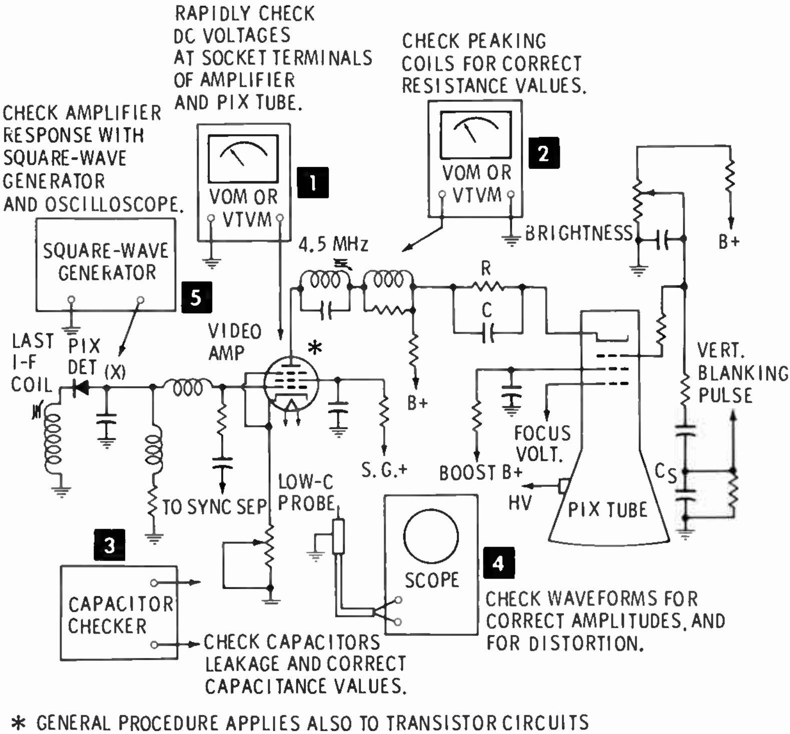


Fig. 9-16. Troubleshooting procedure for preliminary analysis of video-amplifier malfunctions.

BRIGHTNESS CONTROL

At several points, we have indicated that the variation of video, or picture, signal on the control grid of the picture tube is responsible for the instantaneous changes of spot illumination that makes up the elements of the picture. When the signal voltage on this control element changes in a negative direction, a darker spot is produced on the screen. Finally, at some critical negative voltage, the spot of light is entirely extinguished.

One of the essential controls of the television receiver is a bias adjustment on the grid. This adjustment ensures that the blanking

RESISTANCE MEASUREMENTS

Component	E	B	C	Component	E	B	C	Component	E	B	C	
Q4	180 Ω	1400 Ω	400 Ω	Q14	80 Ω	15 K	3500 Ω	Q23	70 Ω	70 Ω	0 Ω	
Q5	220 Ω	1400 Ω	380 Ω	Q15	120 Ω	3500 Ω	2000 Ω	Q24	140 Ω	800 Ω	1700 Ω	
Q6	180 Ω	1200 Ω	110 Ω	Q16	1000 Ω	55 K	180 Ω	Q25	70 Ω	2000 Ω	0 Ω	
Q7	2400 Ω	3000 Ω	300 Ω	Q17	380 Ω	50 K	470 Ω					
Q8	470 Ω	2400 Ω	45 K	Q18	1500 Ω	1200 Ω	8.2 Ω					
Q9	2700 Ω	3000 Ω	500 Ω	Q19	3.3 Ω	8000 Ω	500 Ω	Q26-VHF	180 Ω	2800 Ω	180 Ω	
Q10	150 Ω	3000 Ω	1200 Ω	Q20	80 Ω	180 Ω	13.5 Ω	Q27-VHF	330 Ω	1800 Ω	600 Ω	
Q11	1200 Ω	1200 Ω	80 Ω	Q21	45 Ω	15 K	800 Ω	Q28-VHF	80 Ω	550 Ω	3200 Ω	
Q12	1200 Ω	1200 Ω	0 Ω	Q22	80 Ω	1200 Ω	8 Ω	Q29-UHF	390 Ω	1200 Ω	60 Ω	

TAKEN WITH OHMMETER APPLYING A
MAXIMUM OF 0.08 VOLT ACROSS POINTS UNDER TEST

Courtesy Howard W. Sams Co.

Fig. 9-17. Resistance measurements.

level, or pedestal, of the signal occurs at the black point. Figure 9-19 shows two bias systems in which the voltage established by adjustment of the brightness control biases the control grid with respect to the cathode and determines the correct picture brightness. Because of the polarity of the video signal in Fig. 9-19A, the signal from the plate of the video-output tube is connected to the control grid of the picture tube.

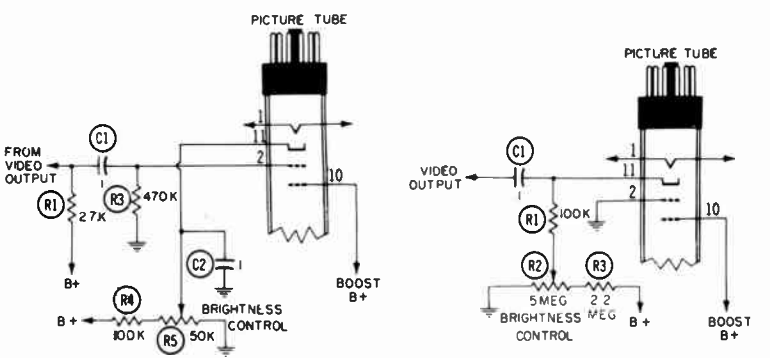
Figure 9-19B shows the video signal applied to the cathode of the picture tube. In either case, the brightness control is a voltage adjustment of the bias between the control grid and cathode, and it establishes the correct blanking or black level.

INTEGRATED CIRCUITS

Integrated circuits (ICs) are now used to a greater extent than previously in RF and IF amplifiers. Most IC units are based on the differential-amplifier configuration shown in Fig. 9-20. The transistors are formed in a single chip: Q1 and Q2 are called a *differential pair*; Q3 is termed a *constant-current sink*. Adjust-

Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 9-18. Electronic multimeter, which provides "hi-power" and "low-power" ohmmeter functions.



(A) Video signal applied to grid. (B) Video signal applied to cathode.

Fig. 9-19. Brightness-control circuits.

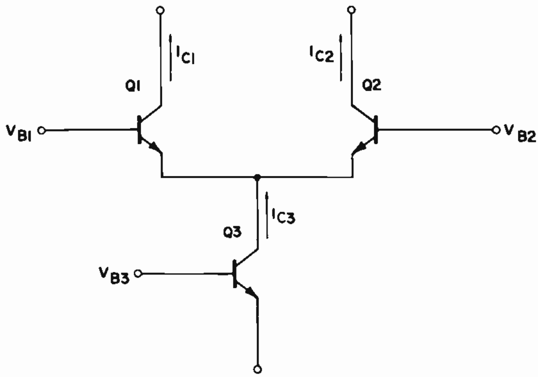


Fig. 9-20. Basic integrated circuit configuration.

ment of the base voltage V_{B3} determines the current I_{C3} and, in turn, the operating voltage of the amplifier circuit. The total collector current I_{C3} branches through Q1 and Q2 in accordance with the applied voltages V_{B1} and V_{B2}. Use of a differential pair makes the amplifier relatively free from effects of temperature changes.

With reference to Fig. 9-21, Q1 operates in a common-emitter configuration with the IF signal applied to the base. In turn, Q1 drives Q2 and Q3, which operate in a common-base configuration called a *cascode pair*. It employs a pair of transistors connected in series. The collector of Q3 is effectively grounded, and the IF signal output is taken from the collector of Q2. Diode D1 provides delayed AGC; the AGC voltage varies over a range of approximately 0.86 volt in normal operation. In this example, if the AGC voltage exceeds the nominal base voltage on Q2 by 57 mV, Q2 will be cut off and the collector current will be confined to Q1 and Q3. Since Q2 is cut off, the stage gain is minimum under this condition of AGC voltage.

Next, if the AGC is less than the nominal base voltage by at least 57 mV in Fig. 9-21, all the collector current from Q1 will pass into the emitter of Q2; Q3 is biased to cutoff. In turn, Q2 develops an amount of gain that depends on the particular value of applied AGC voltage. A supply voltage of 20 volts is used in this example and is applied to terminal 6, as shown in Fig. 9-22. Terminals 8 and 10 are bypassed to ground with 0.005-μf capaci-

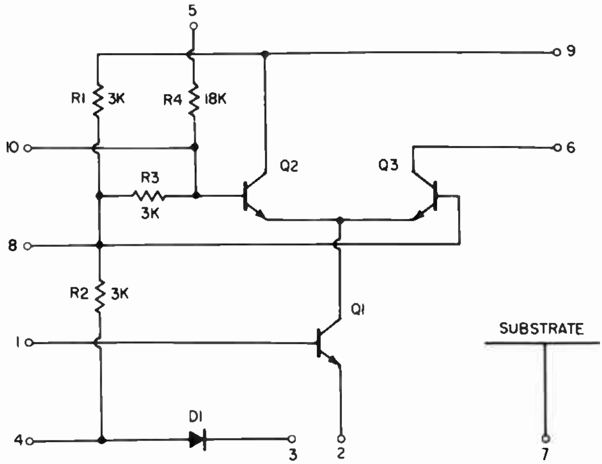


Fig. 9-21. Configuration of an integrated IF amplifier stage.

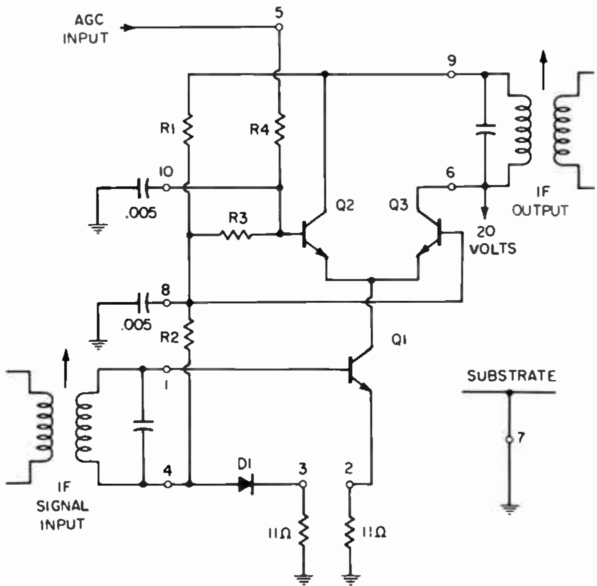


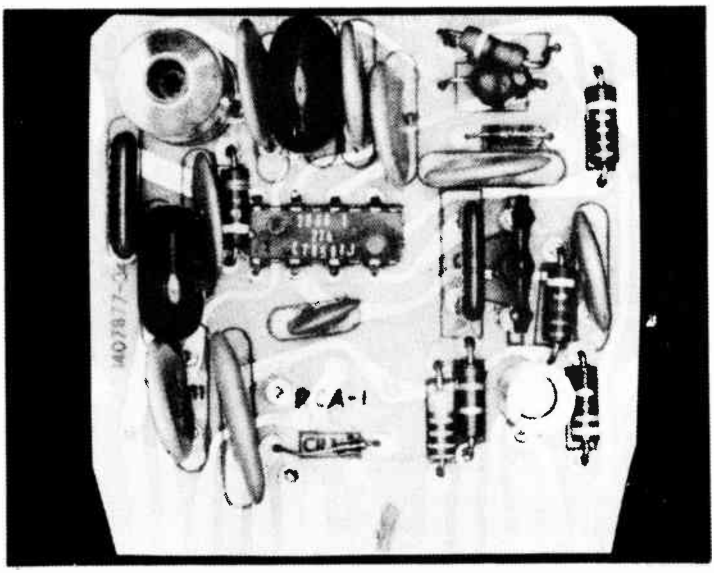
Fig. 9-22. Integrated IF circuit showing connections to external components.

tors; terminals 2 and 3 are connected to ground via 11-ohm resistors. The substrate, terminal 7, is grounded. Ordinary slug-tuned coils and capacitors are used to couple one IC to the next.

MODULAR CONSTRUCTION

Various receiver designs include modular construction. A *module*, such as the one shown in Fig. 9-23, is similar to a printed circuit board, except that it is designed to plug into the receiver. It can be unplugged, in turn, without any disconnection of leads. Modular construction facilitates troubleshooting procedures because a known good module can be quickly substituted for a suspected module. In turn, if normal operation is restored, the defective module can be repaired at any convenient time.

Some receivers are extensively modularized, as shown in Fig. 9-24. However, there are always a few chassis-mounted compo-



Courtesy RCA Corp.

Fig. 9-23. Module for a TV receiver.

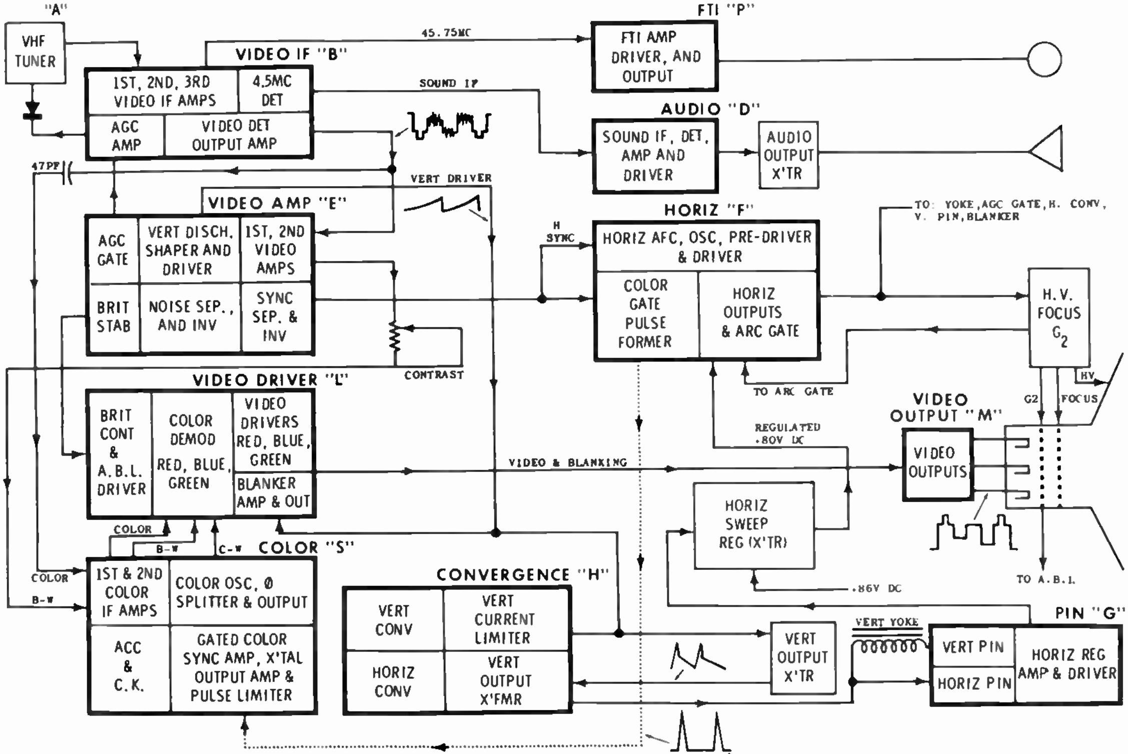


Fig. 9-24. Layout of typical modularized TV receiver.

Courtesy Motorola Consumer Products Inc.

nents. For example, the VHF and UHF tuners and the power transformer are always chassis-mounted.

TURN-OFF AND TURN-ON TESTS

If a transistor is suspected of being defective, it is frequently possible to make in-circuit *turn-off* and *turn-on tests* to determine whether the transistor is workable. These are quick checks that provide basic go/no-go answers.

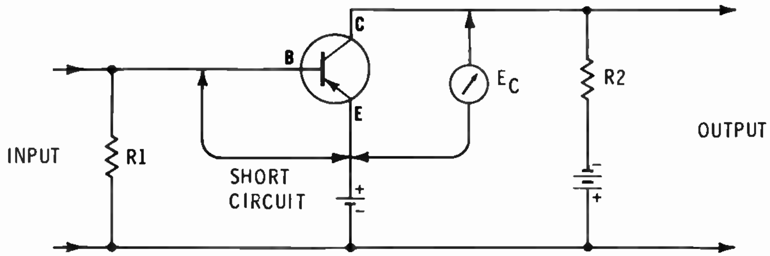
With reference to Fig. 9-25, a turn-off test is made in this type of circuit by measuring the collector-emitter voltage and then applying a base-emitter short circuit to observe any change. If the transistor has normal control action, the voltmeter indication jumps up to the collector supply-voltage value when the short circuit is applied. Otherwise, the transistor is defective and it should be unsoldered from its circuit and replaced.

Next, a turn-on test is made by temporarily connecting a 10-ohm resistor between the collector and base terminals of the transistor. A dc voltmeter is connected across the emitter resistor in the type of circuit. If the transistor has normal control action, the voltmeter indication will increase substantially when the forward bias is increased. Otherwise, the transistor is defective and should be unsoldered and replaced.

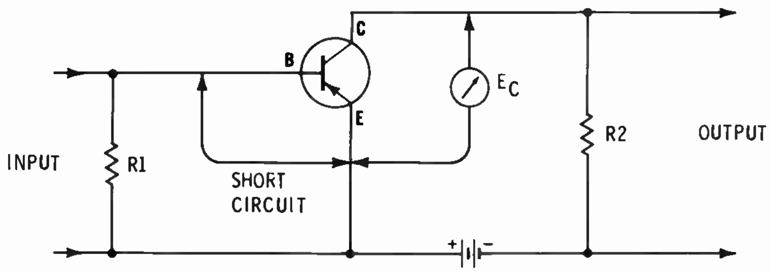
SUMMARY

In early television days the sound and video IF signals were separated directly at the mixer output, and separate IF amplifiers were used for the video and sound. This method, called split sound, is not used in modern receivers. All receivers use the intercarrier system, which is a receiver that uses the picture carrier and associated sound-channel carrier to produce an intermediate frequency equal to the difference between the two carrier frequencies. This intermediate frequency is frequency-modulated in accordance with the sound signal.

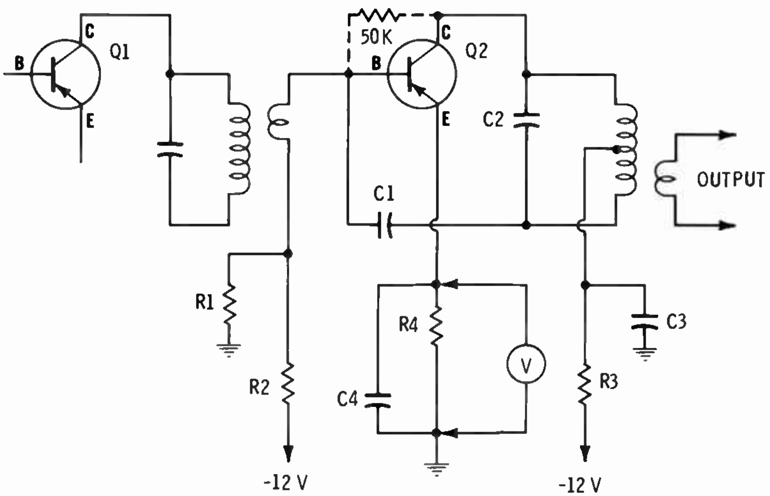
The requirements of the television IF amplifier system are far more complex than the IF amplifiers in broadcast receivers. In



(A) Turn-off test in a two-battery circuit.



(B) Turn-on test in a one-battery circuit.



(C) Turn-on test in a one-battery circuit.

Fig. 9-25. Basic in-circuit turn-off and turn-on transistor tests.

broadcast receivers, the IF amplifier must pass a band of frequencies only 10 kHz wide. FM receivers have a bandwidth of 200 kHz. In television receivers, the IF amplifier must pass a band of frequencies 5 MHz wide.

Vestigial sideband is an amplitude-modulated transmission in which a portion of one sideband has been largely suppressed by a transducer having a gradual cutoff in the neighborhood of the carrier frequency.

REVIEW QUESTIONS

1. What frequencies must the IF amplifier pass in AM receivers? FM receivers? TV receivers?
2. What are the video IF and sound IF frequencies used in modern TV receivers?
3. Explain vestigial sideband transmission.
4. What is the purpose of using IF traps?
5. What is the advantage of a "lo-pwr" ohmmeter?
6. How does a module differ from a printed circuit board?

CHAPTER 10

Sync and AGC Circuits

In commercial receivers, we find circuits in which the sync pulses are separated from the composite video signal by clippers. Processing circuitry develops sync waveforms of suitable polarity, separates the vertical sync pulses from the horizontal sync pulses, clips and levels the pulse trains, and provides either single- or double-ended output as required by subsequent receiver circuits. Sync takeoff may be made either in the video-detector or video-amplifier section.

A sample of the composite video signal is fed to a clipper circuit, as shown in Fig. 10-1. Either a diode or a transistor may be used as a clipping device. The advantage of a transistor is its amplification of the clipped pulses. In Fig. 10-1A, the incoming composite video signal is coupled to the diode circuit via capacitor C. This coupling capacitor removes the dc component from the composite video signal and also provides signal-developed bias across the diode.

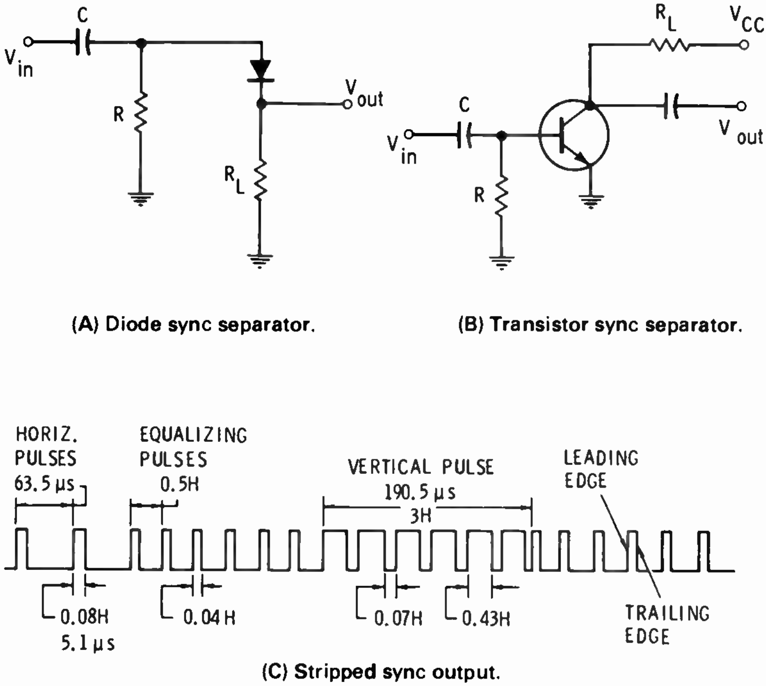
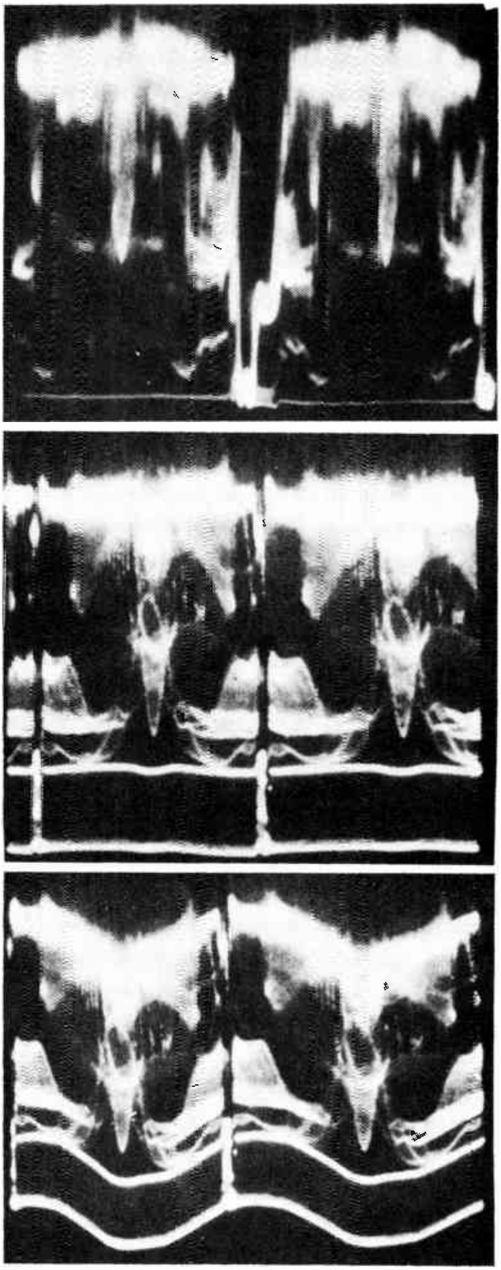


Fig. 10-1. Either a diode or a transistor may be used as a sync separator.

Signal-developed bias provides the best separating action when the incoming signal amplitude varies or when hum voltage is mixed with the composite video signal, as shown in Fig. 10-2C. The clipping level in the waveform is automatically maintained because the value of the signal-developed bias is proportional to the amplitude of the applied signal. Note, also, that coupling capacitor C has comparatively great reactance at 60 Hz and tends to suppress hum voltage.

Signal-developed bias is produced in Fig. 10-1A as follows: Positive portions of the applied waveform cause diode conduction, and negative portions are blocked by the back resistance of the diode. Forward current flow through the diode develops a negative charge on the right-hand plate of capacitor C. In turn, the diode becomes reverse-biased as a voltage that depends on the amplitude of the positive excursion of the video signal.



(A) 7875 Hz deflection.

(B) 30 Hz deflection.

(C) Composite video signal with exessive 60 Hz hum.

Fig. 10-2. Normal proportions of sync-pulse and camera signal amplitudes.

Between sync pulses, the charge on C decays at a rate that depends on the RC time constant of the circuit. When R and C have correct values, clipping occurs at the black level in the composite video signal. Clipping action is checked to best advantage with a oscilloscope. An oscilloscope-control familiarization diagram is shown in Fig. 10-3.

Transistors are also used to perform much the same functions. Figure 10-4 shows a typical transistor-limiter configuration. The collector-current waveform is limited because the base-drive voltage swings the base past the cutoff point. An example of saturation limiting is seen in Fig. 10-5. The collector-current waveform is limited because the base-drive voltage swings the base past the saturation point. Note that when a transistor is saturated, the collector-current flow is so heavy that the voltage drop across the collector-load resistor brings the collector voltage down to a very low value.

Conversely, transistors are employed to obtain clipping action. Figure 10-6 depicts a negative-peak clipper. The input signal causes the base to draw current on negative half-cycles. In turn, the coupling capacitor is charged and applies a positive signal-developed bias voltage on the base. Then the transistor is reverse-biased in the presence of a signal. Between successive signal peaks, some of the bias voltage leaks to ground. Therefore, the peaks of the applied waveform are clipped, and appear in the output circuit.

Many transistor TV receivers employ at least two sync-separator stages. Each stage operates as a clipper: The first stage clips off the top portion of the waveform, and the second stage clips off the bottom portion of the waveform. Note that the first transistor inverts the waveform polarity, thus providing for bottom-clipping. Q14 operates chiefly as a saturation clipper.

In the second stage of Fig. 10-7, Q15 is biased 0.3 volt beyond cutoff by signal-developed bias in normal operation. Accordingly, the first 0.3 volt of the sync tips becomes clipped. Q15 is also driven into collector saturation and thereby clips any residual video signal. The coupling capacitors tend to differentiate the sync waveform; therefore, C94 and R75 are included to provide integrating action that tends to restore the normal waveshape. Another circuit action provided by C94 and R75 is due to the

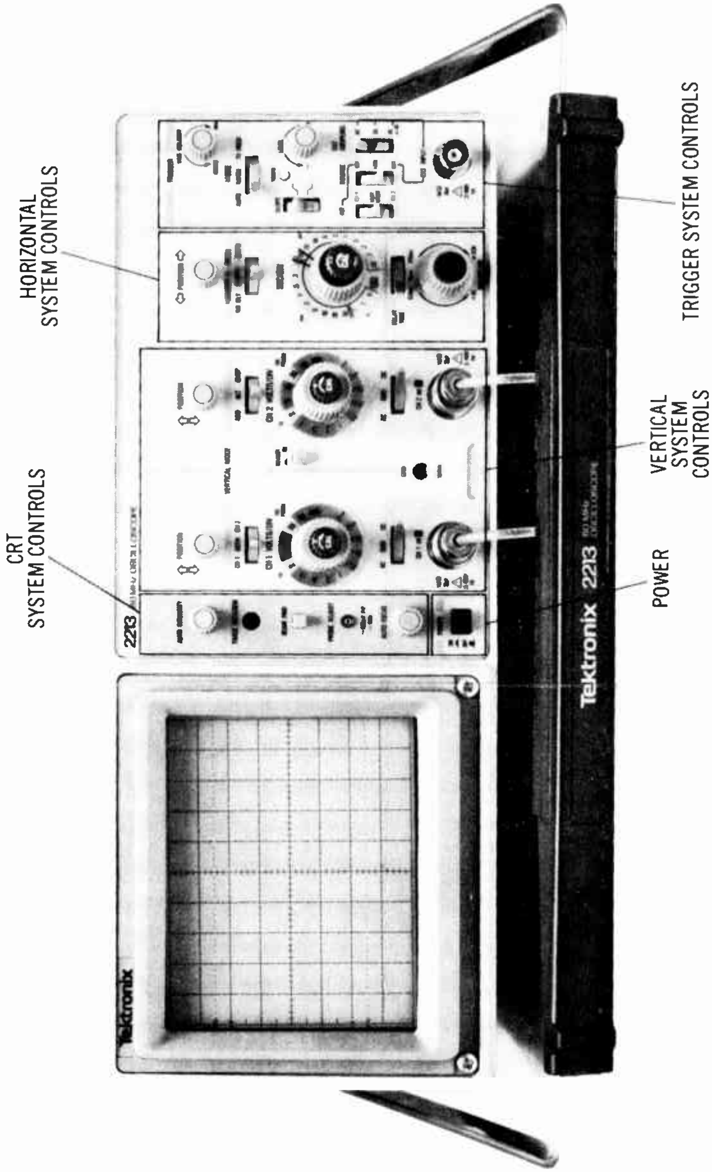
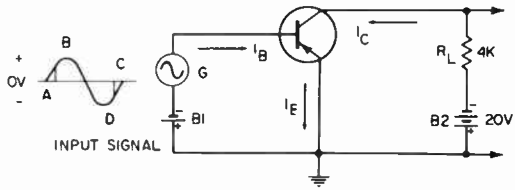
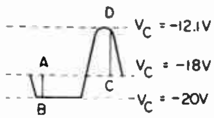


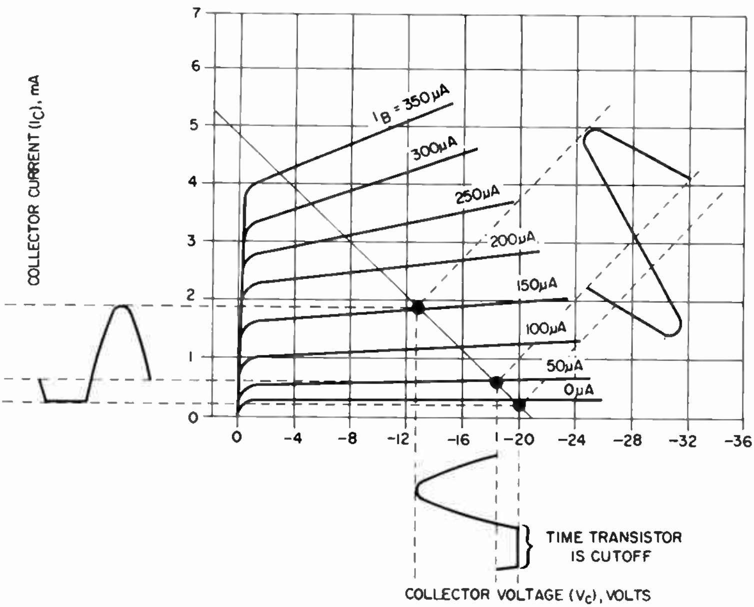
Fig. 10-3. Oscilloscope-control familiarization.



(A) Schematic.

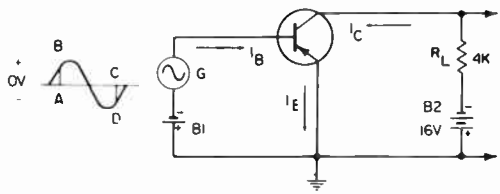


(B) Output signal.

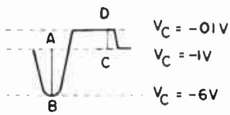


(C) Collector current curve.

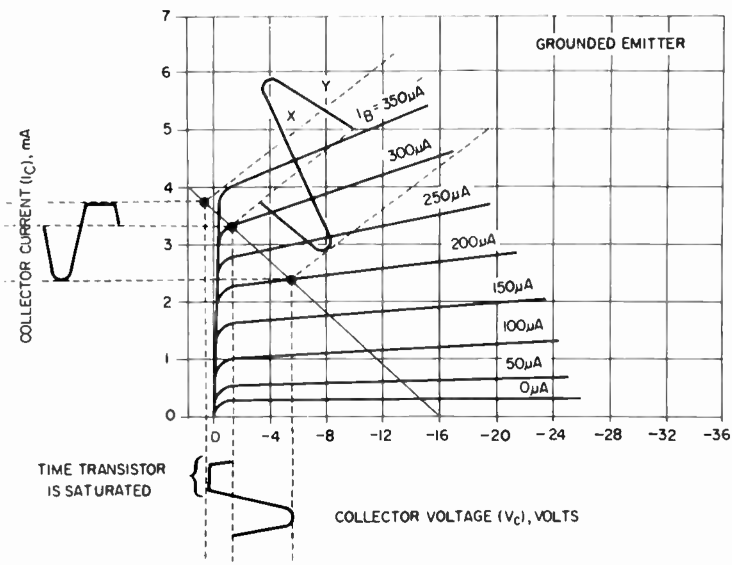
Fig. 10-4. Cutoff using PNP transistor.



(A) Schematic.



(B) Output signal.



(C) Collector current curves.

Fig. 10-5. Saturation limiting using PNP transistor.

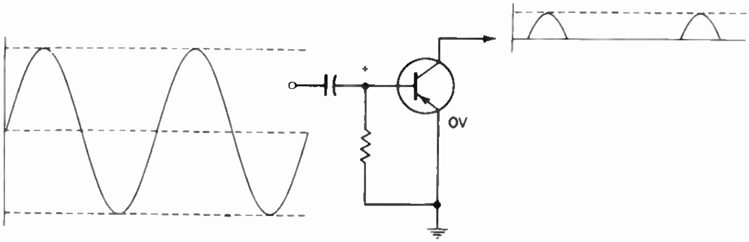


Fig. 10-6. Negative-peak clipper.

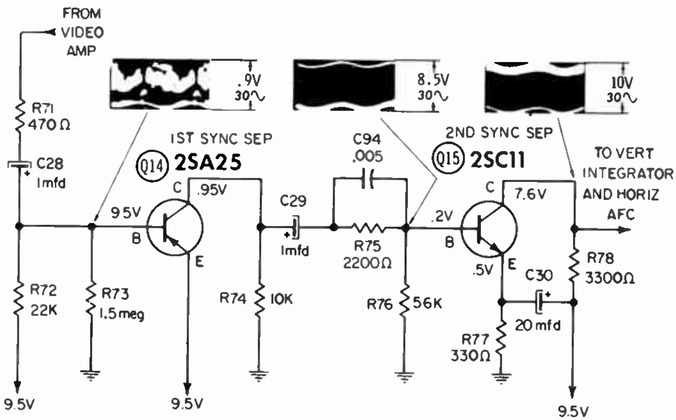


Fig. 10-7. Typical transistor sync-separator configuration.

impedance that they provide between the collector of Q14 and the base of Q15. This impedance prevents overdriving of Q15 on strong signals, which would result in excessive increase of pulse width at the collector of Q15.

A preliminary analysis of trouble symptoms in the sync section is shown in Fig. 10-8.

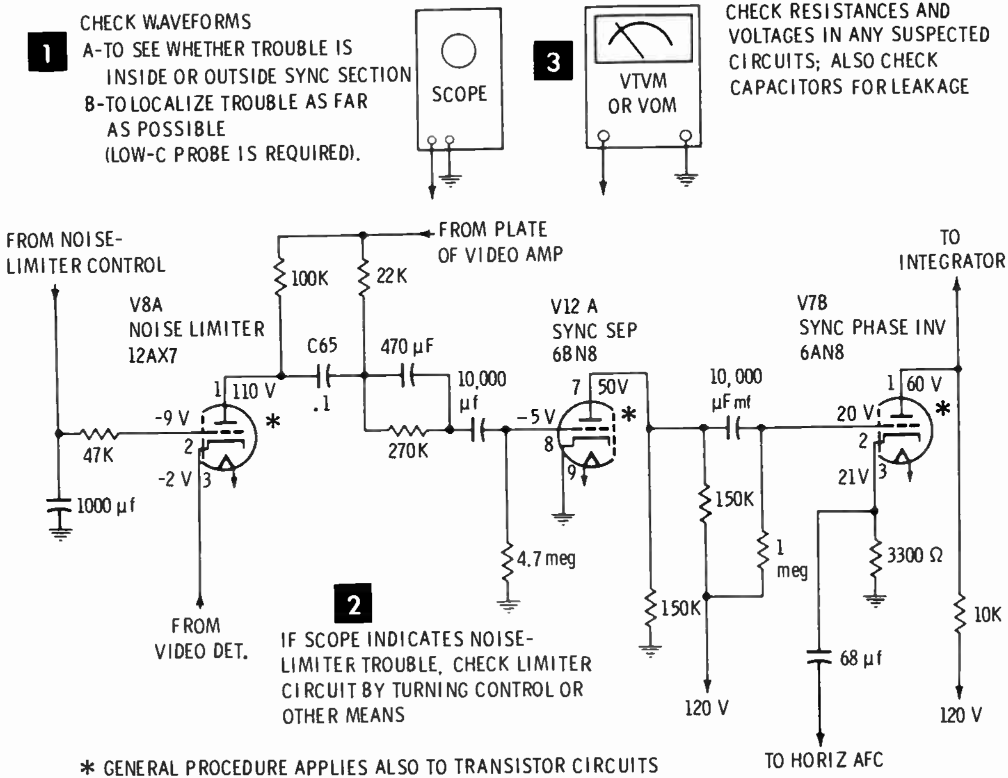


Fig. 10-8. Preliminary analysis of trouble symptoms in the sync section.

SORTING INDIVIDUAL HORIZONTAL AND VERTICAL PULSES

In our foregoing description of various methods of separating synchronizing pulses from the composite video signal, only the narrow horizontal pulses were mentioned. The longer vertical pulses are clipped from the signal in the same separation process.

After the sync pulses have been removed from the video signal, the vertical pulses must be sorted from the horizontal pulses, and each one must be fed to its respective deflection-scanning system. Since the horizontal and vertical pulses are equal in amplitude, the methods of separation for clipping them from the video signal cannot be used to distinguish between them. They do, however, differ in time duration; and on this basis sorting is accomplished.

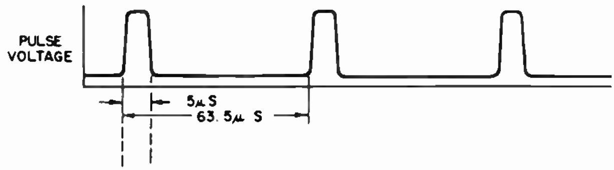
We shall now consider the action of such systems as differentiating networks for removing horizontal pulses and integrating networks for the vertical-pulse acceptance.

Horizontal-Pulse Separation

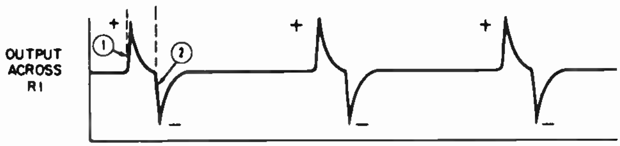
Horizontal pulses of the transmitted signal are approximately 5 μsec in duration. These pulses are impressed on a circuit of the type shown in Fig. 10-9C, which is known as an *RC differentiating circuit*.

Differentiation means the breaking down of a quantity into a number of small parts. The pulses in Fig. 10-9A are made into smaller parts, as shown in Fig. 10-9B by the action of the circuit in Fig. 10-9C. The circuit consists of a capacitive and resistive combination in which the capacitor is in series with the separated pulse input and the resistor is shunted across the output. The time constant of this circuit is made short compared with the duration of a horizontal-sync pulse. The sync pulse is held between 4 and 5 μsec, and the time constant of the horizontal differentiating circuit is made between 1 and 2 μsec. In an RC circuit in which the time constant is short compared with the duration of the applied square-wave pulse, the capacitor is completely discharged between pulses.

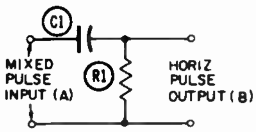
A sharp pip of voltage occurs across the resistor at both the



(A) Horizontal sync pulses.



(B) Output of differentiating circuit.



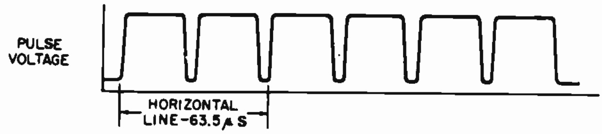
(C) R-C circuit for horizontal separation.

Fig. 10-9. Horizontal-pulse separation, or differentiation.

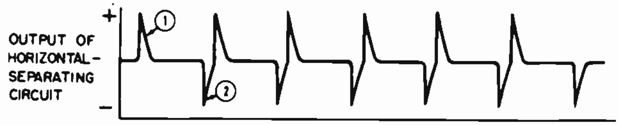
leading and trailing edges of the applied square-wave pulse. The amplitude of the pip is determined, not only by the amplitude of the square wave, but also by the steepness of the edge of the square wave. For this reason, the FCC limits the allowable slope of the leading and trailing edges. These slopes must not occupy more than 0.4 percent of the horizontal-line scanning interval of 63.5 μsec.

The voltage pip due to the leading edge of the horizontal-synchronizing square wave is shown as a positive pip at ① in Fig. 10-10B. The dip due to the trailing edge of the horizontal pulse is shown as a negative voltage at ② . The leading-edge pulses control the horizontal-scanning oscillator. The negative pulses are rejected by cutoff or saturation of one or more stages of the sync system.

When the longer-duration, vertical-synchronizing pulses arrive, the differentiating circuit acts as shown in Fig. 10-10B. Here,



(A) Vertical-sync pulse with serrations.



(B) Output of horizontal-differentiating circuit.

Fig. 10-10. Action of horizontal-differentiating circuit on vertical-sync signal.

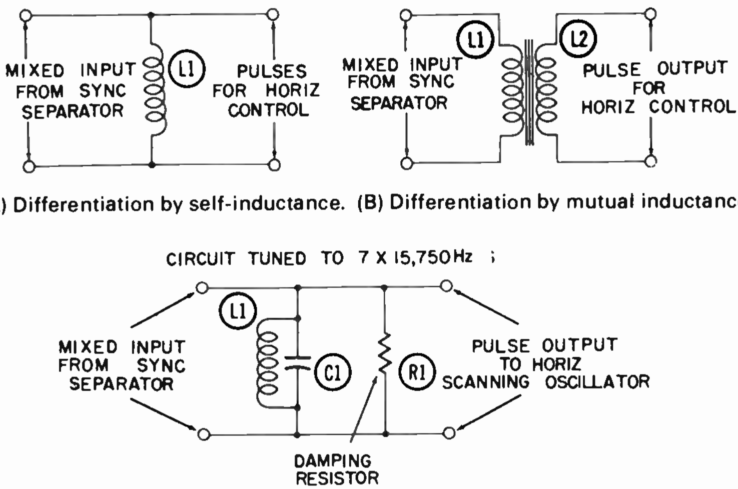
again, a positive pip occurs at the leading edge of each vertical pulse, and a negative pip occurs at the trailing edge. The leading-edge pulses continue to control the horizontal oscillator during vertical retrace. In this instance, however, two pulses occur during a horizontal-line scanning interval. Only the first of these pulses is used to control the horizontal oscillator; the second pulse cannot cause lock-in since it occurs while the oscillator is insensitive to tripping.

The horizontal pulses can be separated by other means than the RC differentiating circuit just described. Figure 10-11 shows two types of differentiating circuits that employ inductance and a third type that uses the properties of a resonant circuit.

The inductance of the circuit in Fig. 10-11A is connected in series with the plate circuit of a tube that has been biased to clip the sync pulses from the video signal. The waveform of the sync-pulse plate current consists of steep slopes, which correspond to very rapid changes of current. The voltage across the inductance is proportional to the rate of change of the current through it. Thus, at the leading and trailing edges of each current pulse, a high voltage is produced across the inductor. This voltage is the same form shown for the RC type of differentiator (Fig. 10-9B).

If the pulses are of proper polarity and sufficient amplitude, they can be applied directly to the scanning generator by a capacitor connected to the plate end of the inductor. If the polarity is incorrect, phase reversal can be accomplished by an amplifier stage or by a transformer, as shown in Fig. 10-11B. When a transformer is used, secondary L2 may be connected so that the output-voltage pulses have opposite polarity to those across primary L1. The secondary can be connected directly to the input circuit of the horizontal-scanning generator.

The circuit shown in Fig. 10-11C operates quite differently from the two circuits just described. The resonant circuit, consisting of L1 and C1, is tuned to approximately seven times the horizontal-line frequency of 15,750 hertz, or 110 kHz. The separated sync pulses are impressed across the circuit and shock-excite it into oscillation at its resonant frequency. The oscillation is quickly damped out by parallel resistor R1. Only the first half-cycle of voltage across the circuit is used to control the horizontal-scanning oscillator, corresponding to a pulse duration of approximately 5 μsec.



(A) Differentiation by self-inductance. (B) Differentiation by mutual inductance.

(C) Horizontal separation by tuned-circuit action.

Fig. 10-11. Other methods of horizontal-sync-pulse separation.

Several advantages can be cited for this method of horizontal-sync discrimination:

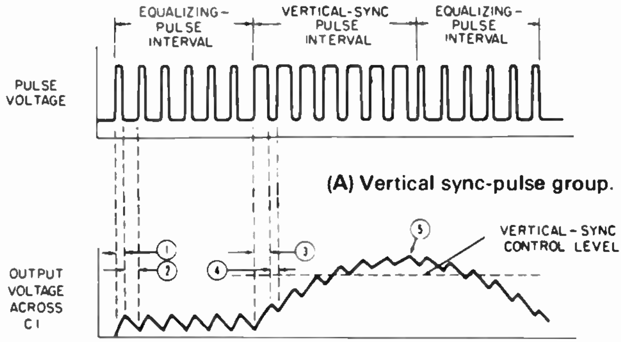
1. An extremely simple pulse-separation and oscillator-control system can be used. The circuit can be connected directly in the plate return of the sync-separator tube and coupled directly to the scanning oscillator because pulse shaping is performed by the resonant action.
2. This method is relatively immune to excitation by static or ignition noise because such pulses would have to be of the proper time duration (5 μsec) and repetition rate (15,750 hertz) to produce ringing; the probability of such coincidence is slight.

Vertical-Pulse Separation

In the description of vertical-scanning systems, we mentioned integrating networks for segregating the long-time, vertical-field pulses from the sharp, horizontal-line pulses. We shall now consider the means of sorting these vertical-field scanning pulses from the composite scanning pulses and of using them to control the vertical-oscillator timing.

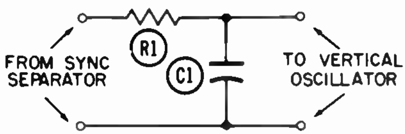
The integrating action that sorts the vertical pulses from the complex video signal is exactly opposite from the differentiation process for separating the horizontal pulses. *Integration* means the addition of a number of small elements to form a whole. Fig. 10-12C shows an integrating circuit; it is the opposite of the differentiation circuit shown in Fig. 10-9. The resistor is in series with the input, and the capacitor is connected across the output. The time constant of the combination is much longer than that employed for sorting the horizontal pulses. This time constant is made approximately equal to the duration of a horizontal pulse. Consequently, the charge accumulated by the capacitor because of the horizontal pulse is small and will decay rapidly.

This action is shown in Fig. 10-12B. During the time shown at ① , the equalizing pulses produce only a small voltage across the capacitor. This voltage decays to near zero in the interval between pulses, as shown at ② . The much longer vertical-synchronizing pulses produce a greater charge in the capacitor during period ③ . This charge does not completely decay during the short serration interval ④ . Consequently, each vertical pulse adds an element of charge to the capacitor, and the voltage

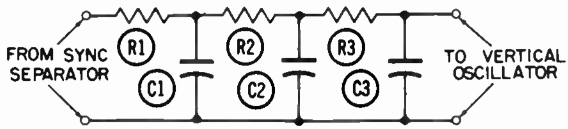


(A) Vertical sync-pulse group.

(B) Output of integrating circuit.



(C) Integrating circuit.



(D) Cascade integrating circuit.

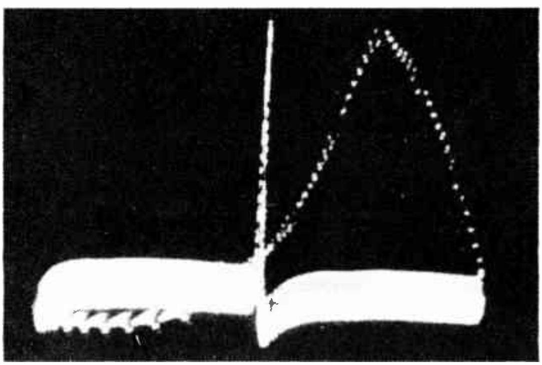


Fig. 10-12. Vertical-pulse separation by integration.

continues to build up during the interval of vertical pulses. The dotted line in Fig. 10-12B indicates the level at which the voltage becomes large enough to trigger the vertical-scanning oscillator. This point usually occurs after two or three vertical pulses have charged the capacitor.

The vertical-integrating network is seldom the two-element type as shown in Fig. 10-12C; it is usually a cascade network, as shown in Fig. 10-12D. The resultant time constant of this network is smaller than that of any of the individual branches (R1–C1, R2–C2, or R3–C3). The overall time-constant calculation is the same as for resistors in parallel. For the three-branch circuit in Fig. 10-12D, with $T1$ for the time constant R1 × C1, $T2$ for R2 × C2, and $T3$ for R3 × C3, the effective circuit time constant T will be:

$$\frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2} + \frac{1}{T_3}$$

Individual time constants for a three-branch circuit in a modern receiver are 30 to 60 μsec. The effective overall circuit time constants, therefore, are between 10 and 20 μsec.

The reasons for using cascaded integrating circuits are:

1. To prevent erratic control of vertical retrace by random noise or static pulses. Before such pulses could control the vertical oscillator, they would have to be more comparable in duration and spacing to the vertical-sync pulses.
2. To smooth out the contour of the rising voltage wave (shown in the interval 3 to 5 of Fig. 10-12D) across the output capacitor. The action is similar to that of the familiar resistance-capacitance, power-supply filter system in which the ripple is reduced by successive stages.

Because of this smoothing action, an individual horizontal pulse cannot cause pairing of lines during retrace. The sections of the cascade network are usually not made with equal time constants. This unbalance prevents accidental triggering by noise pulses.

FUNCTION OF VERTICAL-EQUALIZING PULSES

In Chapter 1 we briefly discussed interlaced scanning, which prevents flicker of the image. For simplicity, the retrace from bottom to top of the picture was shown as a straight line, or single jump. Actually, the horizontal oscillator must be kept in step with the transmitter during vertical retrace, which lasts from 1250 to 1400 μsec (20 to 22 horizontal lines). Figure 10-13 shows a simplified version of the downward scanning, in which 9½ lines have been drawn to represent each field. Actually, a field consists of 262½ lines minus the lines lost during retrace.

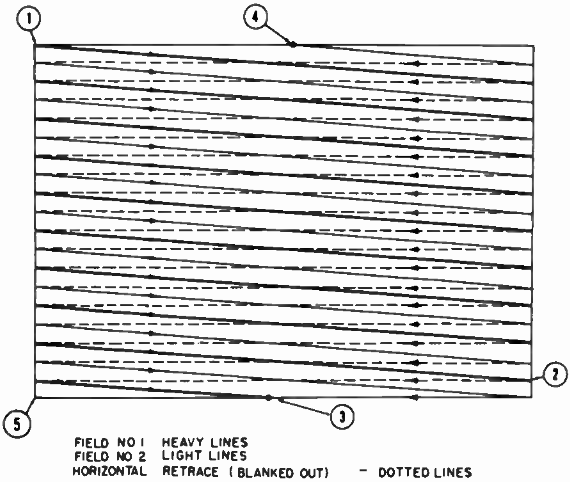


Fig. 10-13. Active downward fields.

The first field, which starts at the upper-left-hand corner ① and ends at the bottom center of the picture ③ , is shown by heavy lines. The second, or interlaced, field starts at the top center ④ and ends at the lower-left-hand corner ⑤ ; it is shown by light lines. During vertical retrace, when the picture is blanked out, the beam moves upward under the combined action of both the vertical- and horizontal-deflection systems. This is represented in simplified form by the diagram in Fig. 10-14. Here, 3 lines represent the 20 to 22 lines actually required during vertical retrace; again, a heavy dotted line represents the retrace of field No. 1, and a light dotted line represents the the retrace of field No. 2.

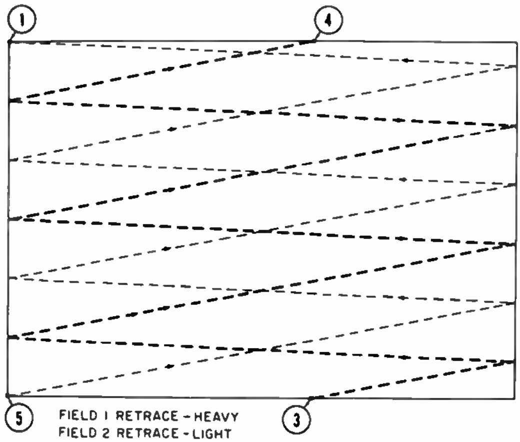


Fig. 10-14. Inactive upward fields (vertical retrace).

The dual functions of producing vertical retrace at the proper instant and keeping the horizontal oscillator in synchronism are controlled by the equalizing and vertical pulses shown in Figs. 10-15 and 10-16. The vertical-sync signal for the retrace of field No. 1 differs from that of field No. 2 by the spacing between the last horizontal pulse and the first equalizing pulse. In Fig. 10-15, for field No. 1, this space "a" consists of only one-half of a horizontal line since field No. 1 ends at the middle of the last line, as shown at ③ of Fig. 10-13. In Fig. 10-16, for field No. 2, the space "b" between the last horizontal pulse and the first equalizing pulse consists of an entire horizontal line. Vertical blanking starts at the leading edge of the equalizing pulses. Thus, the successive field-blanking time is accurately set up by the signal.

Even though retrace blanking is accurately established, vertical retrace may not take place at the proper instant unless the critical

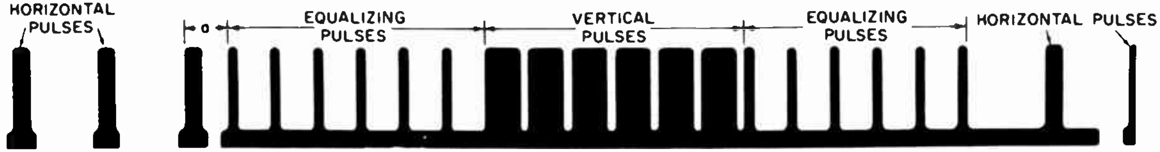


Fig. 10-15. Vertical-sync signal for retrace after field 1.

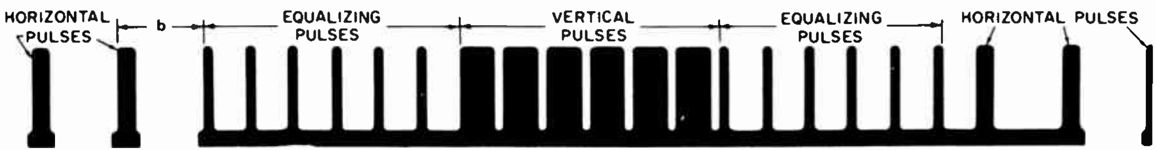


Fig. 10-16. Vertical-sync signal for retrace after field 2.

charge on the integrating capacitor occurs at exactly the same point for each successive vertical-sync signal. How the equalizing pulses ensure this condition is shown in Fig. 10-17. At ① is shown the composition of a vertical-sync signal that would follow field No. 1 if the equalizing pulses were not present. This signal input to the integrating circuit would charge the capacitor, as shown by dotted line ① on the charge curves of Fig. 10-17. This curve crosses the sync-control level at time *X*.

The vertical signal, without equalizing pulses, for retrace at the end of field No. 2, would be as shown at ② in Fig. 10-17. On the charge curves, the critical sync-control level would be reached at time *Y*, which is so much later than time *X* that proper interlace would not occur. When equalizing pulses are employed as shown at ③ , the critical firing point for the vertical oscillator is at time

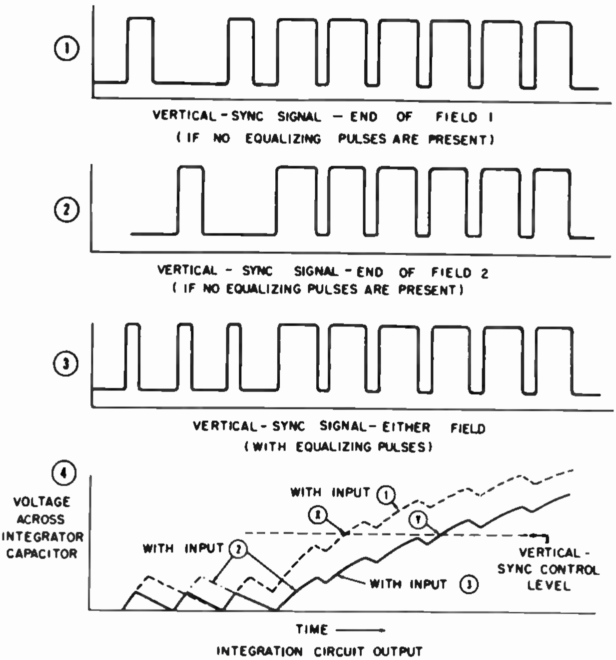


Fig. 10-17. Action of vertical-integrating circuit for successive fields (with and without equalizing pulses).

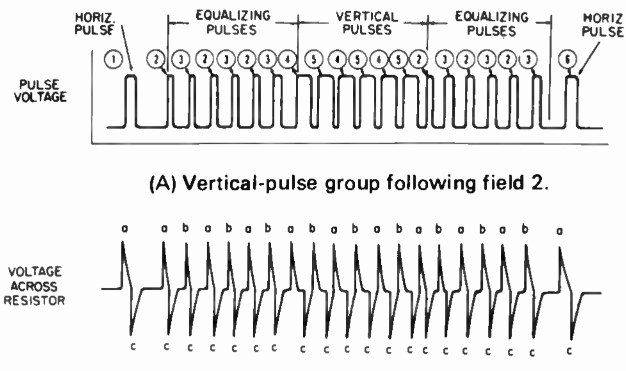
Y for both fields. Successive fields preceded by equalizing pulses will therefore accurately control the oscillator and ensure proper interlace.

ACTION OF HORIZONTAL-DIFFERENTIATING CIRCUIT DURING VERTICAL PULSE

The formation of positive and negative pips at the leading and trailing edges, respectively, of the vertical-sync pulses was described briefly. We shall now consider in detail the action of the horizontal-differentiating circuit during the entire vertical pulse. Figure 10-18 shows the pattern of the vertical signal following field No. 2.

The horizontal pulse, which starts retrace of the bottom line of the picture, is shown at ① in Fig. 10-18A. The positive-output pip produced by its leading edge is shown at "a" in Fig. 10-18. The pips produced by the trailing edge of this horizontal pulse and all the other pulses of the period (labeled "c") are rejected by the sync system, as previously explained.

Each equalizing pulse ② and ③ before and after the vertical pulse also produces a pair of positive and negative pips. Only



(A) Vertical-pulse group following field 2.

(B) Output of horizontal-differentiating circuit.

Fig. 10-18. Action of horizontal differentiating circuit during vertical-pulse period.

the pips marked "a" are used for oscillator control; those labeled "b" are rejected since they occur in the scanning cycle while the horizontal oscillator is not sensitive to pulse control.

Each pulse of the vertical group ④ and ⑤ also produces a pair of positive and negative pips. However, only the positive pips "a" of Fig. 10-18B are used. The horizontal pulse shown at ⑥ is one of a group occurring during the blanking period. The pips produced by the pulse at ⑥ are the same as those produced by horizontal pulse ① .

It is evident that the vertical-pulse group, because of the individual pulses and their different lengths, can ensure vertical retrace at the proper time and keep the horizontal oscillator in step with the scanning in the camera tube at the transmitter.

AGC CIRCUITS

Automatic gain control (AGC) minimizes the effect of changes in signal strength at the receiver antenna. The gains of the RF and IF stages are so regulated that a strong signal is amplified less than a weak signal. As a result, the quality of the TV picture tends to be relatively constant.

Variations in signal strength are of two types: (1) variations between signals received on different channels; and (2) variations occurring from time to time on the same channel.

Both strong and weak channels are available in many locations. If AGC is provided in the receiver, the contrast control does not need to be reset each time a new channel is tuned in. AGC also compensates for extremely strong signals received in powerful station areas.

The AGC system levels out most of the periodic amplitude variations that would cause fading on a particular channel; therefore, a steady picture is obtained even in moderate fringe areas. The rapid flutter caused by airplanes flying near the path of the transmitted signal is also corrected as much as possible through AGC action.

A transistor keyed-AGC system is depicted in Fig. 10-19. Four dc amplifier stages and an AGC-IF amplifier stage are used. The IF signal from the last IF transformer is applied to the base of

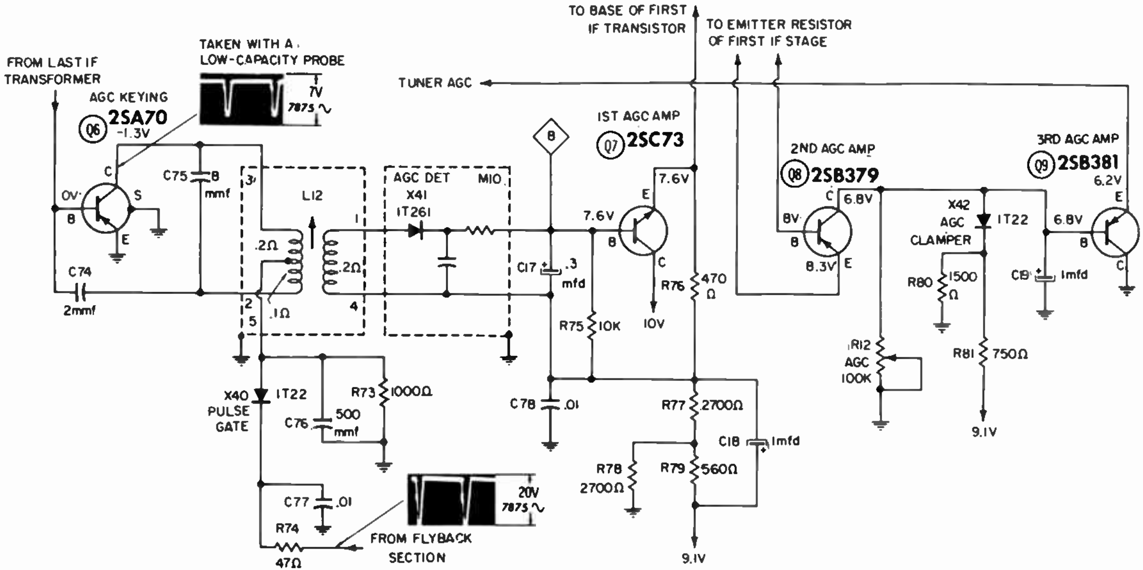


Fig. 10-19. Transistor keyed-AGC system.

transistor Q6, which operates as a keyed amplifier. A 20-volt, peak-to-peak pulse is applied via gating diode X40 to the collector of Q6. In turn, amplified IF bursts are fed to the AGC detector X41. The burst waveform is depicted in Fig. 10-20. The rectified and filtered dc output is stepped up through Q7 and is then applied to the base of the first IF transistor.

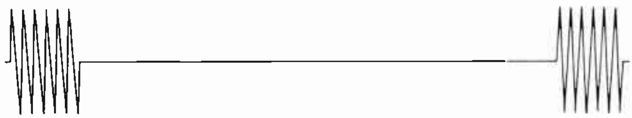


Fig. 10-20. Output from Q6 in Fig. 10-15—a train of pulsed bursts.

Thus, the AGC current is amplified by the first IF stage and fed to the base of transistor Q8 in Fig. 10-19. This is a common-emitter dc amplifier, which supplies output to the AGC delay diode X42 and to the base of Q9. In turn, the delayed AGC current is amplified by Q9 and then applied to the RF amplifier stage. The delay threshold is set by R12 in Fig. 10-19.

We recognize that the transistor AGC system is basically similar to a tube-type amplifier AGC system, except that control current is processed instead of the control voltage. Another difference to be noted in Fig. 10-19 is that part of the dc amplification is provided by the first stage in the IF strip.

The delay circuit holds the AGC bias applied to the RF amplifier to about zero until the incoming signal is strong enough to develop −4 volts of bias in the IF section of the AGC line. The RF bias appears at this signal level, increases more rapidly, and eventually becomes greater than the IF bias. When the incoming signal is strongest, the RF amplifier is biased most heavily, and the signal is promptly reduced before it has a chance to overload any of the IF amplifiers.

Various types of AGC arrangements are found in transistor TV receivers. These may be classified as follows:

1. Unkeyed reverse AGC
2. Keyed reverse AGC
3. Unkeyed forward AGC

4. Keyed forward AGC
5. Amplified AGC (used with any of the foregoing arrangements)

Reverse AGC action is obtained by reducing the base-emitter bias on a transistor. As the cutoff point is approached, the gain of the transistor decreases rapidly. Forward AGC action is obtained by reducing the collector voltage on a transistor by inserting substantial series resistance in the collector circuit. When the AGC bias causes the emitter to draw more current, there is a greater voltage drop across the collector resistance, and the collector voltage decreases. As the saturation point is approached, the gain of the transistors decreases to a small value. Mesa transistors provide better AGC control action with reverse AGC; on the other hand, MADT transistors proved better AGC control action with forward AGC.

In a simple unkeyed-AGC system, a separate AGC detector may be used, as shown in Fig. 10-21, or a single diode may operate as both a video and an AGC detector (Fig. 10-22). To obtain a wide control range, this system must be followed by an AGC amplifier. We shall find that an IF transistor may do double

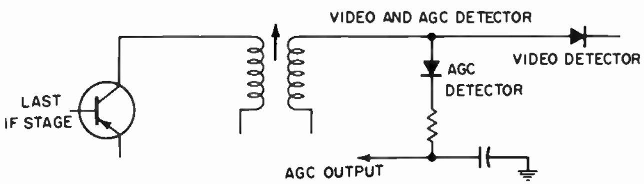


Fig. 10-21. AGC takeoff from secondary of last IF transformer.

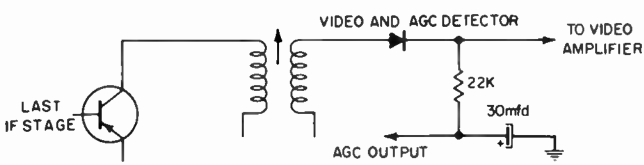


Fig. 10-22. Single diode may operate as both a video detector and an AGC detector.

duty as a common-emitter, IF-signal amplifier, and as a common-collector, dc amplifier for the AGC system. In any case, we usually find a supplementary AGC amplifier employed, as depicted in Fig. 10-23. A common-emitter dc amplifier is followed by an emitter-follower amplifier. The emitter follower matches the comparatively high impedance of the AGC input circuit to the relatively low impedance of the AGC output bus.

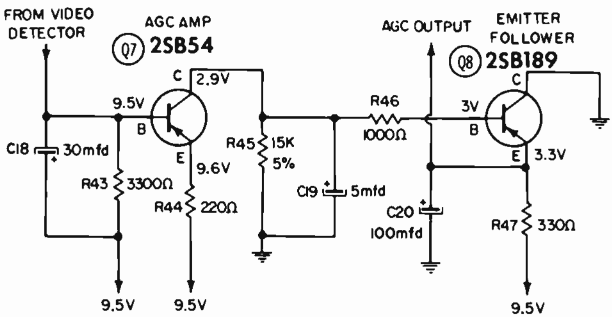


Fig. 10-23. AGC amplifier configuration.

A typical keyed-AGC system is shown in Fig. 10-24. Q7 is an AGC amplifier that operates at the IF frequency. Note that Q7 is keyed by a pulse from the flyback section so that conduction occurs only during the horizontal-sync-pulse interval. Diode OA90 is a keying diode which ensures that only negative pulses are applied to the collector of Q7. The output waveform is a train of pulsed bursts, as shown in Fig. 10-20. This burst sequence is rectified by diode M7, which develops a negative dc voltage across C79. Filtering is provided by C79, R62, and C80. In turn, the base of Q8 is negatively biased in accordance with the prevailing IF-signal level.

Transistor Q8 operates as an emitter follower in Fig. 10-24, in order to match the comparatively high impedance of M7 to the relatively low-impedance AGC line. Note that Q7 also operates as a dc amplifier. When a fairly strong IF signal is applied to the base of Q7, the collector voltage changes very little because the keying pulse drives the transistor into saturation. However, dc

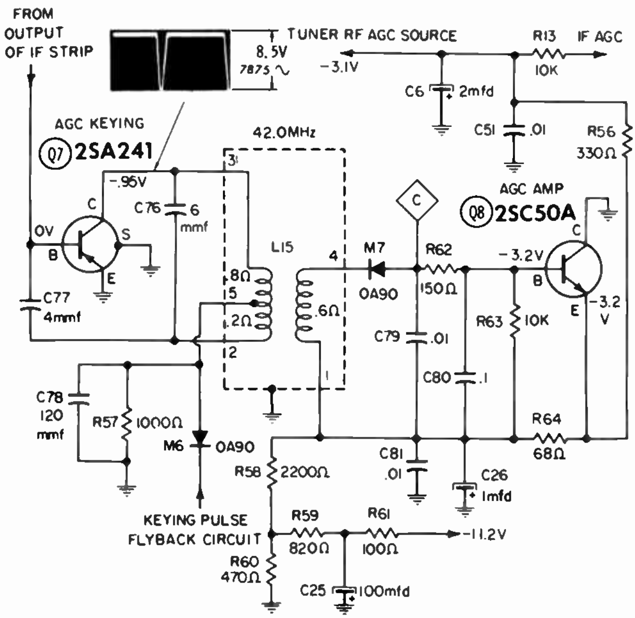


Fig. 10-24. Typical keyed-AGC system.

amplification is obtained because the IF signal increases the emitter current. The control range of an amplified AGC system is typically 25 db at each AGC-controlled IF stage.

Combination AGC and sync arrangements are used in some receivers. The first stage operates as an emitter follower, as shown in Fig. 10-25. Transistor Q33 operates with signal-developed bias and rejects most of the video signal. Q34 is dc-coupled to the emitter of Q33 and is reverse-biased. No polarity reversal occurs in this circuit from the base of Q33 to the base of Q34. Since Q34 operates at a comparatively low collector voltage, the sync signal is clipped both by reverse bias and by collector saturation. Q34 operates in a common-emitter configuration. Separation of horizontal- and vertical-sync pulses takes place in the branch circuits connected to the collector of Q34. These branch circuits have differentiating and integrating circuits, respectively.

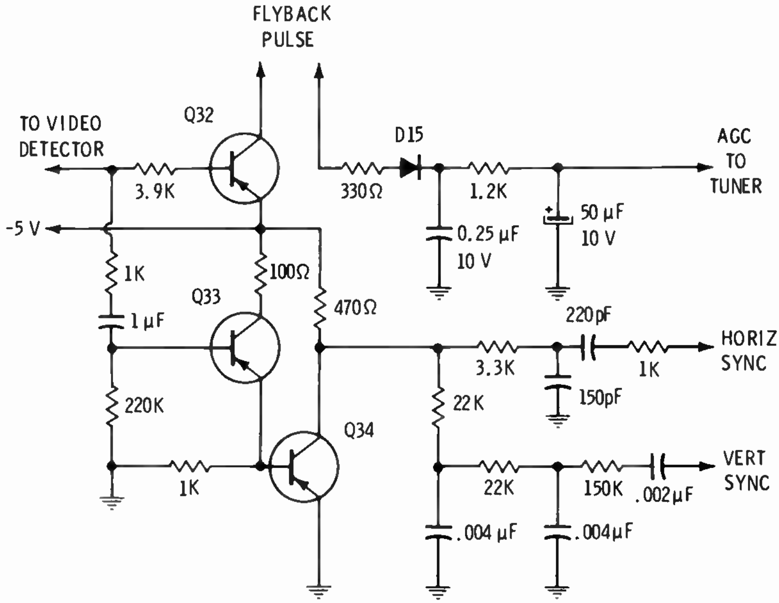


Fig. 10-25. Combination AGC and sync configuration.

Horizontal-sync pulses are processed in the network comprising the 3.3-ohm resistor, 220-pF capacitor, and l-ohm resistor. The horizontal sync pulses are fed into a resistive load (not shown in the diagram) so that the 220-pF capacitor forms a differentiating circuit. Note that this differentiator is preceded by an RC integrator comprising the 3.3-ohm resistor and 150-pF capacitor. This integrator has a time constant of approximately 0.5 μsec and helps to minimize noise voltages by reducing the circuit bandwidth as much as is practical. The highest frequency of importance in a horizontal-sync pulse is about 150 kHz. Noise pulses are comparatively narrow compared with sync pulses in most cases. In turn, bandwidth restriction assists in reduction of noise-pulse disturbances.

Vertical-sync pulses are processed by the network comprising the 22-ohm resistor, 0.004-μF capacitor, second 22-ohm resistor, second 0.004-μF capacitor, 150-ohm resistor, and 0.002-μF capacitor in the collector circuit of Q34. This is a two-section integrator that builds up the vertical-sync pulse and opposes passage of horizontal-sync pulses. The 150-ohm resistor isolates the 0.002-μF capacitor and its subsequent resistive load from the integrator. This capacitor and its load form an integrating circuit that assists in minimizing low-frequency transients in the vertical-sync output circuit. AGC voltage to the tuner is delayed by diode D15. This AGC voltage is derived from a keyed-AGC stage (not shown in the diagram). Figure 10-26 shows basic AGC trouble-shooting procedure.

SUMMARY

As indicated in Chapter 1, the combination of video, blanking, and sync signals is called the *composite video signal.* In addition to the video signal, which contains the actual picture, four additional signals must be transmitted before the picture can be properly displayed on the screen

The horizontal-sync pulse is transmitted to keep the horizontal-deflection circuit in step with the picture; the horizontal-blanking pulse is transmitted to blank out retrace; and the vertical-sync and vertical-blanking pulses are also transmitted to keep the vertical-deflection circuits in step and to blank the beam when it is returning from bottom to top.

The pulses occur when the electron beam in the picture tube is cut off. The pulses can be clipped from the signal at three different places in the circuit—at the video detector input, the video amplifying stages, or the point of restoration of the average background light of the picture.

Some television receivers employ more than a one-stage circuit to separate the sync pulses from the video signal. Additional stages are used to invert the phase of the pulses, clip the pulse-width, amplify the pulse, level the pulse, and eliminate noise pulses to minimize interruption of sync and tearing of the picture.

Automatic gain control is used to minimize the effect of changes in signal strength at the receiver. The gains of the RF and IF stages are so regulated that a strong signal is amplified less than a weak signal. As a result, the TV picture tends to be relatively constant.

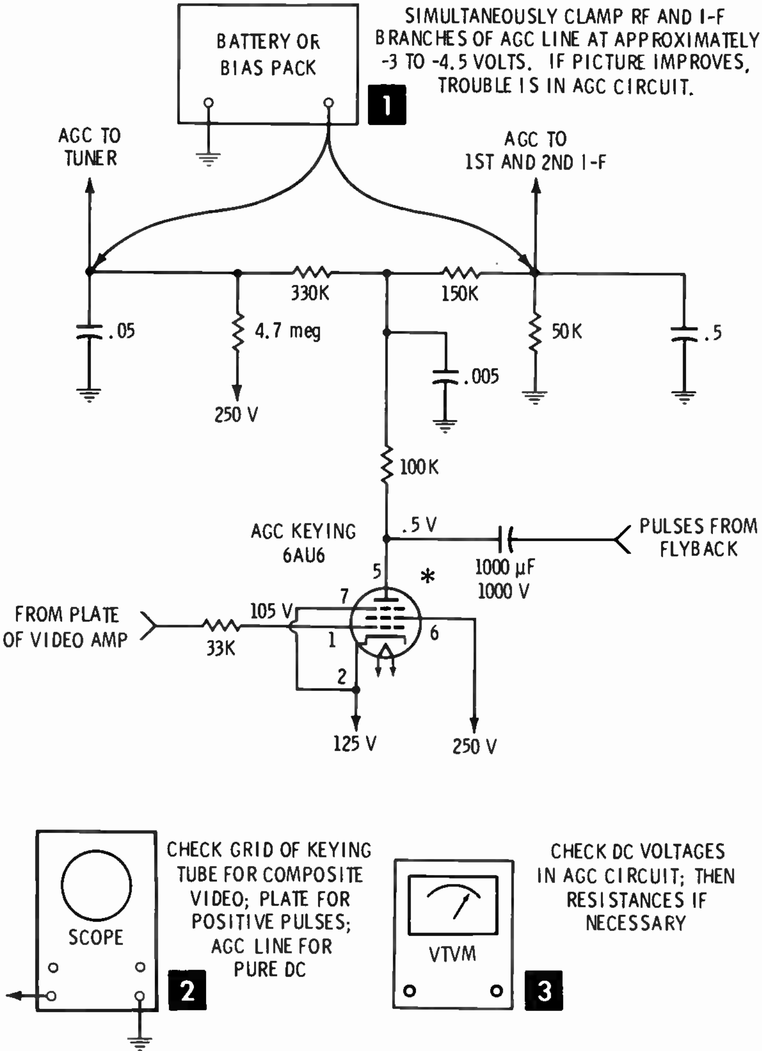


Fig. 10-26. Basic keyed-AGC troubleshooting procedure.

REVIEW QUESTIONS

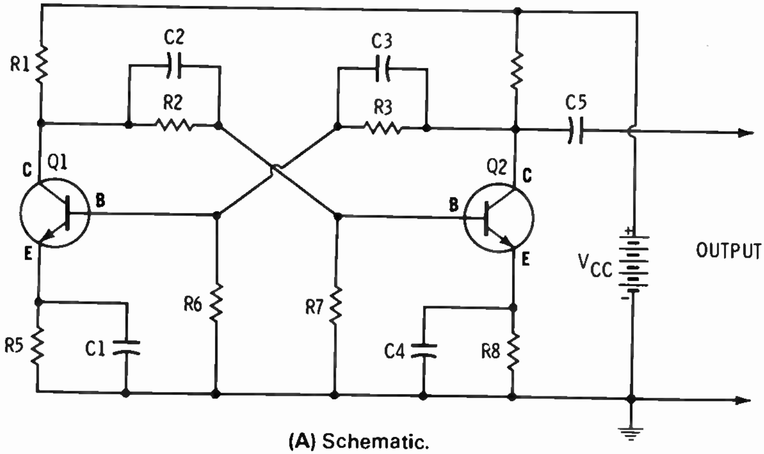
1. Why is a transistor amplifier with base input and collector output called a phase inverter?
2. Explain the basic clipper circuit.
3. Why are transistors more efficient than diodes in clipper circuits?
4. Why is interlaced scanning used?
5. What is the definition of AGC?
6. What is delayed AGC?
7. What is keyed AGC?

CHAPTER 11

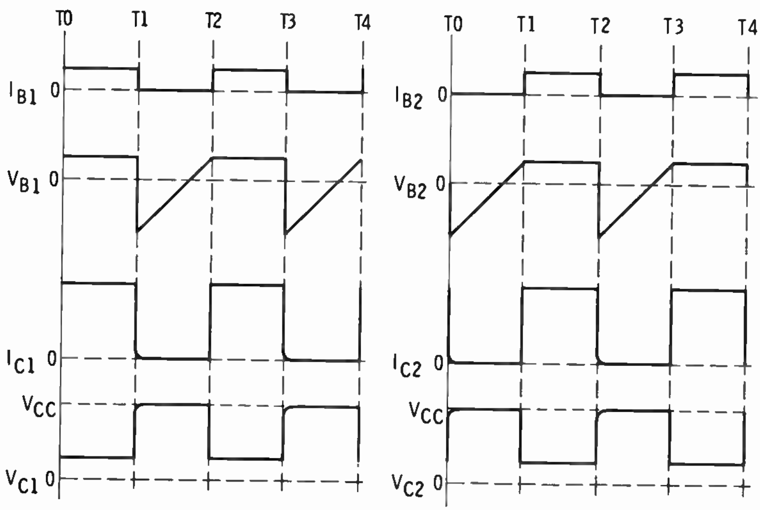
Deflection Circuits

Television receivers have generally employed three types of circuit arrangements (or combinations of these circuits) to produce sawtooth waveforms for scanning purposes:

1. The *multivibrator circuit*, which has many variations, the most popular of which is shown in Fig. 11-1.
2. The *blocking oscillator circuit*, which permits the formation of a short pulse of energy. This pulse can be used to produce the sawtooth wave across a capacitor directly associated with the oscillator device, or the pulse can trigger a discharge device that acts as a switch across the capacitor. (See Fig. 11-2)
3. The *sine-wave oscillator circuit*, in which an oscillator of the correct frequency supplies the timing voltage for the discharging device. The sine-wave output of this oscillator is modified into short pulses by wave-shaping circuits. These pulses then operate a discharge device to produce sawtooth waves.



(A) Schematic.

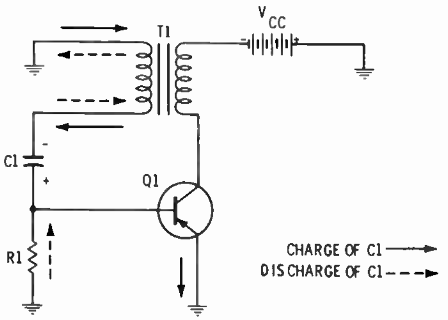


(B) Waveforms.

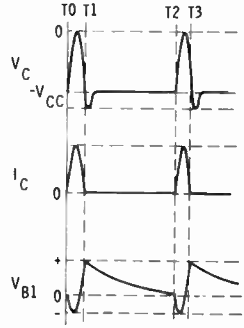
Fig. 11-1. Transistor multivibrator arrangement.

SAWTOOTH GENERATION

A *sawtooth waveform* is the basic deflection waveform, which can be generated in a suitable modified-blocking-oscillator configuration, as shown in Fig. 11-3. Circuit action occurs as follows:



(A) Schematic.



(B) Waveform

Fig. 11-2. Transistor blocking-oscillator arrangement.

As transistor Q conducts, capacitor Cs charges toward the bias voltage level. As collector current flows, a transient voltage is induced into the base circuit by transformer T. The base is driven more negative, and the transistor is driven rapidly into saturation. At this instant, Cs is fully charged, and flow of collector current stops. No more voltage is induced in the base circuit. Thus, the emitter is more negative than the base due to the charge on Cs, which cuts the transistor off. The transistor remains cut off while Cs discharges through Rs, producing the rising slope of a sawtooth wave. When Cs discharges sufficiently so that the transistor comes out of cutoff, positive-feedback action starts up once more, thereby forming the flyback portion of the sawtooth wave.

Observe that the vertical-sync pulse is coupled into the base circuit of Q in Fig. 11-3. Since R2 is normally adjusted so that the blocking oscillator has a slightly lower frequency than the sync-pulse-repetition rate, the sync pulse triggers the transistor out of cutoff sooner than would occur in the free-running mode of operation; thereby, the sawtooth oscillator is synchronized. Resistor R2 establishes the oscillator frequency because it determines the bias level and, in turn, selects the time at which Q will come out of cutoff in the free-running mode. Diode X is a protective device connected across the primary of T to dissipate the inductive kickback surge that would otherwise cause transistor breakdown. The waveform V_{R1} is described as a positive-going sawtooth because it rises from a more negative value to a less negative value.

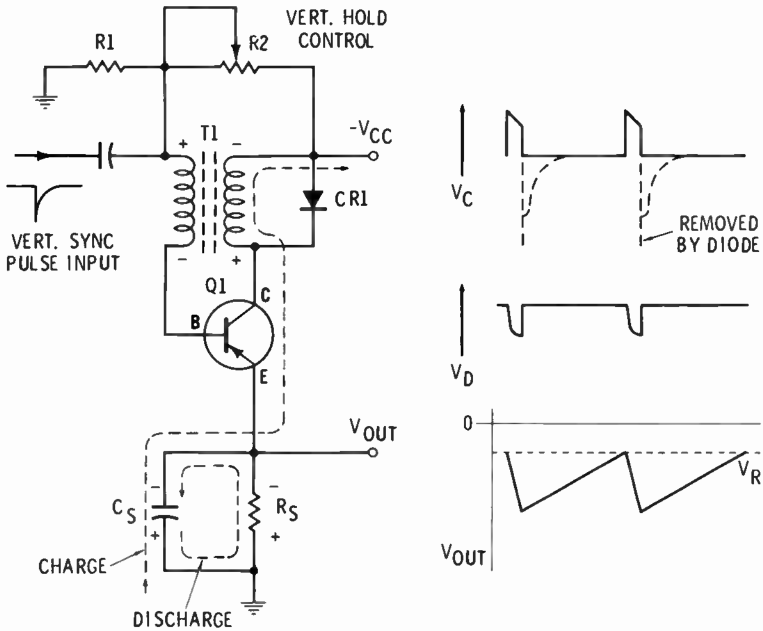


Fig. 11-3. Sawtooth-generating circuit of the blocking-oscillator type.

Some designs require a negative-going sawtooth waveform. With reference to Fig. 11-4, Cs is uncharged at the time that the receiver is turned on. The base voltage on transistor Q is zero, and the transistor is cut off because of negative bias from R3; in turn, Cs charges through Rs to generate the falling slope of the sawtooth waveform. Meanwhile, the base bias on Q is becoming more negative because of R5.

There is a point at which Q suddenly goes into conduction. Consequently, positive-feedback action via transformer T drives the base voltage highly negative, and the transistor goes into saturation. At this time, Cs rapidly discharges via T and Rs to ground, forming the flyback portion of the sawtooth wave. A sync pulse is fed to the base of the transistor to synchronize the oscillating frequency, as explained previously. A damping resistor R6 is connected across the primary of T to reduce the inductive kickback surge, thereby preventing damage to Q.

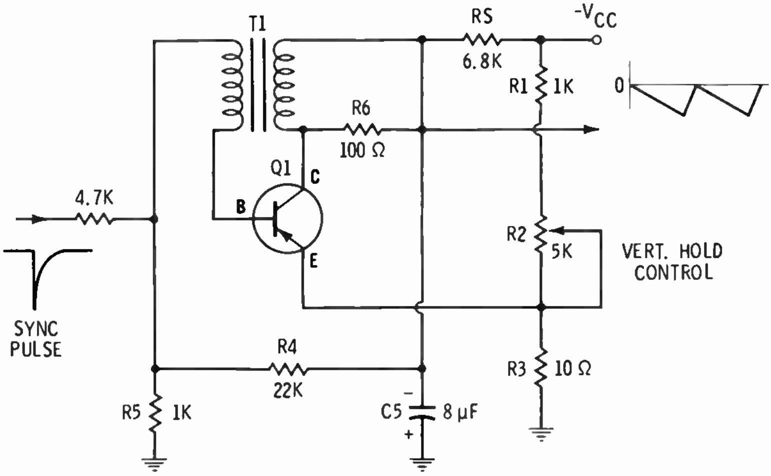


Fig. 11-4. Sawtooth-waveform generator that provides a negative-going output.

Next, consider the two-transistor, peaked-sawtooth multivibrator shown in Fig. 11-5. This is an example of the trend that has been taking place in the discard of separate oscillator and output stages and adoption of combined transformerless circuitry in which positive feedback takes place from the output stage. This circuit uses a common-emitter arrangement for both the input and output transistors. A diode is used as an electronic switch to charge and discharge the sweep capacitor in the feedback loop from the output transistor. Note that the instant power is turned on to the circuit, the voltage across the sweep capacitor C_S is zero. The diode is connected between C_S and a positive-bias voltage that is tapped off at the junction of R1 and R2. Initially, the diode is reverse-biased, and it isolates the sweep capacitor from R1 and R2 as well as from the feedback circuit via C_S.

While the diode is reverse-biased, C_S charges through R_S to the value of the applied positive voltage. This rising positive voltage is applied to Q1 and forms the slope portion of the sawtooth wave. In turn, this rising positive voltage is applied across the deflection yoke. At the instant that the charge on C_S equals the voltage across R2, the diode starts to conduct and the voltage across Cs cannot increase further. Also, the sweep capacitor is connected to the feedback loop, and the voltage across the yoke falls quickly to zero. In other words, a regenerative discharge cycle starts, in which Cs discharges through the diode Cs and the yoke. A high amplitude negative kickback pulse is applied to the collector of Q2 at this time, causing Cs to discharge rapidly. Then the yoke voltage starts to swing positive, the diode cuts off, the feedback loop is disconnected, and Cs starts to charge once more.

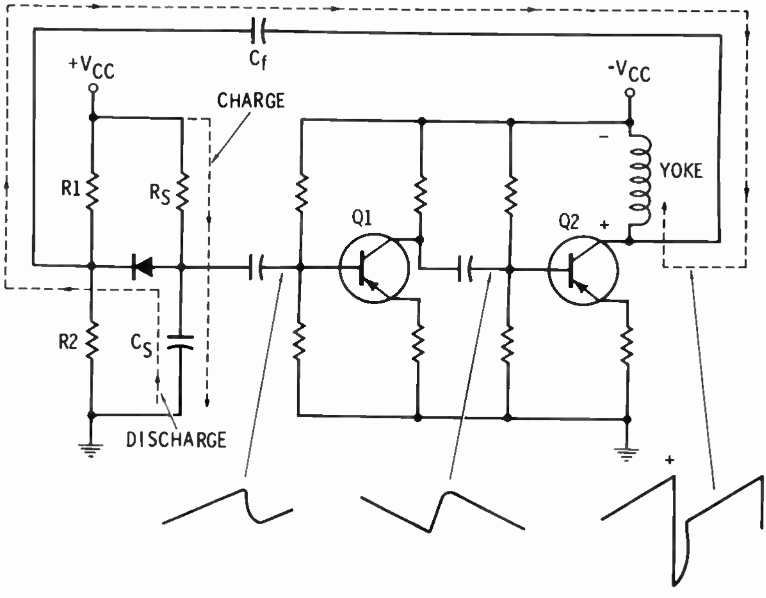


Fig. 11-5. Multivibrator peaked sawtooth-waveform-generator configuration.

A vertical-output circuit is always designed to provide a retrace blanking pulse for the picture tube. A blanking pulse of suitable amplitude and polarity is often obtained from a secondary winding, which is wound on the coupling choke, as depicted in Fig. 11-6. Thus, the coupling choke has a transformer construction, and it is sometimes called a *vertical output transformer*, although it is technically a blanking transformer and coupling choke. An RC wave-shaping circuit is used between the transformer and picture tube to change the peaked-sawtooth waveform into a pulse train.

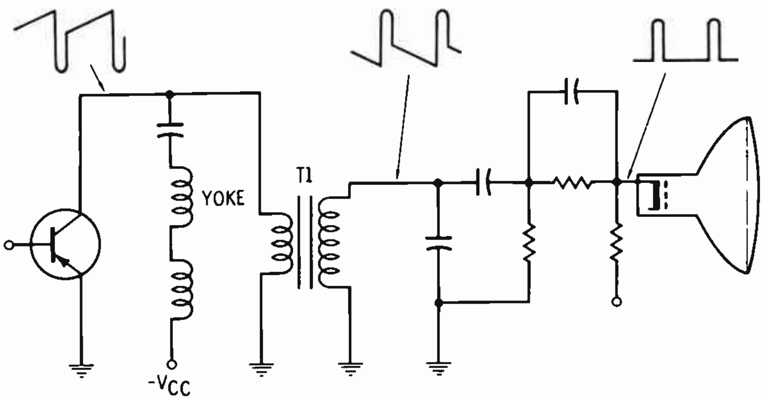


Fig. 11-6. Typical vertical-retrace blanking circuit.

In transistor TV receivers, blocking oscillators are commonly employed in both the vertical- and horizontal-deflection sections. Figure 11-7 shows a typical vertical-oscillator configuration. The tightly coupled windings of transformer T2 provide positive feedback from collector to base of transistor Q14. This transistor operates in class C and conducts only for brief intervals; that is, the circuit operates as a pulse oscillator. During conduction, the base of Q14 is driven strongly by the amplified output from the collector. The base-emitter junction rectifies these negative-going pulses and charges C21 negatively; after the passage of each pulse, Q14 is cut off, or blocked. Note that Q14 is reverse-biased due to this blocking action.

With the emitter more negative than the base, Q14 (Fig. 11-7) remains cut off until C21 discharges sufficiently through R79 that the base voltage reaches the conduction level. Then, as Q14 comes out of cutoff, another sudden surge of oscillation occurs, after which Q14 is again blocked. The time at which the transistor comes out of cutoff is adjusted by varying the base bias with control R4. Vertical-hold control R4 is set to a point at which the blocking rate is somewhat slower than 60 Hz. Negative-going,

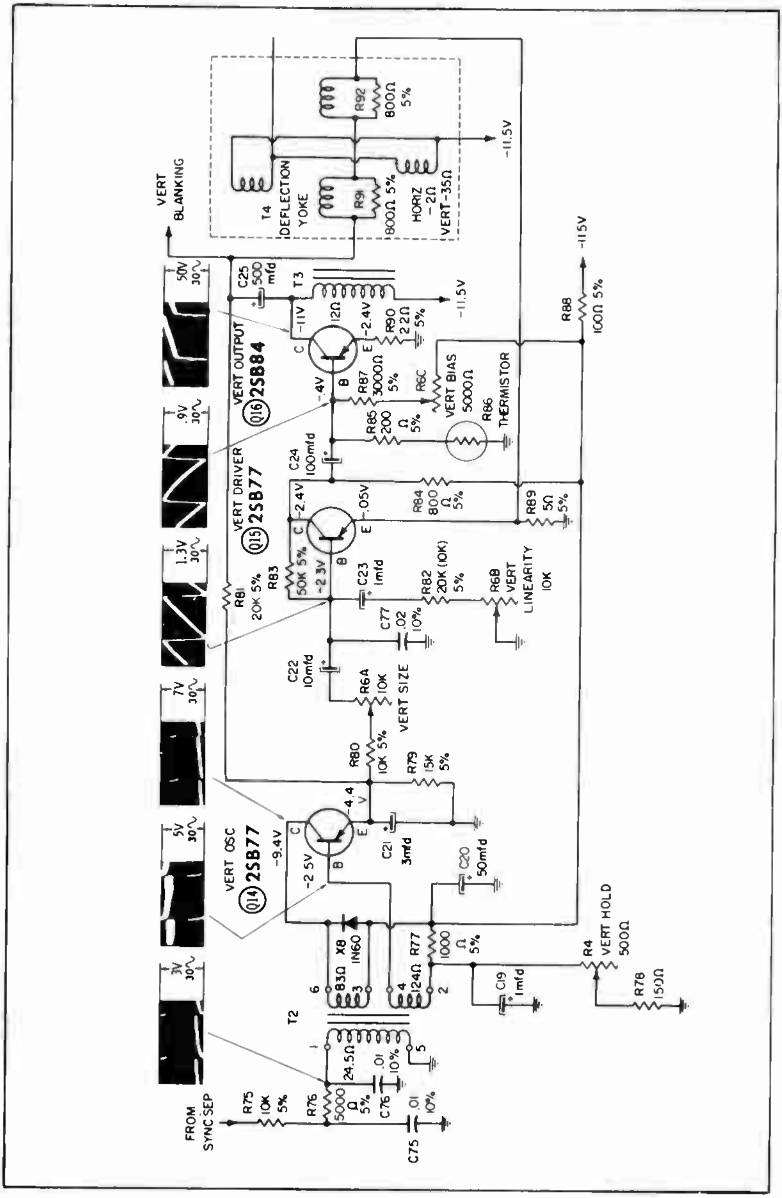


Fig. 11-7. Typical transistor vertical-sweep system.

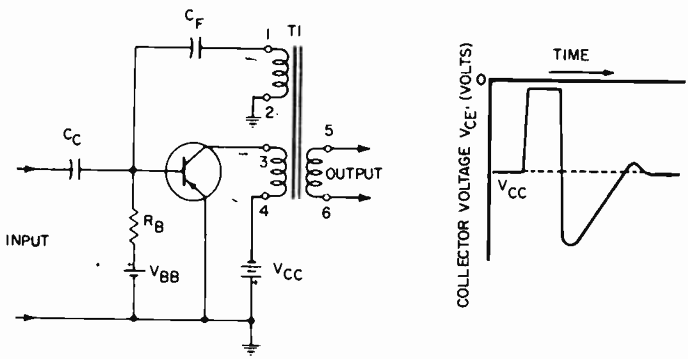
vertical-sync pulses are coupled to the base of Q14 via T2. In turn, the sync pulses trigger the blocking oscillator into conduction a bit earlier than the stage would otherwise come out of cutoff, thereby obtaining vertical-sync lock.

Diode X8 in Fig. 11-7 prevents the transformer from applying an excessive peak voltage to the collector of Q14, which could result in damage to the transistor. The action of the diode can be explained clearly by considering a simpler blocking oscillator circuit that does not require a protective diode. Thus, in Fig. 11-8, the circuit action is as follows:

1. When a negative trigger pulse is applied to the base, the transistor begins to conduct. Collector current then flows through the transformer windings 3 and 4 and produces a varying magnetic flux, which induces a voltage of opposite polarity in windings 1 and 2. This voltage is coupled through capacitor C_F to the base, thereby providing regenerative feedback. The transistor is quickly driven into collector saturation, and the collector current cannot rise further.
2. Since the collector current is now constant, T1 can induce no more feedback voltage into the base circuit; the base is now reverse-biased, and the transistor is cut off.
3. Stopping the collector current results in a collapsing magnetic field through windings 1 and 2, which induces a voltage in windings 3 and 4 that exceeds the supply voltage; this is seen as the backswing following the pulse in Fig. 11-8. In this example, the backswing approximately doubles the collector voltage. Unless the transistor is rated for this peak value of collector voltage, the collector junction will break down.

With these points in mind, let us consider the action of diode X8 in Fig. 11-7 and observe how the backswing is eliminated. The current action is as follows:

1. When a negative trigger pulse is applied, transistor Q14 is driven from cutoff into conduction. The collector current suddenly increases due to feedback, and the collector voltage drops because of the voltage drop across windings 3 and 6.



(A) Circuit schematic. (B) Collector waveform.

Fig. 11-8. Triggered blocking oscillator showing collector-to-emitter-voltage waveform.

2. As the collector voltage suddenly falls, diode X8 is reverse-biased; therefore, X8 is effectively out of the circuit at this time. The transistor is quickly driven into collector saturation, and the collector current cannot rise further.
3. Since the collector current is now constant, T2 can induce no more feedback voltage into the base circuit. The base is now reverse-biased, and the transistor is cut off.
4. Stopping of the collector current results in a collapsing magnetic field through the windings, which quickly increases the collector voltage. However, the collector voltage cannot rise above the supply voltage because X8 then becomes forward-biased and short-circuits windings 3 and 6, thereby eliminating the backswing.

Next, let us consider a blocking oscillator utilized in a horizontal-oscillator section. With reference to Fig. 11-9, transistor Q20 operates as a blocking oscillator, and the time at which it comes out of cutoff (and hence its repetition rate) depends on the value of base-bias voltage. L16 and C99 form a ringing circuit that stabilizes the cutoff point for Q20 by superimposing a sine wave on the blocking-oscillator waveform.

The action of the horizontal stabilizer is seen in Fig. 11-10. When a ringing coil is not used, the decay of the voltage is exponential and approaches the cutoff level slowly. In turn, the instant

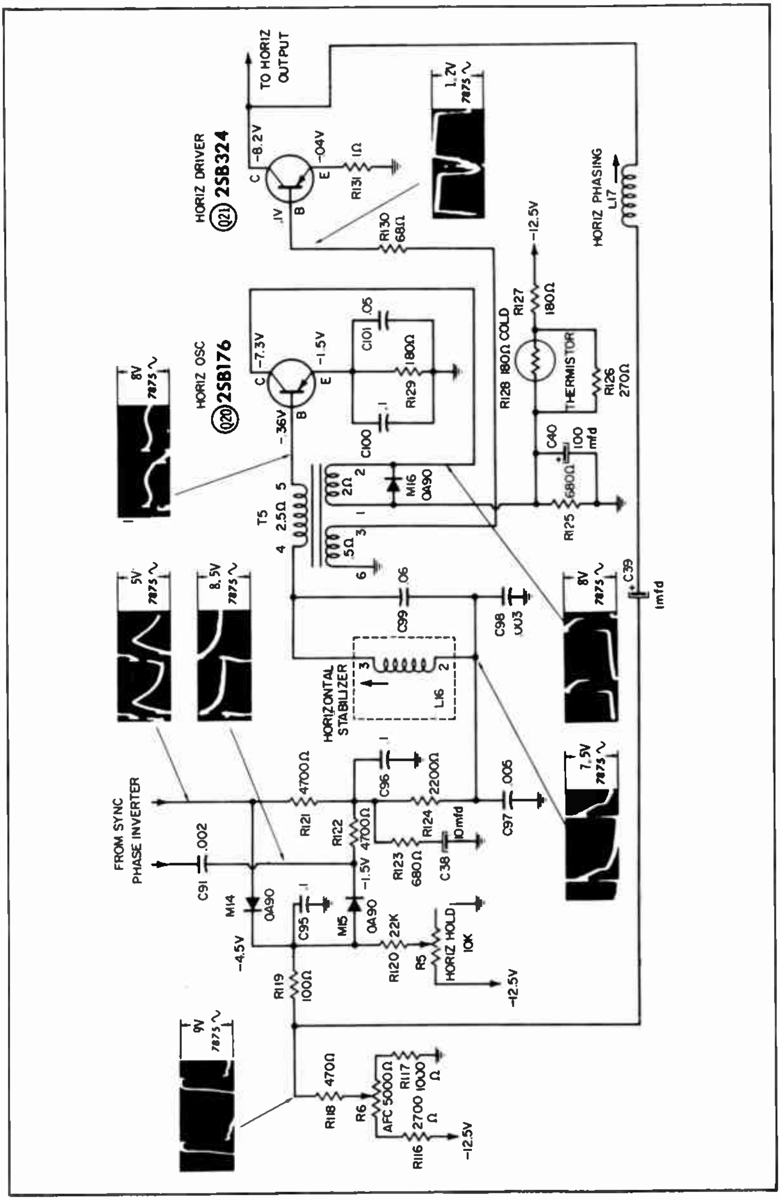
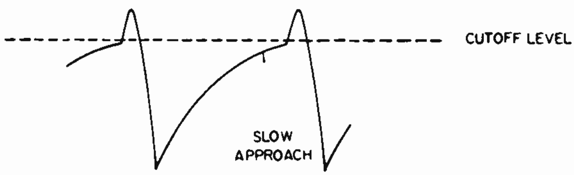
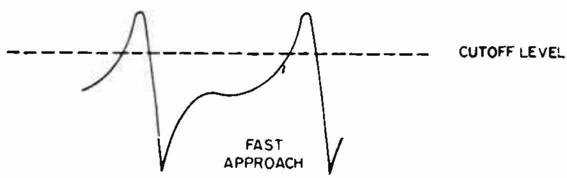


Fig. 11-9. Typical transistor horizontal AFC, oscillator, and driver configuration.

at which conduction is initiated can vary appreciably due to slight voltage fluctuations or small noise voltages. On the other hand, when a ringing coil is used, a sine wave is superimposed on the exponential waveform, and the combined waveform approaches the cutoff level rapidly. Because of the steep slope of the waveform through the conduction level, the instant at which conduction is initiated does not vary to a disturbing extent even when small-noise voltages or other fluctuations are present. Horizontal-stabilizer coil L16 is adjustable so that the optimum phase of ringing waveform can be utilized.



(A) Without ringing coil.



(B) With ringing coil.

Fig. 11-10. Oscillator waveforms with and without a ringing coil.

Regenerative feedback occurs from collector to base of Q20 in Fig. 11-9. This feedback is provided by the tightly coupled windings of transformer T5. As a result, blocking oscillation occurs. Diode M16 short-circuits the backswing of the generated waveform, as explained previously. This prevents excessive peak-collector voltage from being applied to Q20. Collector-current stabilization is provided by thermistor R128. If the temperature rises, the resistance of R128 increases, thus reducing the collector voltage and preventing Q20 from drawing increased current from the dc supply.

Sine-Wave Generators

The familiar sine-wave oscillator can produce pulses that will trigger a discharge tube associated with a sawtooth-waveforming capacitor. Only a short portion of the sine wave is used; it is passed through clipping stages to "bite off" a small section of the wave. The output of the clipper is a pulse. The usefulness of this type of circuit will be discussed in the section "Control of Scanning Generators by Sync Pulses" (page 278).

SAWTOOTH-GENERATOR CONTROL AND PRODUCTION OF SCANNING WAVEFORMS

At this time, let us examine in greater detail the sawtooth scanning waves that produce the raster. We have mentioned before that the horizontal and vertical sawtooth motion of the electron beam must keep in step with similar sawtooth scanning movements occurring at practically the same instant in the camera tube at the transmitter.

To accomplish this synchronization, pulses that control the horizontal and vertical scanning are transmitted in the television signal. These pulses occur between each horizontal frame. During the scanning of the frame, the receiver is "on its own." However, during the short interval between successive horizontal frames, the deflection circuits of the receiver are the absolute "slave" of the transmitter if the set is well designed, operating properly, and being used in an area of adequate field strength.

How the synchronized pulses are separated from the complex signal has already been covered. At this point, we shall examine the relationship between the timing of these pulses and the control of the sawtooth scanning of the receiver. Figure 11-11 shows the sequence of events during the scanning of one horizontal line and during the return of the electron beam to start the scanning of the next line. The sawtooth line in Fig. 11-11 shows the desired linear trace and retrace motions of the electron beam in the TV picture tube. It does not necessarily depict the exact wave of current that must be passed through the deflection coils of the picture tube. As a matter of fact, we shall find later that the

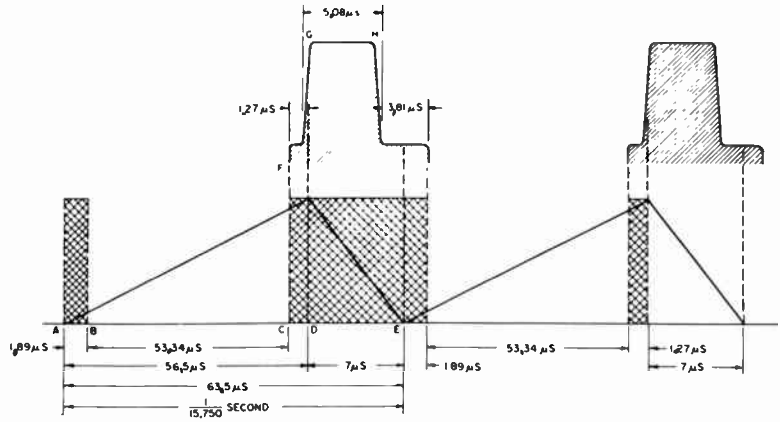


Fig. 11-11. Horizontal-scanning wave and synchronizing signal.

deflection current must be distorted somewhat to accomplish the linear sweep and rapid flyback of the beam of electrons tracing the picture.

Figure 11-11 shows, therefore, the *ideal* sawtooth for controlling the horizontal scanning motion in a television receiver. At point A, the electron beam starts to cross the face of the picture tube horizontally from left to right. (We shall assume the picture tube is a 17-in. type and has an active picture width of 14 in.) The beam has blanked out from A to B, and the picture starts at point B. Between points B and C, as the uniform motion progresses, the video modulation produces the picture.

As stated previously, the picture frame consists of 525 horizontal lines reproduced each 1/30 sec (30 frames/sec × 525 lines per frame = 15,750 horizontal lines/sec). This means that the time for the trace of a line and its return to start another line is 1/15,750 sec.

We should introduce the idea of talking about these extremely short time intervals in multiples of one-millionth of a second. The unit of measurement is a microsecond (μsec), which is the length of time required for the completion of one cycle of carrier wave at the middle of the broadcast band, or 1,000 kHz. The entire horizontal action, including the tracing of the picture line and the return to start a new line, occurs in 63.5 μsec.

Let us divide the picture width (14 in.) by the time of active scanning (53.34 μsec). We obtain a velocity of 4.1 mi/sec. The retrace time (between retrace points D and E in Fig. 11-11) is 7 μsec. Since this retrace is over the same 14 in. of horizontal motion, the speed of the spot (blanked out to produce no light) must obviously be much faster. Actually, this retrace can reach a speed of 31.5 mi/sec.

As stated previously, the sequence of events must occur exactly in step with a similar sequence occurring at the same instant in the camera tube of the transmitter. To accomplish this action, pulses are sent out from the transmitter between each horizontal trace. The shape of these pulses is shown above the sawtooth wave shown in Fig. 11-11. At the instant shown as F, enough voltage appears at the grid of the picture tube to blank out all light. The region from F to G is known in television slang as the "front porch." This region is slightly more than one-millionth of a second in duration. At point G, the carrier wave of the transmitter abruptly increases by approximately 25 percent of its average value. This sharp rise in the carrier triggers the scanning generators in the receiver. The scanning generators produce the required sawtooth motion of the electron beam. (Exactly how the pulse accomplishes this triggering will be described later.)

The horizontal beam does not trace a line parallel with the top of the picture but has a slight downward slope. This vertical motion is controlled by a scanning sawtooth, which moves the scanning spot to the bottom of the image and then rapidly returns it to the top. The electron beam moves from the top to the bottom of the picture and back to the top in 1/60 sec. It is easy to see that this vertical scanning is much slower than the horizontal-line-tracing action and requires 16,666 μsec. Pulses are sent out between successive fields to lock in, or control as a slave, the vertical-scanning oscillator of the receiver. A cycle of the vertical-deflection sawtooth wave, together with an enlarged section of that part of the wave which occurs during blanking and retrace, are shown in Fig. 11-12.

The portion of the television signal that controls vertical retrace and synchronization is much more complicated than the single horizontal pulses, which occur between successive horizontal lines. The vertical-synchronizing signal resembles a comb with uneven teeth. If its only function were to trigger the vertical

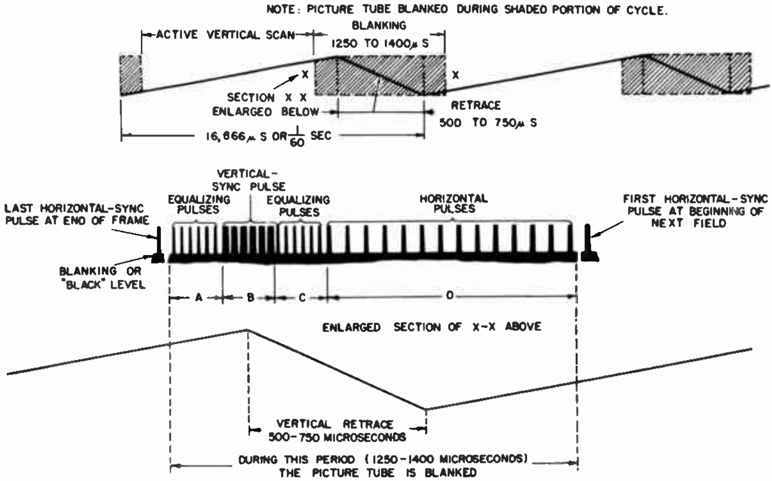


Fig. 11-12. Vertical-scanning wave and synchronizing signal.

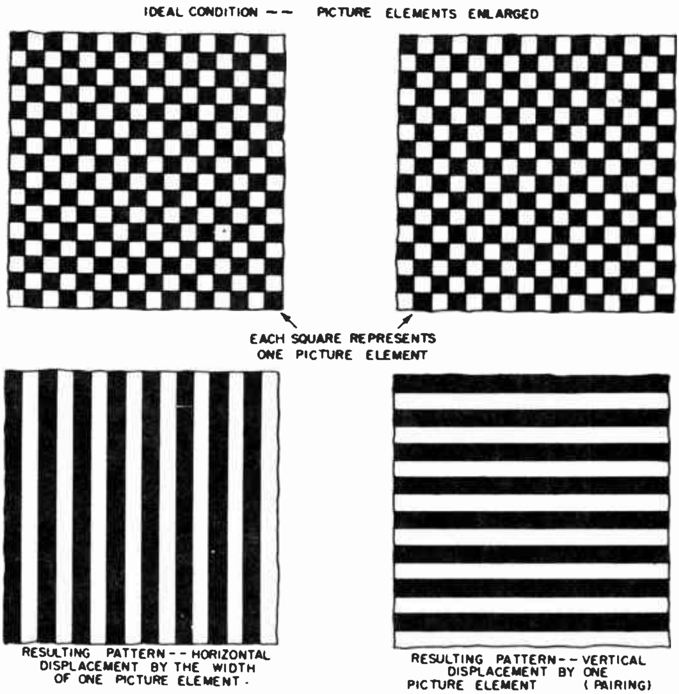
oscillator and blank out the picture-tube screen during retrace, it could be made in the form of a single, long, rectangular pulse whose time duration would be from 20 to 22 horizontal lines (1,250 to 1,400 μsec). However, the vertical-synchronizing signal must perform two other functions: It must continue to keep the horizontal-scanning oscillator in step during vertical retrace, and it must ensure that alternate fields have proper interlace of the horizontal lines.

Horizontal synchronization is kept in step by notches B and pulses A, C, and D (Fig. 11-12). Interlace is controlled by equalizing pulses A and C (Fig. 11-12) preceding and following the vertical-sync pulse.

CONTROL OF SCANNING GENERATORS BY SYNC PULSES

We have seen that the scanning systems of the receiver must keep in accurate step with the scanning raster of the camera tube at the transmitter, and that the synchronization pulses satisfy this requirement. For a satisfactory reproduced picture, the picture elements of adjacent horizontal traces must line up accurately, and the lines of alternate fields must interlace, or space, accurately between each other.

To avoid a displacement of more than one picture element in successive horizontal lines, the frequency stability of the horizontal oscillator must be 0.2 percent or better. Figure 11-13A shows horizontal displacement.



(A) Horizontal displacement.

(B) Vertical displacement.

Fig. 11-13. Picture-element displacement that might result from scanning-oscillator instability.

To avoid "pairing" of the lines of successive fields (the line lying on top of those of the preceding field instead of being properly interlaced), the stability of the vertical oscillator must be better than 0.05 percent. Figure 11-13 shows this displacement.

Note, in passing, that there are various receiver sections generally associated with the horizontal-output system. As shown in Fig. 11-14, these sections typically comprise the high-voltage system, AGC and AFC sections, horizontal oscillator, vertical sweep circuit, yoke, and picture tube. Thus, the horizontal-output system supplies feedback pulses to the AGC and AFC sections, boost voltage to the vertical-sweep circuit and horizontal oscillator, high voltage to the picture tube, and horizontal drive to the yoke. The horizontal oscillator supplies a drive signal, and the low-voltage power supply provides (B + (V_{CC}) voltage to the horizontal-output section. When checking the linearity of horizontal- and vertical-sweep action, an audio oscillator may be used, as shown in Fig. 11-15. Note that the extended high-frequency output, up to 1.5 MHz, is required for checking horizontal linearity.

The horizontal and vertical pulses are clipped from the signal, amplified, and passed through circuits that classify the pulses so

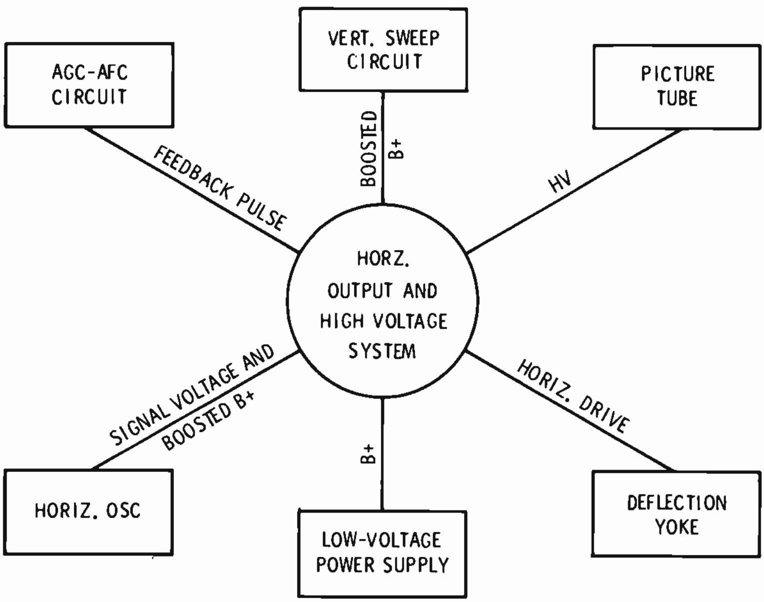


Fig. 11-14. Some circuits commonly associated with the horizontal-output and high-voltage system.

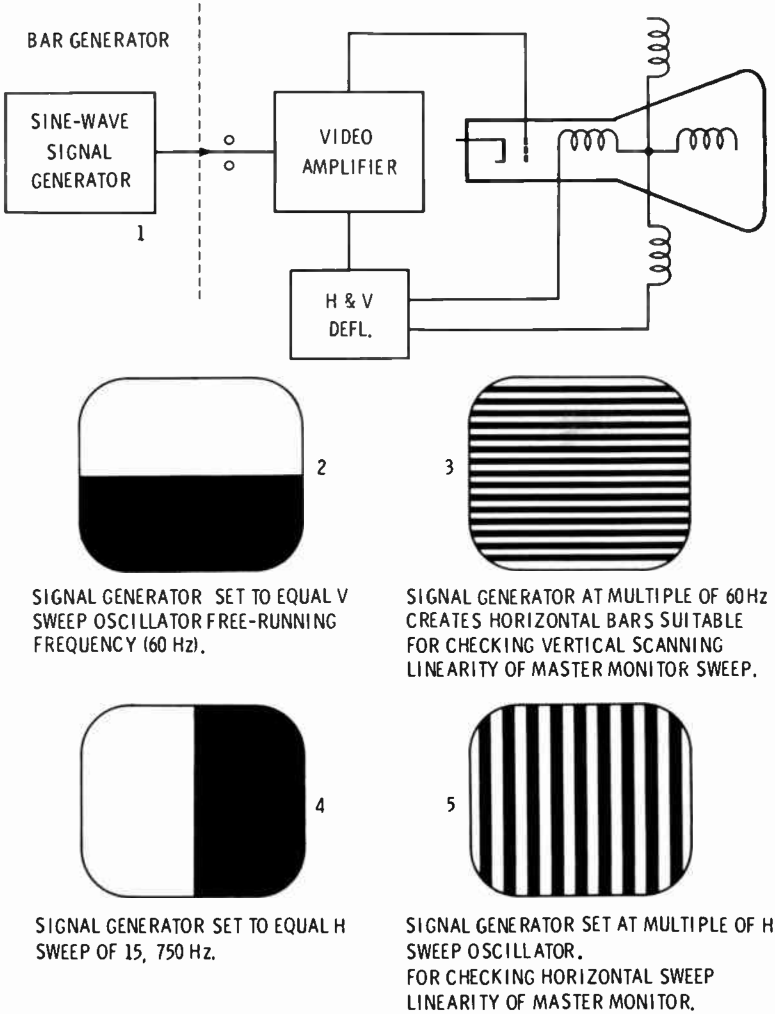


Fig. 11-15. Check of vertical- and horizontal-scanning linearity.

that each will control its own scanning oscillator only. The end result is a short, sharp "pip" for the horizontal control and a long, triangularly shaped pulse for the vertical control.

In considering how the pulse controls the oscillator frequency, three items are important:

1. Free-running frequency of the sweep generator—This frequency is that which would be generated at any particular setting of the hold control if the sync pulses were not present. The frequency can be slower or faster than the pulse-repetition rate or in exact step. Later we shall show that for proper stable operation, the slow rate is required.
2. Firing point of the sweep generator—This is the bias voltage required for the controlled device in order to initiate conduction in the discharge device and start capacitor discharge and scanning-wave retrace. At this point in the cycle the oscillator is most sensitive to control by the sync pulse.
3. Synchronizing frequency—This is the rate at which the pulses are applied to the control-input terminal of the oscillator: 60 hertz for vertical synchronization and 15, 750 hertz for horizontal synchronization.

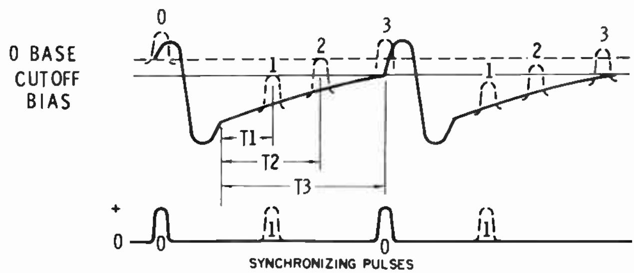
Since the control action of the blocking oscillator can be diagrammed more readily, we shall consider it first.

Pulse Control of Vertical Blocking Oscillator

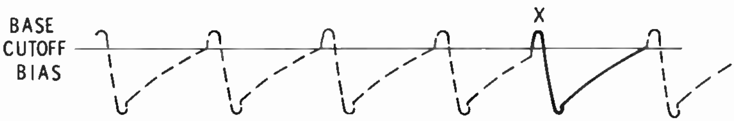
The triggering, or firing, of the blocking oscillator occurs when the bias voltage passes the cutoff point. The free-running frequency of the oscillator (if no sync pulses are present) is determined solely by the time constant of the base capacitance and resistance. Once the oscillator is fired, it functions on its own until it is blocked again by the base-cutoff voltage.

If a pulse of positive potential from an external source is fed to the base while the base capacitor is discharging through the resistor, the base voltage will pass the cutoff point and the device will begin to conduct. The sawtooth-forming capacitor will discharge, and retrace will occur; a new scanning cycle then begins. Therefore, the repetition of the positive-sync pulses can control the firing of the blocking oscillator and lock the picture into synchronization.

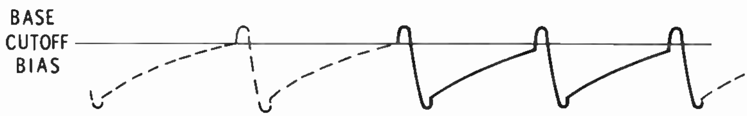
Figure 11-16 shows this action in detail. Figure 11-16A is an enlarged portion of the blocking-oscillator base voltage. The synchronizing pulses below the base waveform show a series of pulses marked 0, with leading edges that are exactly in step with



(A) Grid-voltage waveform with a series of sync pulses.



(B) Oscillator frequency fast.



(C) Oscillator frequency slow.

Fig. 11-16. Pulse control of a free-running oscillator.

the wave. These pulses do not affect the free-running frequency of the oscillator. They merely add to the base voltage at the same instant it is being driven positive by the collector-current pulse. On the other hand, if the sync pulses occur at the points indicated as 1, the pulse voltage added to the discharge voltage is still short of the cutoff bias point and will not fire the device. However, if the pulse occurs at points 2 or 3, the critical bias will be exceeded, the device will immediately conduct, and retrace will begin.

Since the free-running frequency of the blocking oscillator can be changed by varying the time constant of the capacitance and resistance in the base circuit, we shall examine this action under the following conditions: (1) oscillator running faster than the sync-pulse rate; and (2) oscillator running slower than the sync-pulse rate.

Figure 11-16 shows what happens when the oscillator is running faster than the sync-pulse rate. The dotted portion of the waveform indicates lack of synchronization at that point. Notice that several cycles occur before the pulse reaches point X. At this point the base-cutoff voltage is exceeded and the tube fires. Normally, you would expect the picture to lock in satisfactorily; however, this is not true. Lock-in occurs only momentarily during the field initiated at point X. Succeeding fields do not lock in. With the oscillator running in this fast condition, the sync pulses occur during the scanning interval; consequently, the picture is divided by the blanking bar. Also, the oscillator, running faster than the sync-pulse rate, can easily be triggered into erratic operation by automobile ignition and static interference; therefore, the picture will be unstable. In modern receivers, however, improved circuit designs have resulted in more stable pictures even under heavy interference conditions.

Figure 11-16C shows what happens when the free-running frequency of the blocking oscillator is slower than the sync-pulse rate. Notice that lock-in occurs much faster and a good stable picture is obtained. This is obviously the desired condition because the oscillator should run slightly slower than the sync-pulse rate. The sync pulses will then take over and force the blocking oscillator to lock in with each succeeding sync pulse. The height and width of the sync pulses are not important as long as they are high enough to drive the base above the cutoff point. With the sync-pulse amplitude reasonably high, the hold control can be varied over a fairly wide range without loss of synchronization.

For control of the blocking oscillator just described, the sync pulses are positive. Sync pulses can be made either positive or negative with respect to ground (or chassis), depending on receiver design.

Pulse Control of Transistor Horizontal Oscillator

The basic function of pulse control in a transistor-oscillator configuration is to provide horizontal-sync lock in a manner that rejects disturbing noise interference insofar as possible. This control of the horizontal-oscillator frequency is similar to that found in tube-type TV receivers. To minimize picture tearing or other disturbances due to random-noise pulses, the horizontal-sync pulses are processed in a comparator circuit that has a comparatively long time constant. The frequency of a horizontal oscillator, in turn, is controlled indirectly, and the noise-pulse voltages tend to average out and cancel.

Horizontal-sync pulses are mixed in a diode circuit along with comparison waveforms from the horizontal-sweep section. In turn, a dc control voltage is developed that opposes any tendency of the horizontal oscillator to drift off frequency. The control voltage is applied through an RC network that has an appreciable time delay, so that successive noise pulses tend to cancel one another.

Figure 11-17 shows the plan of the pulse-control network. A basic AFC circuit is shown in Fig. 11-18. Sync pulses and the comparison sawtooth waves are fed into the diode circuit. In turn, the sync pulses ride on the sawtooth waves. Note that the peak-to-peak voltage of the combination waveform is thereby increased.

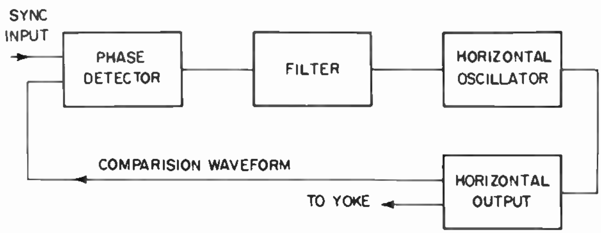
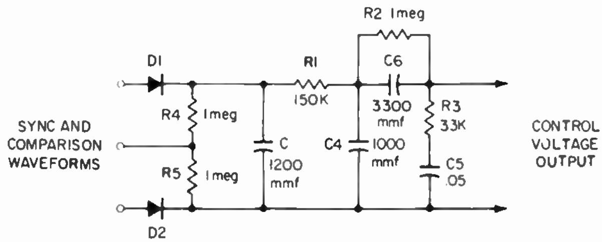
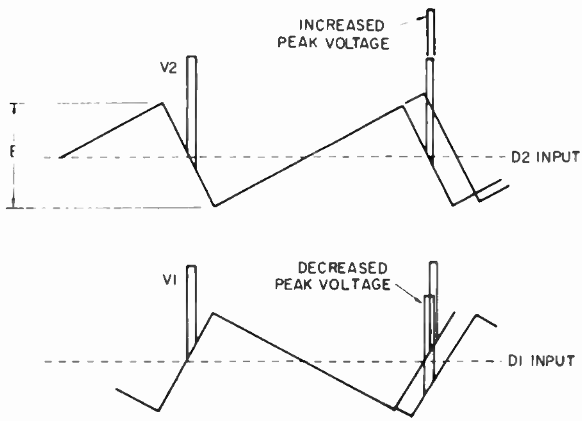


Fig. 11-17. Block diagram of horizontal AFC and deflection system.

Capacitor C in Fig. 11-18 can be charged only if one of the diodes conducts more than the other. If the oscillator happens to be exactly on frequency, both diodes conduct equally because voltages V1 and V2 are equal. On the other hand, if the oscillator tends to run too slowly, the waveforms are changed and D2 conducts more than D1. Hence, the upper terminal of C becomes negative, and a negative voltage is produced. If the oscillator tends to run too slowly, a positive control voltage is produced. This control voltage is fed directly to the oscillator or to a control device; in either case, the control voltage corrects the oscillator frequency.



(A) Basic AFC circuit.



(B) Operating waveform.

Fig. 11-18. Peak-voltage change when phase of comparison waveform changes.

The RC network to the right of C in Fig. 11-18 is basically an integrating and filter circuit that delays and smooths the control voltage. This configuration also provides a fast initial correction, followed by a slower correction in the same direction, which eases the oscillator to its correct frequency without overcorrection. When a defect occurs in this network, the result is often an overcorrection alternating with an undercorrection, resulting in a symptom called the *piecrust effect*. Technicians term the circuit action as *hunting* when the picture has a piecrust or gear-tooth appearance (see Fig. 11-19).

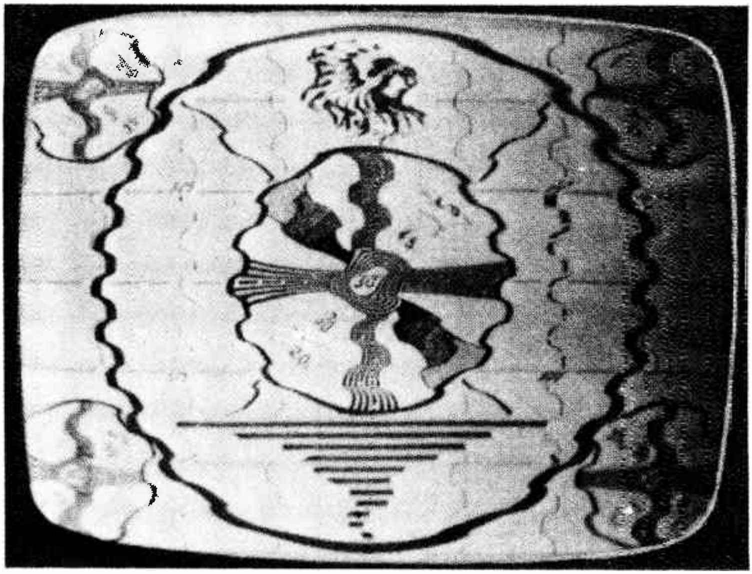


Fig. 11-19. Typical piecrust trouble symptom.

Summary of Scanning-Generator Pulse Control

1. A positive synchronizing pulse controls the frequency of a blocking oscillator.
2. A negative pulse controls the frequency of a cathode-coupled multivibrator.
3. The free-running frequency of the scanning oscillator should always be slightly less than the synchronizing-pulse-repetition rate; the hold, or frequency, control of the oscillator controls this action.
4. As the base voltage of a pulse generator approaches the "trigger" point, the oscillator becomes increasingly sensitive to control by additional base voltage. At this point, the scanning can be "tripped" by interference. Special circuit combinations have been devised that are controlled by the pattern of the pulses rather than by the individual pulses. Such a system is relatively insensitive to interference, which seldom has a regular pattern. Figure 11-20 shows the basic

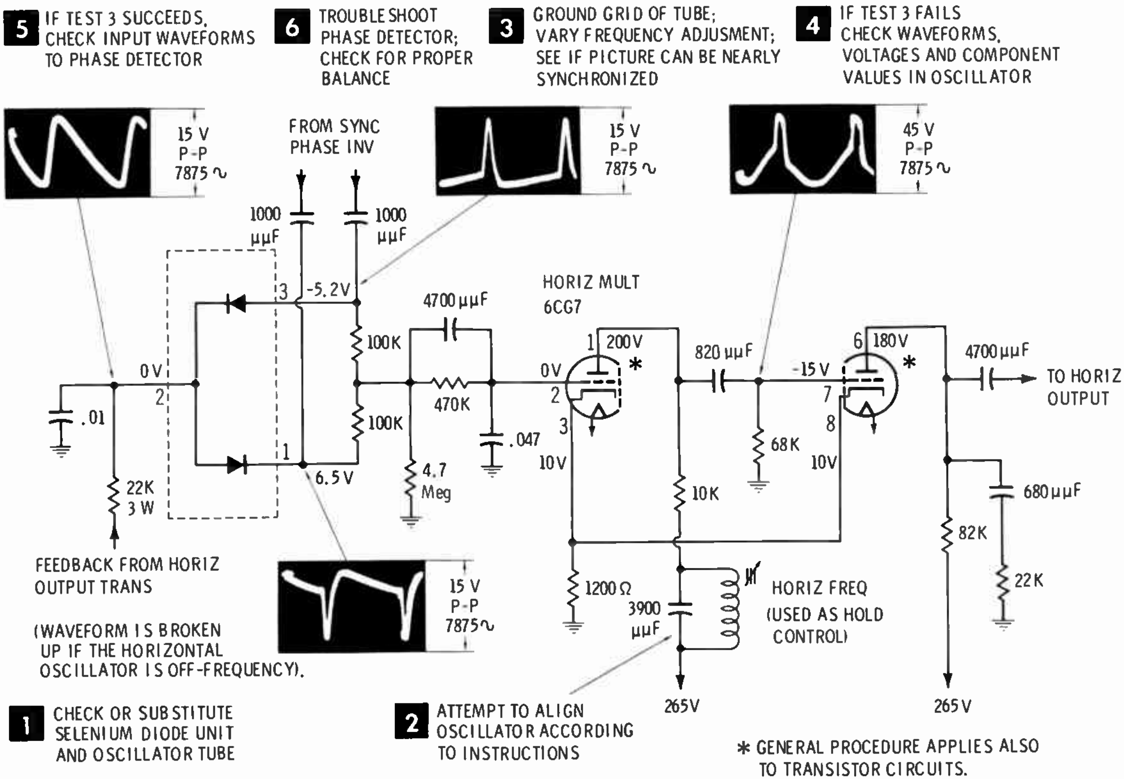


Fig. 11-20. Basic troubleshooting procedure for horizontal AFC oscillator section using two semiconductor diodes.

troubleshooting procedure for a horizontal AFC and oscillator section.

SCANNING

The amount an electron beam in an electromagnetically deflected cathode-ray tube is deflected depends upon the strength of the magnetic field produced by the deflecting coils. The magnetic field is proportional to the amount of current passing through the coils, and these fields cross the path of the electron beam within the neck of the tube.

We must supply a linear sawtooth of current through the coil so that the electron beam will trace the proper raster under the combined influence of the horizontal- and vertical-deflecting coils. In Fig. 11-21 we see the resultant shape of a current wave that would flow through a pure inductance if a symmetrical square wave of voltage were applied across its terminals. This

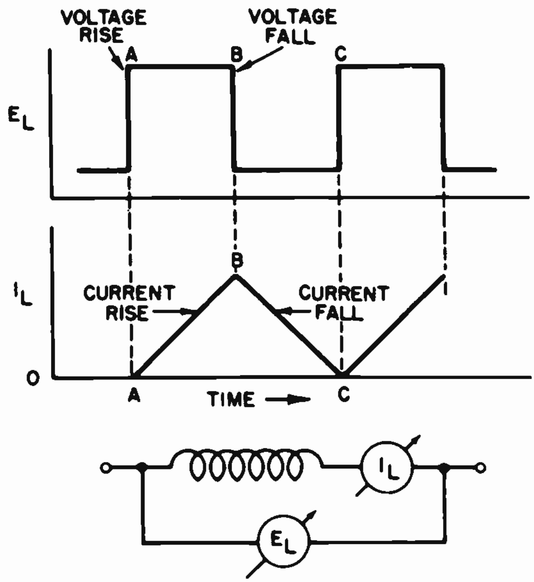


Fig. 11-21. Rise and fall of current through a pure inductance when a square voltage wave is applied.

type of wave, as we have seen, can be developed by a conventional or symmetrical multivibrator. At point A, the voltage suddenly has been applied to the coil in much the same fashion as if a switch had been closed to connect the coil to a DC source of potential, for example, a battery.

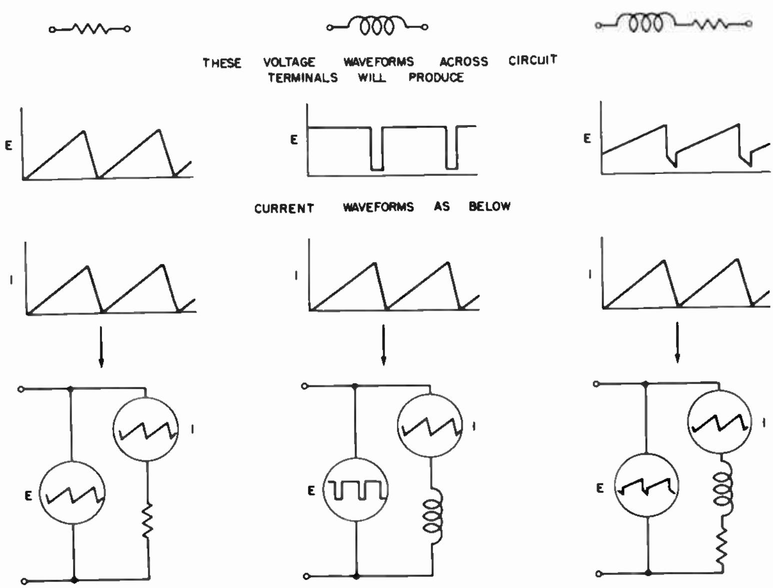
Notice that the current through the coil did not immediately rise to maximum. The self-induced voltage of the coil opposed the sudden change. The current, therefore, increased linearly over that portion of the cycle when the applied voltage was steady. (Theoretically, the current rises exponentially; but for practical purposes, we can consider it to be a linear change.) At point B, the impressed voltage suddenly was removed (the switch was opened). At this point, the current did not immediately fall to zero since it was maintained by the energy stored in the magnetic field. The self-induced voltage of the coil served as the driving potential to produce the linear fall of current from point B to point C.

We have now produced a triangular wave of current through the coil. If we can make the rise portion of the curve longer than the decay portion, we can produce the desired sawtooth-scanning current wave by making the impressed voltage wave asymmetrical, as shown in Fig. 11-22.

Since a deflection coil cannot be built as a pure inductance, we must now consider what effect the resistance of the windings will have on the voltage waveform producing a sawtooth of current. Figure 11-22 shows three types of circuits and the voltage waveform necessary to produce a sawtooth wave of current through each circuit. Figure 11-22A shows a pure resistance. The current is in phase with the voltage, and a sawtooth wave of voltage impressed across the resistor will cause a sawtooth wave of current through it. Energy losses occur only in the form of heat. The voltage required to produce a certain current is equal to the IR drop, as determined by Ohm's law.

Figure 11-22C shows the circuit represented by a deflection coil. The voltage waveform will be seen as a combination of the sawtooth of A and the rectangular wave of B (often called a *trapezoidal waveform*). In reality, this shape is the sum of an instantaneous pulse and a sawtooth. We might think of its function as follows:

1. The sawtooth, or linear rise, portion of the wave tends to produce a sawtooth wave of current through the resistive part of the circuit.
2. The instantaneous pulse portion of the wave forces a sawtooth wave of current through the inductive part of the circuit.



(A) Pure resistance. (B) Pure inductance. (C) Series inductance and resistance.

Fig. 11-22. Voltage and current waveform in inductive and resistive circuits.

To produce this combination waveshape, additional circuit elements are added to the sawtooth-capacitor-charging circuit. The circuit is then known as a *peaking* type of waveshaping circuit. By proper choice of capacitor and resistor values, either the sawtooth portion or the impulse portion of the wave can be made to predominate. (The circuit action will be described later.)

It is interesting to note that one part of the wave must predominate over the other because of the difference between the horizontal- and vertical-deflection coils. In the vertical-deflecting coil, the resistive component predominates over the inductive component; thus, the sawtooth portion of the wave predominates over the impulse portion. For example, this coil might have a resistance of 68 ohms and an inductance of 50 mH. When the retrace rate is 60 hertz, a predominantly resistive circuit is presented.

In the horizontal-deflecting coil of the same receiver, the conditions are reversed; the inductive component predominates. The impulse portion is more important, and the required waveshape approaches that of Fig. 11-22B. For example, we would find a resistance of only 14 ohms and an inductance of 8 mH. Since this coil operates at the much higher frequency of 15,750 Hz/sec, the circuit is essentially inductive.

TRANSISTOR HORIZONTAL-DEFLECTION SYSTEM

A typical transistor horizontal-deflection circuit is shown in Fig. 11-23. This is called a *hybrid arrangement* because a tube is used in the high-voltage section. The driver transistor Q602 is first cut off and then driven into collector saturation by the output from the horizontal oscillator. Figure 11-24 shows the normal waveforms at the base and collector of Q602. The rectangular waveform from the collector is transformer-coupled to the base of the horizontal-output transistor Q603. Q602 is said to operate in the switching mode, which means that the transistor is driven rapidly back and forth between cutoff and saturation.

Diode D604 in Fig. 11-23 helps to damp out the ringing of transformer T602 and also rectifies the overshoot to boost the +dc supply for the preceding phase-splitter stage. Q603 is operated in the switching mode. When Q603 conducts, the yoke current increases linearly. Meanwhile, capacitor C617 is charging. At the end of the forward-scan interval, the base waveform suddenly cuts off Q603. Due to the inductance and capacitance of the horizontal-output system, a ringing oscillation starts: Ringing begins with a large positive-overshoot pulse that quickly reverses

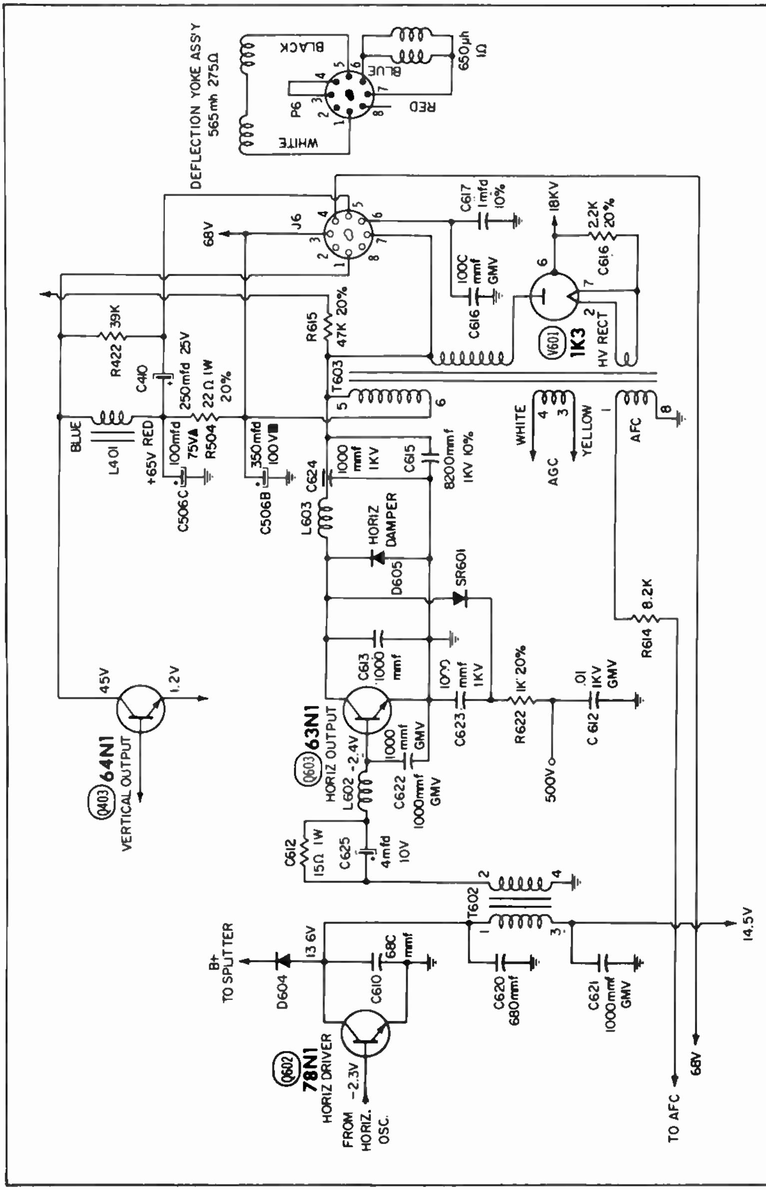


Fig. 11-23. Typical horizontal-output and high-output voltage configuration.

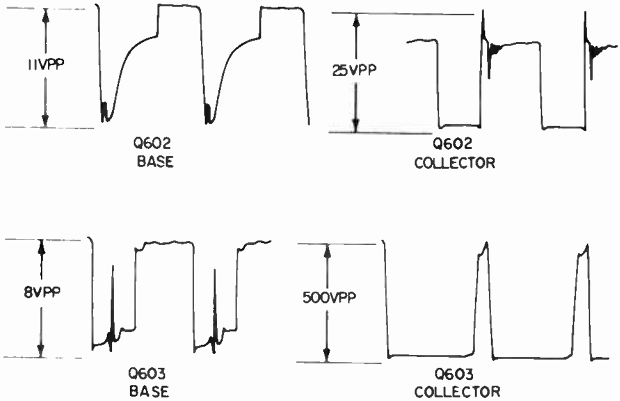


Fig. 11-24. Waveform found in horizontal-output system of Fig. 11-23.

the current through the horizontal-deflection coils and thereby initiates the flyback interval.

As the negative half-cycle of ringing starts, damper diode D605 becomes forward-biased. In turn, the low impedance imposed by D605 limits the negative-ringing excursion. At the same time, C617 discharges linearly through the horizontal-deflection coils and D605 to ground. This linear discharge provides the first half of the ensuing forward-scan interval. Figure 11-25 shows this sequence of circuit action. To summarize briefly, the first half of the forward scan occurs while Q603 is cut off, and while C617 discharges through the yoke and D605. The second half of the scan occurs as Q603 is switched into conduction, and C617 proceeds to charge once more through the yoke.

Silicon controlled rectifiers (SCRs) are also used to a considerable extent in horizontal-deflection configurations. Figure 11-26 shows the arrangement of a typical system. It operates from an unregulated dc power supply of +155 volts. Current and voltage waveforms required by the circuit action are obtained from LC resonant circuits. A regulator stage is included in the circuitry to stabilize scanning under conditions of varying line voltage and changes in picture-tube beam current. With reference to Fig. 11-27, the trace-switch diode D_T and the trace-switch, silicon-controlled rectifier SCR_T provide the switching action that controls current flow in the horizontal-yoke windings L_y during the

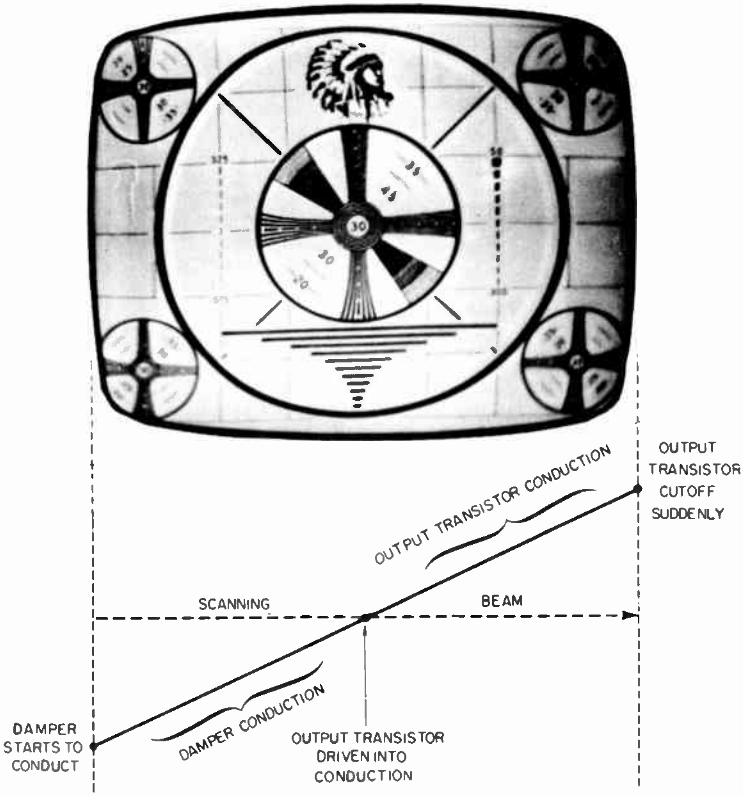


Fig. 11-25. Sequence of circuit action in horizontal-output system.

picture-tube, beam-trace interval. The commutating-switch diode D_C and the controlled rectifier SCR_C initiate the retrace and control the yoke current during the retrace interval.

Inductor L_R and capacitors C_R, C_A, and C_Y supply the required energy storage and timing cycles for the circuit action. Inductor L_{CC} provides a charge path for capacitor C_R from the dc supply voltage so that the system recharges from the receiver power supply. The secondary of inductor L_{CC} provides the gate-trigger voltage for the trace switch SCR. Capacitor C_R determines the optimum retrace time by its resonant action with inductor L_R. Figure 11-28 shows the voltage and current relations during the

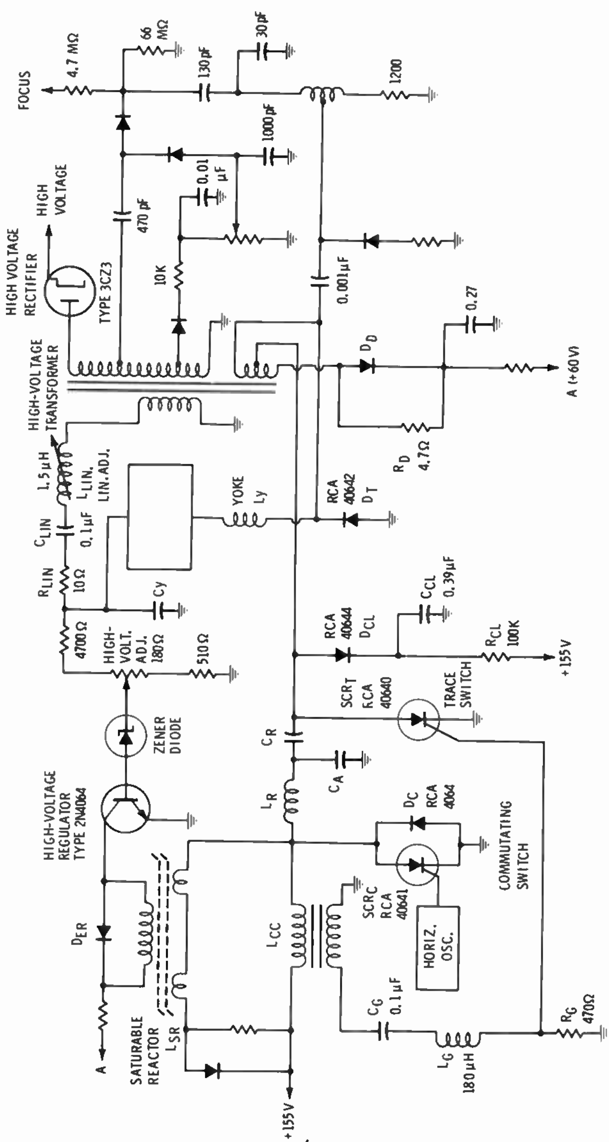


Fig. 11-26. Configuration of SCR horizontal-deflection system.

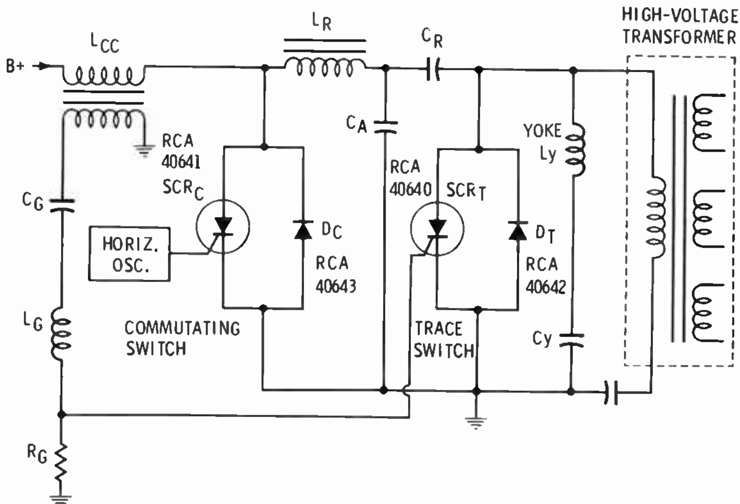


Fig. 11-27. Basic circuit that generates the deflection-current waveform.

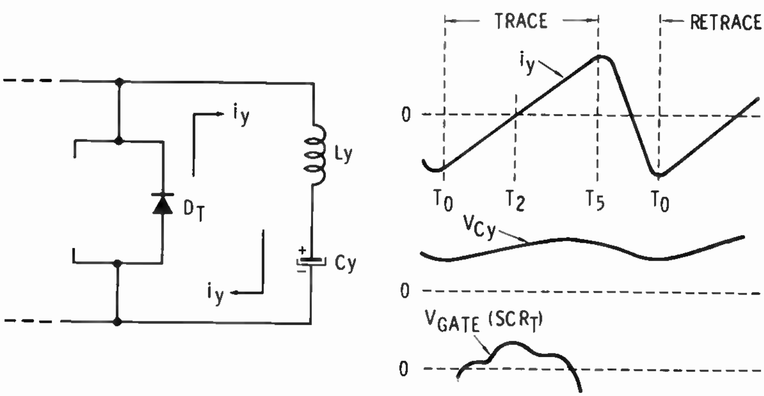


Fig. 11-28. Circuit action during first half of the trace interval.

first half of the trace-deflection-current interval, from T_0 to T_2. At time T_0, the magnetic field has been established in the horizontal yoke windings L_y. This field generates a decaying yoke current i_y that decreases to zero when the energy in the yoke winding is depleted at time T_2. This current charges capacitor C_y to a positive voltage V_{Cy} through the trade-switch diode D_T.

Note that, during the first half of the trace interval, just before T_2, the trace-controlled rectifier SCR_T is prepared to conduct by applications of a gate-voltage pulse V_{GATE}. However, SRC_T does not conduct until a forward bias is also applied between its anode and cathode. This forward bias is applied during the second half of the trace interval. Next, consider the second half of the trace interval. At time T_2, current flow is no longer maintained by the yoke inductance, and C_y begins to discharge into this inductance. The direction of current flow in the circuit is then reversed, and trace-switch diode D_T becomes reverse-biased. Trace-switch-controlled rectifier SCR_T is then forward-biased by V_{Cy} across the capacitor, and the capacitor then discharges into the yoke inductance through SCR_T, as shown in Fig. 11-29. Capacitor C_y is sufficiently large that V_{Cy} is almost constant during the complete trace and retrace cycle. This ensures a linear current rise through the yoke inductance L_y over the complete scan interval from T_0 to T_5.

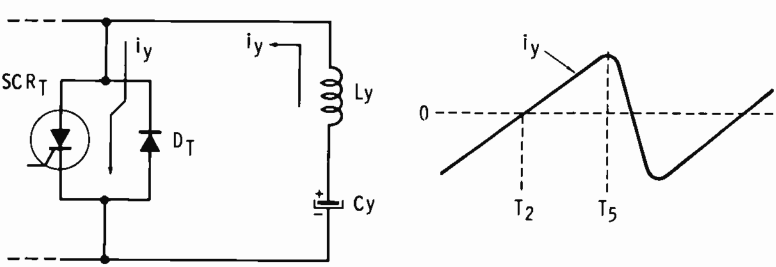


Fig. 11-29. Circuit action during second half of the trace interval.

Next, consider the start of the retrace interval. Figure 11-30 shows the components and the voltage and current waveforms that are involved. At time T_3, before the end of the trace period, the commutating-switch-controlled rectifier SCR_C is turned on by a pulse to its gate from the horizontal oscillator. C_R is then permitted to discharge via SCR_C and inductor L_R. The current in this loop (the commutation circuit) builds up as a half-sine pulse. At time T_4, the magnitude of this current pulse exceeds the yoke-current value and the trace-switch diode D_T again becomes forward-biased. The excess current in the commutating pulse is then bypassed around the yoke winding by the shunting action of diode D_T. From T_4 to T_5, the trace-switch-controlled rectifier SCR_T is reverse-biased by the amount of the voltage drop across D_T. Therefore, the trace-switch-controlled rectifier is turned off during this interval, during which it recovers its ability to block the forward voltage that is subsequently applied.

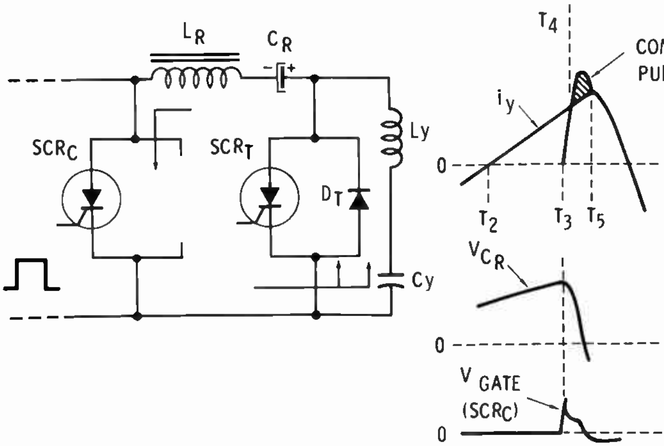


Fig. 11-30. Circuit action from time T_3 to T_5.

We shall next observe the circuit action during the first half of the retrace interval. At time T_5, the commutating pulse no longer has a greater amplitude than the yoke current, as seen in Fig. 11-31. At this time, the trace-switch diode D_T stops conduction. The yoke inductance maintains the yoke-current flow. However, with SCR_T in its off state, this current flows in the commutating loop comprising L_R, C_R, and SCR_C. Note that time T_5 is the start of retrace. While the current through the yoke windings decreases to zero, the energy supplied by this current charges capacitor C_R to a voltage of opposite polarity as a result of resonant oscillation. At time T_6, the yoke current is zero, and capacitor C_R is charged to its maximum negative value. This circuit action completes the first half of the retrace interval.

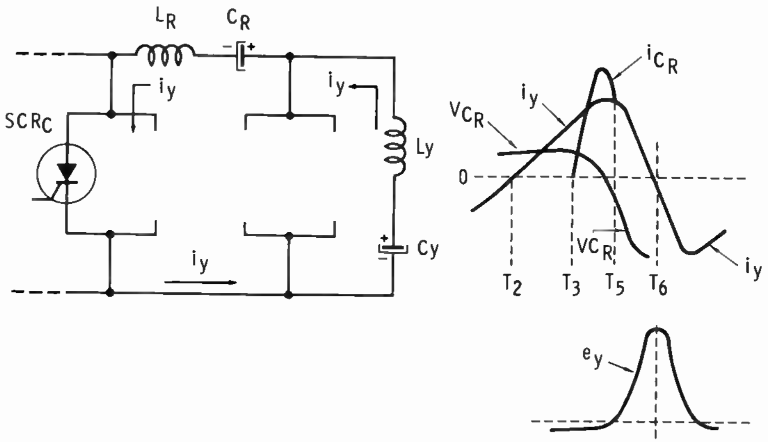


Fig. 11-31. Circuit action during the first half of retrace.

Next, consider the circuit action that occurs during the second half of the retrace interval. At time T_6, the magnetic energy in the yoke inductance is depleted and the stored charge in the retrace capacitor is then returned to the yoke inductance. This circuit action reverses the direction of current flow through the yoke. During the reversal of yoke current, the commutating-switch diode D_C provides the return path for the loop current, as shown in Fig. 11-32. The commutating-switch-controlled rectifier SCR_C is reverse-biased by the value of the voltage drop across diode

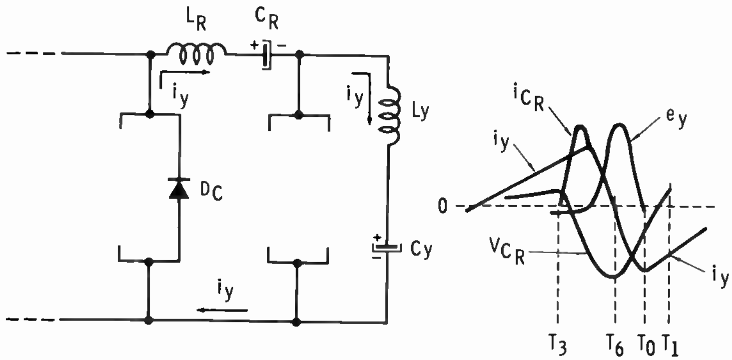


Fig. 11-32. Circuit action during the second half of retrace from T_6 to T_0.

D_C. Therefore, the commutating-switch-controlled rectifier turns off, and its voltage-blocking capability is recovered. As the yoke current builds up in the negative direction, the voltage across the retrace capacitor C_R decreases.

Note that at the time T_0 the voltage across capacitor C_R no longer supplies a driving voltage for the yoke current to flow through the loop comprising L_R, C_R, and L_y. In other words, the yoke current finds an easier flowpath through the trace-switch diode D_T, as shown in Fig. 11-33. This circuit action represents the beginning of the trace period for the yoke current or the beginning of a new cycle of operation at time T_0. Once that the negative-yoke current is decoupled from the commutating loop by the trace-switch diode, the current flow through the commutating circuit decays to zero. In turn, the stored energy in L_R charges C_R to an initial amplitude of positive voltage. Since the resonant frequency L_R/C_R is high, this energy transfer is accomplished in the short period from T_0 to T_1, as shown in Fig. 11-32.

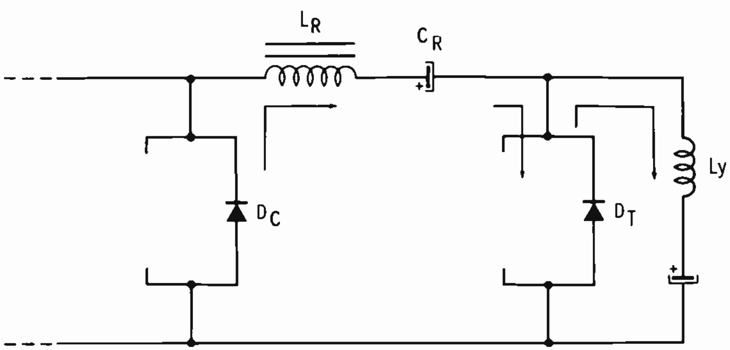


Fig. 11-33. Operation of deflection circuit during switchover from retrace to trace at T_0.

We shall now follow the circuit actions in the recharging and resetting modes of system operation. The circuit actions required to restore energy to the commutating circuit and reset the trace SCR are also basic considerations in deflection-circuit operation. Both of these actions involve inductor L_{CC}. During the retrace period, L_{CC} functions between the dc supply voltage and ground via the commutating switch SCR or the diode (SCR_C or D_C), as shown in Fig. 11-34. When the SCR and diode stop conducting, however, the path from Lcc to ground is opened. In turn, the energy stored in Lcc during the retrace interval proceeds to charge C_R through the B+ supply, as shown in Fig. 11-35. This charging action continues through the trace period until the start

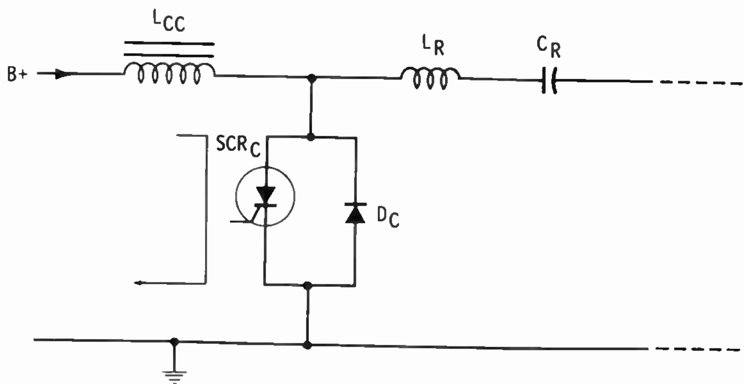


Fig. 11-34. Energy is supplied from L_{cc} from T_3 to T_1.

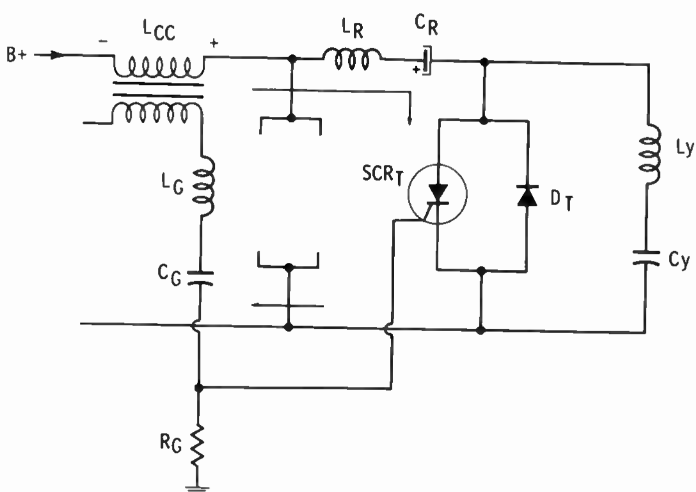


Fig. 11-35. Circuit action during the period from T_1 to T_3.

of retrace. The resulting charge on C_R resupplies energy to the yoke during the retrace interval.

Observe that the voltage developed across L_{CC} during the charging period of C_R functions to forward-bias the gate electrode of the trace SCR, thereby readying this device for conduction. This voltage is inductively coupled from L_{CC} and is applied to the gate of SCR_T via the waveshooting network comprising L_G, C_G, and R_G. This signal voltage is applied to the gate of SCR_T. The device conducts when a forward-bias voltage is applied from anode to cathode at approximately the midpoint of the trace interval. Next, it is helpful to observe the function of capacitor C_A. It affects some of the circuit waveforms, as shown in Fig. 11-36, assists in turnoff of the trace SCR, and reduces the retrace time while providing increased energy storage in the circuit.

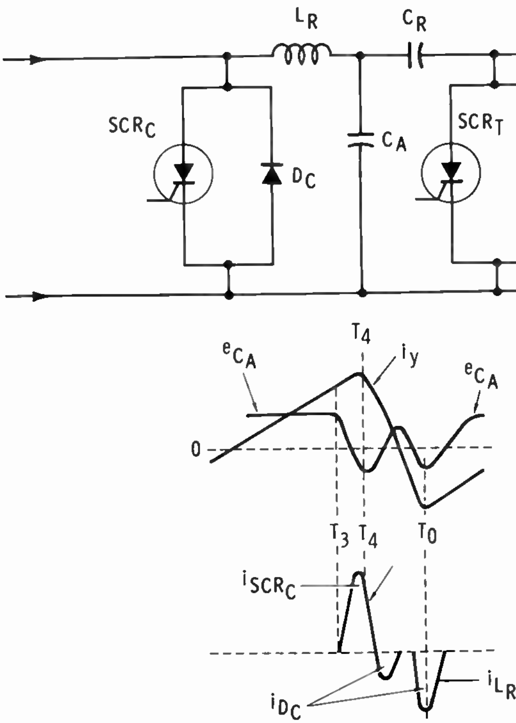


Fig. 11-36. Effect of C_A with current and voltage waveforms.

During the larger portion of the trace interval, from T_0 to T_4 and including the interval from T_3 to T_4 while the commutating pulse is present, the trace switch is closed and C_A operates in parallel with C_R. From the start of the retrace at T_4 to the beginning of the next trace interval at T_0, the trace switch is open. At this time, C_A operates in series with L_y and C_R so that the capacitance in the retrace circuit is decreased. In turn, the resonant frequency is decreased, thereby reducing the retrace time. Note that C_A is also in parallel with L_R. This operation changes the voltage- and current-deflection waveforms to some extent; in other words, the discharge around the loop occurs at a higher frequency than would otherwise take place. Troubleshooting of the deflection system is often facilitated by a careful checkout of the operating waveforms. Note that if an error is made and SCR_C–D_C is interchanged with SCR_T–D_T, the deflection will operate almost (but not quite) normally.

TRANSISTOR VERTICAL-SWEEP SYSTEM

Operation of the blocking oscillator shown in Fig. 11-7 has been explained previously. The pulse waveform from Q14 is first changed into a sawtooth waveform by the same circuit that provides the time constant of the blocking oscillator, namely, C21 and R79. Discharge of C21 through R79 produces a curved (exponential) waveform, which is then linearized by means of negative feedback via R81. Manual control of vertical linearity is necessary, and this is provided by R6B, which operates in combination with C77 to introduce controlled waveshaping. The resulting sawtooth wave can be made either convex or concave by adjustment of R6B. Between these two extremes, the desired linear-sawtooth waveform is obtained.

It is also necessary to control the amplitude of base drive to Q15 in Fig. 11-7 in order to adjust the raster height; this is provided by control R7A. Negative feedback is also provided for Q15 and R89; that is, the waveform from the vertical-deflection coil returns to ground through the emitter resistor for Q15. Some additional negative feedback is also provided from collector to base of Q15 via R83. These negative-feedback circuits not only serve to produce basic linearity in the system, but also make tolerances on replacement transistors less critical than otherwise. Any residual nonlinearity is corrected by adjustment of R6B.

The vertical-output transistor shown in Fig. 11-7 employs a power transistor. Because of the comparatively critical bias that is required, a bias-control R6C is provided for maintenance adjustment. Q16 operates near its maximum-rated output, and since the collector current is heavy, the collector junction heats up appreciably. Although a heat sink (heavy metal mounting) is used, the transistor heats sufficiently in normal operation that the bias voltage must be stabilized. Unless the base-emitter voltage is stabilized, thermal runaway and resulting damage to the transistor will occur. R86 is a thermistor that operates to control the forward bias on Q16 and thereby stabilizes operation. When the emitter-base current tends to increase, R86 heats up and its resistance decreases, thereby decreasing the base voltage.

Since the vertical-deflection coils have both resistance and inductance, a peaked-sawtooth waveform is required to produce a sawtooth current through the coils. The negative peaking spike at the collector of Q16 is produced by inductive kickback from inductor T3 and the vertical-deflection coils. Note that although there are only 8.6 volts dc between the collector and emitter of Q16, this inductive kickback generates a total peak-to-peak voltage of 50 volts for the output waveform. The peaking pulse is tapped off for vertical-retrace blanking of the picture tube. Negative feedback is provided by the unbypassed emitter resistor R90, which also assists in dc stabilization of Q16.

SUMMARY

The multivibrator, blocking oscillator, and sine-wave oscillator are three types of circuit arrangements generally used to produce sawtooth waveforms for scanning purposes. One of the most popular circuits is the multivibrator because devices can act as automatic switches to control the charge and discharge of capacitors.

The horizontal and vertical pulses are clipped from the signal, amplified, and passed through circuits that classify the pulses so that each will control its own scanning oscillator only. The end result is a short, sharp pip for the horizontal control and a long, triangularly shaped pulse for the vertical control. The height and width of the sync pulses are not important as long as they are high enough to drive the grid above the cutoff point.

REVIEW QUESTIONS

1. What three circuits are used for scanning purposes?
2. Which circuit for scanning is most popular?
3. How does an SCR deflection circuit operate?
4. Sync pulses can be either positive or negative. Which pulse is ideal for the cathode-coupled multivibrator?
5. What type oscillator is generally used in transistor television receivers?

CHAPTER 12

Power Supplies

Power supplies in television systems are more complicated than those normally found in radio and other electronic devices. At least two separate and basically different load conditions must be provided for in the set:

1. A low-voltage, high-current system to power the oscillator, amplifier, and similar stages where applied potential does not exceed 450 volts. In addition, some receivers power the modulation and deflection systems from this source.
2. A high-voltage, low-current system to supply the accelerating anode potential for the cathode-ray or picture tube.

LOW-VOLTAGE, HIGH-CURRENT SUPPLIES

The signal-reception portion of the receiver, which includes sound and video amplifier or control tubes, presents a power requirement that does not differ greatly in voltage range from that of other electronic devices. Therefore, this portion of the television power supply is similar to the one found in large radio receivers.

In general, the voltage requirement is no more than 450 volts. The current required, however, is frequently much greater than that necessary for radio operation. In addition, a good supply regulation is needed to operate the sawtooth oscillators for deflecting the electron beam of the cathode-ray tubes. These oscillators tend to produce currents in the power supply. If not properly filtered, these currents would appear as serious modulation hum in the beam control and sound circuits.

Early receivers required heavy-duty power supplies to provide the current (as much as 300 mA in some receivers) drawn by the 30 to 40 tubes in the receiver. These supplies employed from one to three rectifiers; the number, of course, depended upon the current requirements and the designer's preference as to voltage and current distribution.

Practically all power supplies use one of the basic rectifier circuits: the half-wave rectifier, the full-wave rectifier, or the bridge rectifier, as shown in Fig. 12-1. Half-wave- and bridge-rectifier circuits may be modified to provide power supplies that have two different output voltages. These output voltages may have different values and the same polarity or the same values and different polarities. Polarity is defined with respect to ground. For example, Fig. 12-2 shows a basic half-wave rectifier arrangement that provides a positive-output voltage via diode A. In addition, a negative-output voltage may be obtained by connecting diode B in reversed polarity to the "hot" end of the secondary winding.

Dual-output voltages can also be obtained from bridge rectifiers. An advantage of a bridge rectifier is that it does not require a center-tapped transformer. However, in case the center-tapped transformer is utilized with a bridge-rectifier configuration, a power supply can be provided that has two output voltages. Addition of a grounded center tap, as shown in Fig. 12-3, permits each half of the bridge rectifier to function as an ordinary two-diode, full-wave rectifier of a chosen polarity. If one end of the bridge is grounded, as shown in Fig. 12-3B, the arrangement

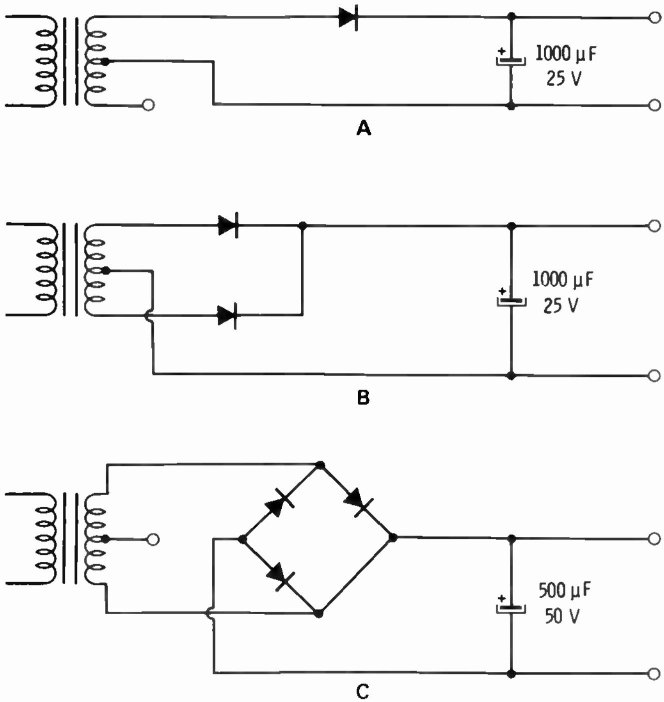


Fig. 12-1. Three basic rectifier circuits.

functions as an ordinary bridge rectifier that provides a high output voltage at the ++ terminal, and as a two-diode, full-wave rectifier that provides half as much output voltage at the + terminal.

The next step in complexity concerns voltage multipliers. These are configurations that supply dc voltages that are multiples of the ac input voltage.

Full-Wave Voltage Doubler—The circuit shown in Fig. 12-4C can be modified by removing the ground connection between the two capacitors, and a standard full-wave, voltage-doubler arrangement is obtained, as shown in Fig. 12-4A. Note that two half-wave rectifier circuits of opposite polarity have been combined, with the output taken from across both capacitors to obtain double-output voltage. A voltage-multiplier circuit is

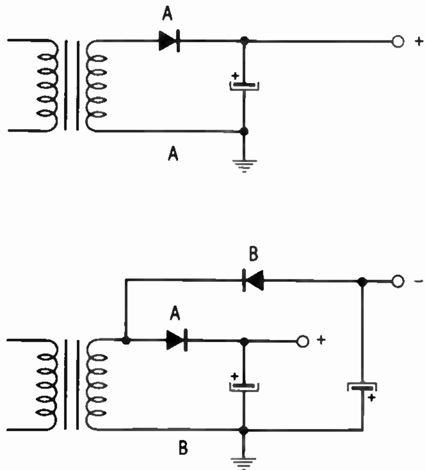


Fig. 12-2. Dual-output, half-wave rectifier arrangements.

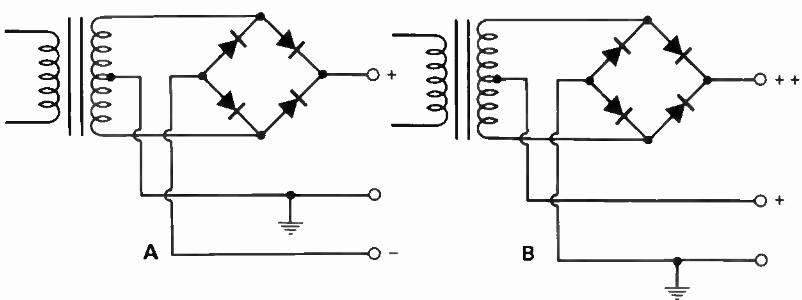
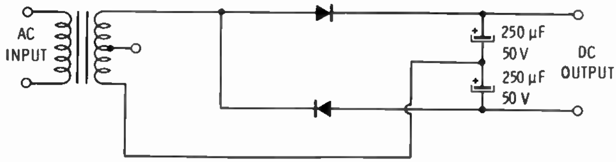


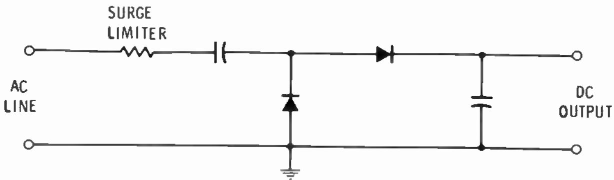
Fig. 12-3. Dual-output, bridge rectifier configurations.

often used in equipment where a high dc output voltage is required from a transformerless power supply.

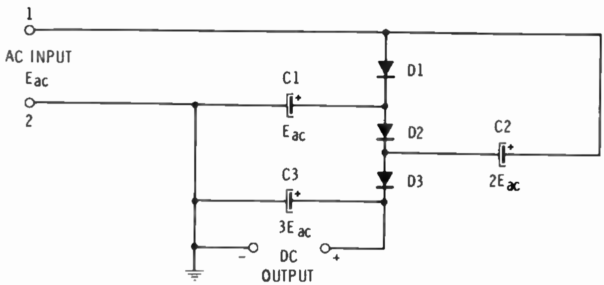
Half-Wave Voltage Doubler—A standard half-wave doubler arrangement, shown in Fig. 12-4B, is often preferred to the full-wave arrangement. An advantage of the half-wave doubler is that it does not require a transformer. On the other hand, a half-wave doubler has a ripple frequency equal to the line frequency, whereas a full-wave doubler has a ripple frequency equal to



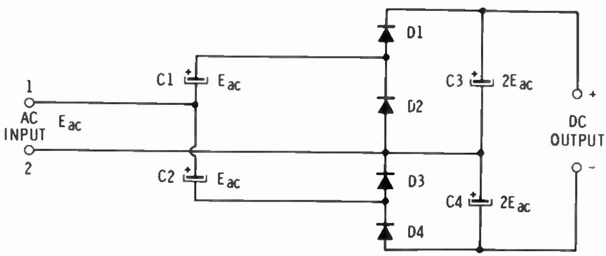
(A) Full-wave doubler.



(B) Half-wave doubler.



(C) Half-wave tripler.



(D) Full-wave quadrupler.

Fig. 12-4. Voltage-multiplier configurations.

twice the line frequency. In turn, larger filter capacitors are required in the half-wave doubler arrangement.

Half-Wave Voltage Tripler—A half-wave voltage tripler operates on the same basic principle as a half-wave voltage doubler.

Fig. 12-4C shows the tripler configuration. Since it uses a ground connection to one input line, a transformer is not required.

Full-Wave, Voltage Quadrupler and Sextupler—When two half-wave voltage doublers are connected so that their outputs are effectively in series, a full-wave, voltage-quadrupler arrangement results, as shown in Fig. 12-4D. In the same manner, a full-wave voltage sextupler results from connecting two half-wave voltage triplers so that their outputs are effectively in series. Note that the comparatively complex quadrupler and sextupler arrangements are practical because their semiconductor rectifiers require no heater windings and heater circuits. In other words, their production cost is not excessive.

As a practical note, the foregoing voltage-multiplier circuits use capacitor input filters, and their voltage regulation (reduction of output voltage with increased current demand) is comparatively poor. Under heavy current demand, the output voltage may decrease as much as 30 percent, which can be minimized by the use of very-large-filter capacitors.

Filter Arrangements

Since a semiconductor rectifier has a very low voltage drop in its forward-conduction state, surge currents drawn by filter capacitors must be limited to avoid rectifier damage. With reference to Fig. 12-5, the starting surge is limited to some extent by the series impedance of the transformer winding.

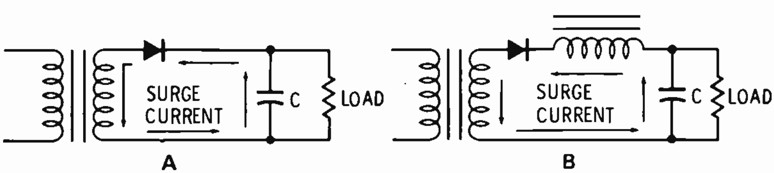


Fig. 12-5. Example of surge-current paths for two basic filter circuits.

However, if the series resistance of the transformer winding is low and capacitor C has a large value, a starting-current surge can result that damages the rectifier. Capacitor input filters are especially vulnerable to starting current surges. Therefore, it is poor practice to replace an input-filter capacitor with a higher value than specified in the receiver service data. In other words, when the power is turned on, a large current flows through the rectifiers to charge the input-filter capacitor. At the moment of starting operation, the input-filter capacitor appears as a dead short, and the momentary current demand can be extremely high. Therefore, it is often necessary to include circuit means to limit the initial charging current.

Choke-Input Filters—Power supplies that use choke-input filters do not require surge-limiting means. Note that the filter choke shown in Fig. 12-5B limits the surge current in the same manner that it limits the peak-rectifier current during maximum current demand.

Resistor Surge Limiter

With reference to Fig. 12-6, a small-valued resistor is often included in series with the ac input to the rectifier. Its value is chosen to limit the surge current to the maximum amount that the rectifier can handle for a short time. Note that surge-current ratings are generally much greater than the average dc rating for a rectifier.

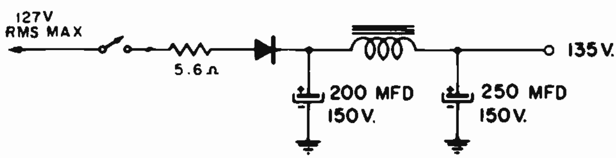


Fig. 12-6. Typical low-voltage supply using a surge resistor.

For example, a silicon rectifier that is rated for an average current of 750 mA has a surge-current rating of 35 A for 4 msec. Observe, also, that the series resistance that limits the surge current is chosen with the worst case in mind. Thus, the worst case occurs when power is applied at the instant the ac voltage is swinging through its positive peak, and the input filter capacitor has zero charge. In the example of Fig. 12-6, the maximum input voltage is 127 volts rms; its peak voltage is 180 volts, accordingly. In turn, to limit the surge current to 35 A, the surge-limiting resistor should have a value of 5.2 ohms, in accordance with Ohm's law.

Following the initial current surge, the filter capacitors become fully charged. Thereafter, the voltage drop across the surge resistor is small. For example, if the current demand in Fig. 12-6 is 300 mA, the drop across the surge resistor will be 1.56 volts. In practice, transformer power supplies may or may not require a surge resistor with a capacitor-input filter, depending on the winding resistance of the transformer secondary.

DC VOLTAGE REGULATORS

A basic power supply has significant internal resistance. For example, rectifier diodes have a certain forward resistance, and transformers and chokes have winding resistance. In turn, there is an IR drop across the internal resistance of a power supply that is directly proportional to the current demand, and the output voltage is reduced by the amount of internal voltage drop.

Another factor that reduces the output voltage with increased current demand is the fact that the filter capacitors do not charge up to the same voltage as when the discharge rate is small. When the output voltage drops considerably under heavy current demand, the power supply is said to have poor regulation. Note that changes in ac input voltage also cause changes in dc output voltage.

Zener-Diode Regulator

Zener diodes are used in configurations such as shown in Fig. 12-7 to regulate the output voltage. The breakdown voltage of typical zener diodes ranges from 3.9 volts to several hundred volts. Two or more zener diodes may be connected in series to regulate voltages higher than the breakdown value of a single diode, as shown in Fig. 12-8. Various regulated voltages can be tapped off from a series arrangement of diodes, if needed. The value of the series dropping resistor must be sufficient that the maximum current rating of any diode is not exceeded under worst-case conditions. If the source voltage varies considerably,

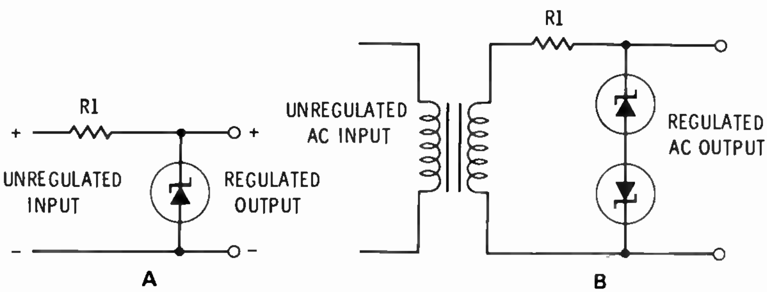


Fig. 12-7. Basic zener-diode-regulator arrangements.

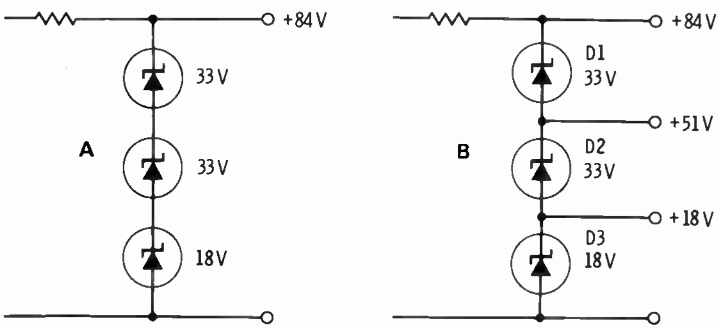


Fig. 12-8. Stacked zener-diode configuration.

the cascaded regulator arrangement shown in Fig. 12-9 is more appropriate.

Low-Voltage Zener Regulators

Regulation of very low voltage is done on a differential basis, as shown in Fig. 12-10. The diodes are selected so that the difference in their breakdown voltage values is equal to the regulated voltage value that is required. The load is connected between the ungrounded terminals of the zener diodes. In the example of Fig. 12-10, the regulated voltage value is 1.2 volts. Note that zener diodes are never connected directly in parallel with each other.

Another method of obtaining low-voltage regulation is to use a forward-biased diode, as shown in Fig. 12-11. The forward vol-

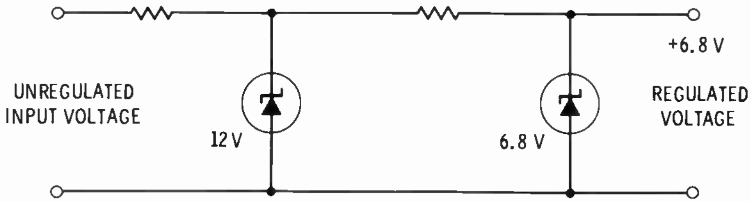


Fig. 12-9. Cascaded zener-diode-regulator arrangement.

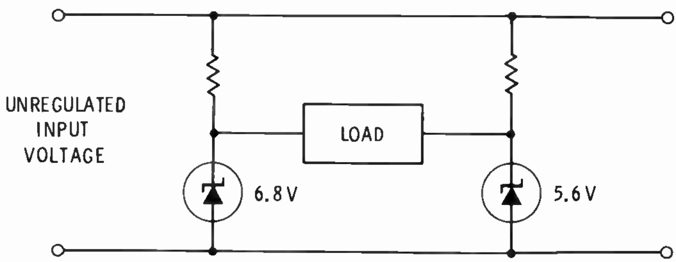


Fig. 12-10. Zener-diode configuration for regulation of small valves.

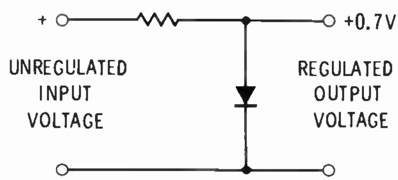


Fig. 12-11. Basic circuits for very-low-voltage regulation with a forward-biased diode.

tage drop across a conducting semiconductor diode is relatively constant over a comparatively great current range. A forward-biased diode can regulate voltages in the range from 0.5 to 1.1 volts, depending upon the type of diode that is used. Note that the efficiency of regulation is not as good as provided by zener arrangements.

Transistor Voltage-Regulator Arrangements

Low-voltage-regulated power supplies often use transistors. This is accomplished by means of some form of feedback circuit that senses any change in the dc output voltage and, in turn, develops a control voltage that operates to cancel the change. The control that is operative in the feedback or regulator circuit is a function of the circuit arrangement and may be a series or a shunt configuration.

In a transistor type of regulator, the output voltage developed by the dc power supply is compared with a reference voltage. The difference between these voltages is amplified and fed back to the base of a pass transistor, either linearly or in the switching mode, thereby regulating the value of the output voltage. In case the pass transistor can be operated at any point on its characteristic between cutoff and saturation, the regulator circuit is said to be a *linear voltage regulator.* On the other hand, if the pass transistor operates only at cutoff or at saturation, the circuit is said to be a *switching regulator.*

SERIES-REGULATOR OPERATION

A series-regulator configuration uses a pass transistor that is connected in series with the load. In turn, regulating action takes place by a circuit that senses any variation of current flow through the series-pass transistor due to a change in line voltage or in current demand from the power supply.

A corresponding change in voltage drop across the pass transistor in consequence of feedback circuit action will be in opposition to changes in line voltage or to current demand, so that a practically constant voltage drop is maintained across the load. By way of comparison, a shunt regulator uses a pass transistor connected in parallel with the load, and a voltage dropping resistor is connected in series with this parallel circuit branch. In turn, if the load-current demand changes, the current flow through the pass transistor will increase or decrease as required to maintain a virtually constant current flow through the dropping resistor.

As noted previously, the series-voltage regulator functions with a pass transistor connected in series with the load. Consequently, regulation takes place as the result of variation in the voltage drop across the series transistor. Note that the small-load efficiency of a series regulator can be much greater than that of a shunt regulator inasmuch as no output current is wasted through a branch path shunting the output. However, the full-load efficiency of the series and shunt regulators is about the same.

A basic series-voltage-regulator arrangement is shown in Fig. 12-12. Observe that a dc amplifier is used to step up the error (difference) voltage obtained from a comparison between a sample of the output voltage and the reference voltage. This amplified error voltage is then applied to a regulating transistor connected in series with the load. The control voltage is developed across the regulating transistor and is applied to the error detector and amplifier. This error amplifier and the series transistors may include any appropriate number of transistor stages.

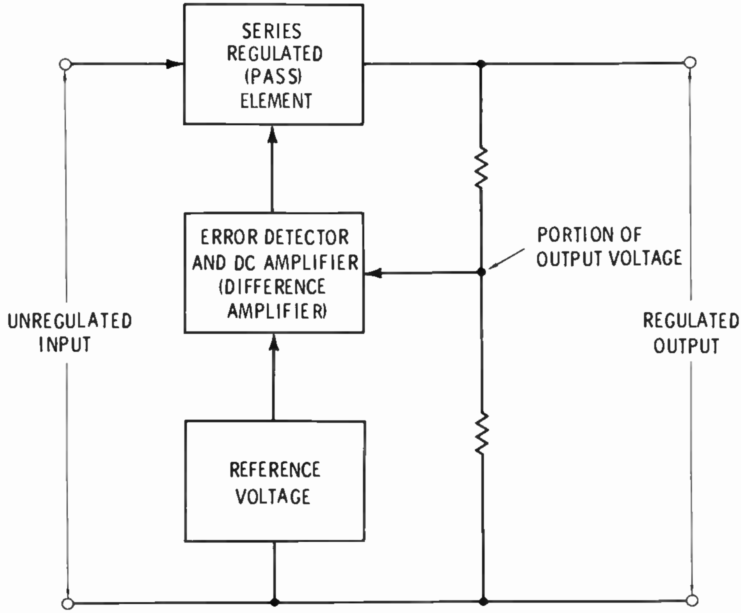


Fig. 12-12. Arrangement of basic series-voltage regulator.

Observe the simple series-regulator circuit depicted in Fig. 12-13. The transistor operates in the emitter-follower mode. Input voltage for the transistor is obtained from across the zener diode. Note that the resistor provides breakdown current for the zener

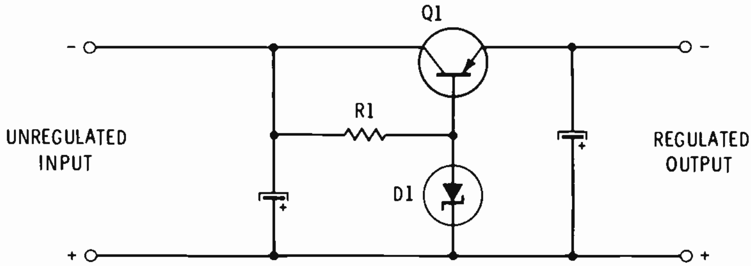


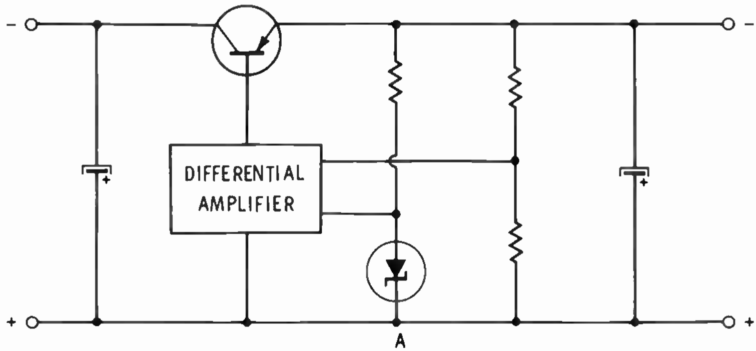
Fig. 12-13. Configuration of simple series-voltage regulator.

diode and also base current for the transistor. This configuration provides a considerable degree of regulation, which is ample for many applications.

Any change in the unregulated input voltage will cause a change in the breakdown voltage of the zener diode, thereby causing a small change in the regulated output voltage. Note that the load "sees" an output resistance, which is slightly higher than the emitter input resistance of the transistor. This output resistance has a value of approximately 30 ohms with a load-current demand of 30 mA, and it drops to about 1 ohm with a 1-A current demand.

Two general methods are used to apply voltage gain to a series-regulator transistor. One method, shown in Fig. 12-14A, operates the series transistor in the emitter-follower mode. This method places the input to the series transistor between its emitter and collector, with the output voltage taken between the collector and emitter. In the second method, shown in Fig. 12-14B, the transistor functions as a common-emitter amplifier. This method applies the control voltage between the base and emitter, with the output voltage taken between the collector and emitter.

Both of these methods have approximately the same performance. Note that the differential amplifiers shown in Fig. 12-14A and B function as difference or error amplifiers. They are basically high-gain, direct-coupled arrangements that provide low noise, low drift, and high stability when operated in a feedback loop. Because a differential-amplifier configuration is often used as a difference amplifier, the arrangement is commonly called a *differential amplifier*.



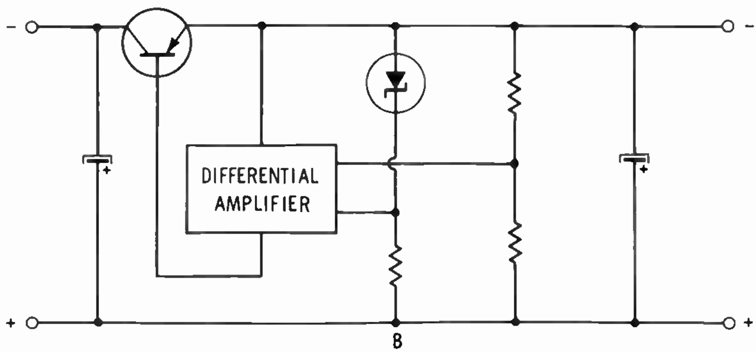


Fig. 12-14. Examples of series-regulating arrangements using error feedback and amplification.

If a wide-output voltage range is required, the emitter-follower arrangement has an advantage because the voltage applied between the base and emitter is always low, regardless of the output voltage from the regulator. In most cases, it is convenient to have the output from the entire regulating amplifier approximately equal to the emitter voltage of the series transistor. Only a voltage-sensing lead is connected to the other output terminal. Accordingly, there is no limitation placed on the regulator-output voltage by the regulating amplifier.

By way of comparison, an emitter-follower configuration operates the regulating amplifier at about the same voltage as the output lead, which does not include the series transistor. In turn, the regulating amplifier senses the voltage across the output terminals and drives the base of the series transistor. Note that the voltage of the base with respect to the regulating amplifier may be too high when used in a high-voltage regulator, and a dangerously high collector-emitter voltage may be required in the last transistor stage of the regulating amplifier.

The collector-emitter voltage will be comparatively constant in nonadjustable regulator arrangements. In turn, a large portion of the voltage may be divided by a zener diode connected in series with the collector. On the other hand, a wide-range voltage regulator cannot use this method of voltage division.

It is instructive to note that both arrangements shown in Fig. 12-14 are similar in various other respects also. Thus, the voltage divider senses the output voltage from the power supply and develops an input voltage that is applied to the differential-regulating amplifier. In turn, the output voltage changes by feedback action to equal the voltage on the zener-diode reference source. As in ordinary power supplies, the electrolytic capacitors assist in ripple filtering and protect the regulator devices against high transient voltages. Observe that a regulated power supply has very considerable inherent filtering action, and that the ripple voltage is normally very small. However, some capacitive filter action is required between the rectifier(s) and the regulator. Also, the effective internal impedance of a regulated power supply is very low.

A series-regulating device may consist of a single very-high-power transistor or several power transistors may be connected in parallel, as shown in Fig. 12-15. In such a case, the base-current (control-current) demand may be greater than can be supplied by the error amplifier. To meet this requirement, a Darlington pair may be employed, as shown in Fig. 12-15B. In this circuit, transistor Q2 operates in the emitter-follower mode and drives the series-regulating transistor Q1. Observe that, due to the current gain provided by Q2, the control current required from the error amplifier is reduced by a factor equal to the beta value of the emitter-follower transistor Q2. For example, if Q2 has a beta value of 50, and the series-regulating transistor Q1 requires a

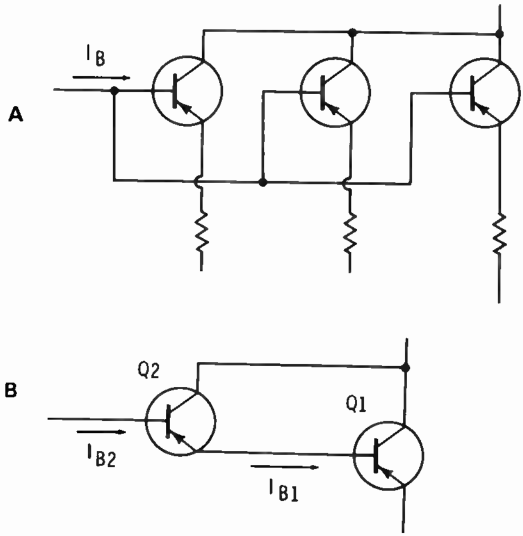


Fig. 12-15. High-power-regulating arrangements.

10-mA control current, the error amplifier must provide only 0.2 mA of control current.

A series-regulator arrangement does not have inherent overload protection, and it can be destroyed by a momentary short circuit across the output terminals unless suitable protective measures are provided. For example, an overcurrent-sensing circuit may be included, which automatically limits the value of output current. Of course, voltage regulation is absent past the current limiting point.

SHUNT-REGULATOR ARRANGEMENTS

Although shunt regulators often have comparatively simple circuitry, they are usually least efficient for voltage regulation. An advantage of a shunt-regulator configuration includes a shunt device and a reference-voltage element, as shown in Fig. 12-16A. Observe that the output voltage remains constant because the shunt-element current changes as the load current varies or as the

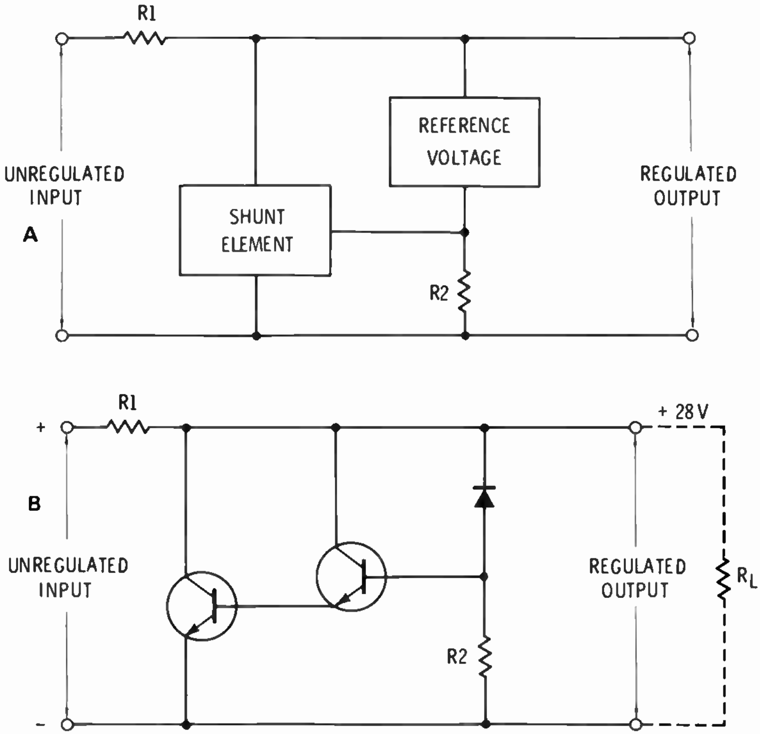


Fig. 12-16. Basic shunt-regulator arrangement.

input voltage changes. Any current change is reflected as a voltage change across R1, which is connected in series with the load.

Note that the shunt transistor connected in parallel with the load operates in the common-emitter configuration. For high-power applications, several transistors may be connected in parallel or in a Darlington configuration. A Darlington pair is utilized in the example of Fig. 12-16B. An arrangement such as the one shown in Fig. 12-17 provides very close regulation of the output voltage.

In some receivers, series-connected semiconductor diodes are used for high-voltage rectification, as shown in Fig. 12-18. Semiconductor diodes are also used instead of rectifier tubes in voltage-multiplier circuits. They provide simplicity and lower

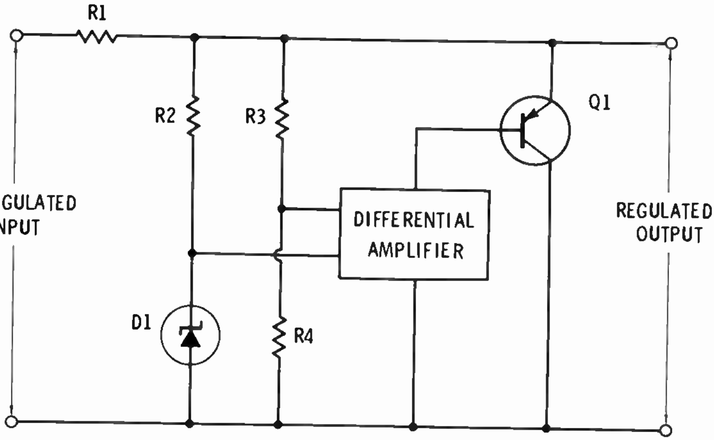


Fig. 12-17. Configuration that provides close regulation of the output voltage.

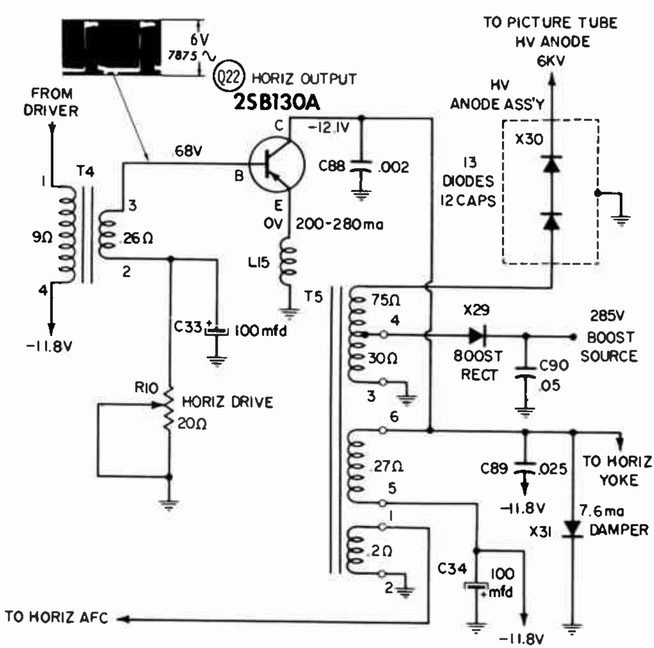


Fig. 12-18. High-voltage rectifier assembly using a stack of 13 semiconductor diodes.

manufacturing cost because no filament supply is required. Figure 12-19 shows basic troubleshooting procedures.

SUMMARY

Power supplies in television receivers are generally more complicated than those normally used in radio and other electronic equipment. A low-voltage, high-current supply must be used to feed video IF, sound amplifier, and other similar stages where applied potential will not exceed 450 volts. In addition a high-voltage, low-current system is needed to supply the accelerating anode potential for the picture tube.

The introduction of semiconductor rectifiers offered an opportunity to simplify and lighten receivers by eliminating the heavy and bulky power transformers. Some circuits have one disadvantage: The chassis is connected to one side of the power line, and so the user could receive a dangerous electrical shock between the chassis and any grounded metal object.

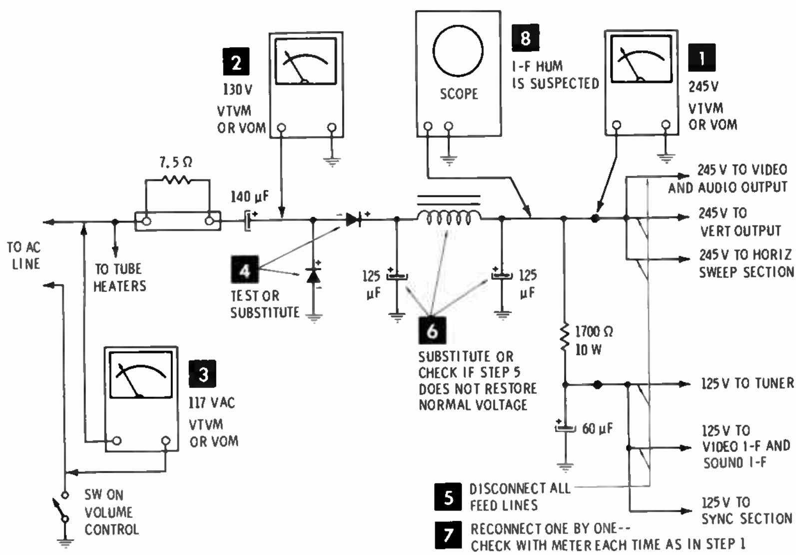


Fig. 12-19. Basic troubleshooting procedures for a semiconductor power supply.

The flyback system of obtaining high voltage is used in nearly all modern TV receivers. It uses a high-voltage pulse created in the output circuit of the horizontal amplifier during retrace. This high voltage is then fed to a rectifier, where it is rectified and filtered and becomes a high-anode potential for the picture tube.

REVIEW QUESTIONS

1. What are the advantages in using semiconductors in the power supply?
2. What can be used in a power supply to eliminate electrical shock?
3. How many different types of high-voltage power supplies have been used in television receivers? Name them.
4. What are the voltage and current requirements for low-voltage power supplies? High-voltage?
5. What is the approximate high-voltage potential in modern TV receivers?
6. What method is used in nearly all modern TV receivers to obtain high voltage?

CHAPTER 13

Sound IF Amplifiers and Audio Detectors

The sound IF system of the television receiver is similar to the IF system of an FM radio receiver. Two major differences from the standard FM receiver should be noted:

1. The intermediate frequency for FM receivers has been standardized at 10.7 MHz, whereas the sound IF for intercarrier television receivers has been standardized at 4.5 MHz. (This is the frequency difference between the video and sound carriers, and it is held constant at the transmitter.)
2. The deviation of the television sound carrier for maximum modulation has been established at 25 kHz (a total sweep of 50 kHz), whereas the maximum deviation for standard FM broadcasting has been set at 75 kHz (a maximum sweep of 150 kHz). Because a lower deviation is employed for television sound, a narrower passband can be used for the televi-

> sion sound IF system, and a shorter linear region can be used for the detector. The passband of a typical intercarrier sound IF amplifier is about 150 kHz, and the linear region of the detector usually does not exceed 100 kHz. A high-quality FM receiver might have an IF passband of 300 kHz and a linear range in the detector of as much as 2 MHz.

A typical intercarrier sound IF stage has a voltage gain of 100 times. If the stage is operated as a limiter, its gain is approximately five times. Note that the overall gain from the RF tuner to the FM sound detector is approximately the same as the overall gain from the RF tuner to the picture detector. In other words, the sound IF amplifier compensates for the reduced amplification of the sound signal through the video IF amplifier.

Unlike the video IF amplifier, automatic gain control is not used in the intercarrier sound IF amplifier; that is, the sound IF section operates at maximum gain regardless of the incoming-signal strength. A limiter stage operates as a peak clipper, and, in turn, little change in sound volume is normally observed from strong- to weak-station reception. However, the sound output may become slightly noisy, or "buzzy," if the incoming signal is very weak. Adequate sound output is normally obtained although the picture signal is so weak that the image is barely visible in the snow interference. Of course, in case of sound IF or FM detector malfunction, the situation may be reversed—little or no sound output may be present although the picture display is normal.

SOUND IF TAKEOFF

The takeoff point in an intercarrier receiver must follow the video detector. A sound detector requires a definite amount of signal to provide a noise-free signal. The amplification this signal receives is provided by the sound IF amplifier, the video amplifier, or combinations of both. The video IF amplifiers do not amplify the sound signal very much because the signal is attenuated in these stages.

The takeoff point for most modern receivers is at the video-detector output (Fig. 13-1). The 4.5-MHz signal is coupled through a small capacitor from the video-detector output to the sound IF amplifier input. In other receivers, the sound IF takeoff point is in the output circuit of the video amplifier to take advantage of the gain supplied by the video amplifier. Typical circuits are shown in Fig. 13-2.

Semiconductor intercarrier sound circuitry can be classified into transistor and integrated types. Figure 13-3 shows a typical transistor intercarrier sound-system configuration. In most transistor TV receivers, the 4.5-MHz intercarrier sound signal is taken from the video-driver stage and it is amplified in two sound IF stages. The 4.5-MHz sound IF amplifiers can be compared with video IF amplifiers, except that the former have narrower passbands. Triode transistors that require neutralization are commonly employed; for example, C64 and C66 are neutralizing capacitors.

Some transistor TV receivers utilize integrated sound circuitry, as shown in Fig. 13-4. An equivalent circuit of the IC unit is seen

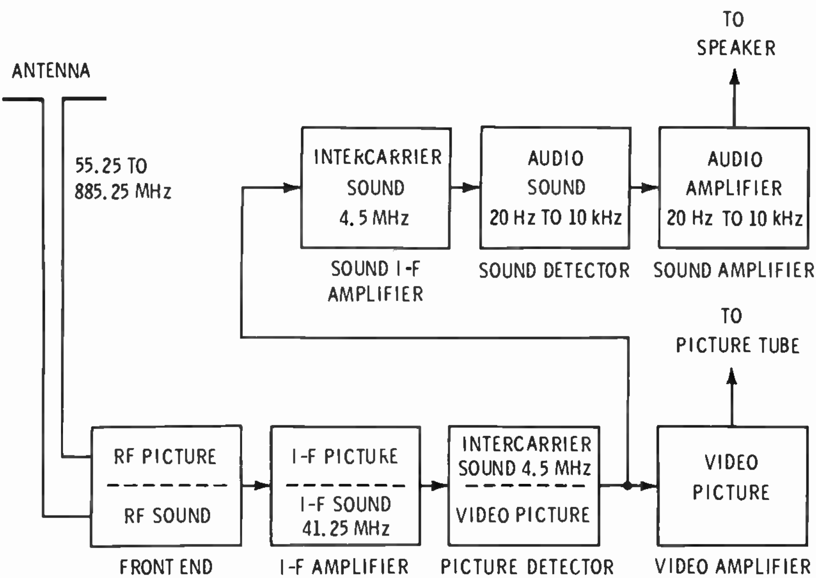


Fig. 13-1. Sound takeoff point after picture detector.

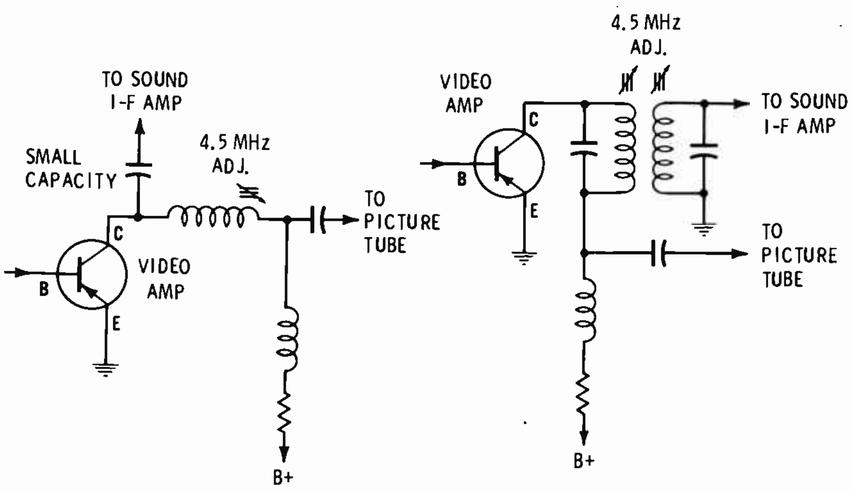


Fig. 13-2. Sound IF takeoff points in video amplifier.

in Fig. 13-5. This unit performs the functions of 26 conventional components. As is customary in most designs, the tuned circuitry is external to the IC unit. The tuned input circuit in Fig. 13-4 applies the 4.5-MHz signal to a three-stage, direct-coupled amplifier in the IC unit. Each differential stage is coupled by an emitter-follower to the next stage, as seen in Fig. 13-5.

Q1 and Q2 in Fig. 13-5 form the first differential-amplifier stage, coupled in turn by Q3 to Q4 and Q5, the second differential stage. Output from the second stage is coupled by Q6 to the third differential stage comprising Q7 and Q8. As shown in the block diagram, the intercarrier sound signal is transformer-coupled to the base of Q1; Q9 and Q10 operate in a voltage-regulator configuration. We recognize that although fewer tuned circuits are employed with an IC unit, more semiconductor devices are included.

Frequency modulation of a carrier wave is depicted in Fig. 13-6. In turn, a detector is required to discriminate between the deviations above and below the center frequency and convert these deviations into a signal voltage having an amplitude that varies at audio frequencies. Figure 13-7 shows an FM detector configuration that is called a *balanced phaseshift discriminator*. The mutually coupled tuned circuits in the primary and secon-

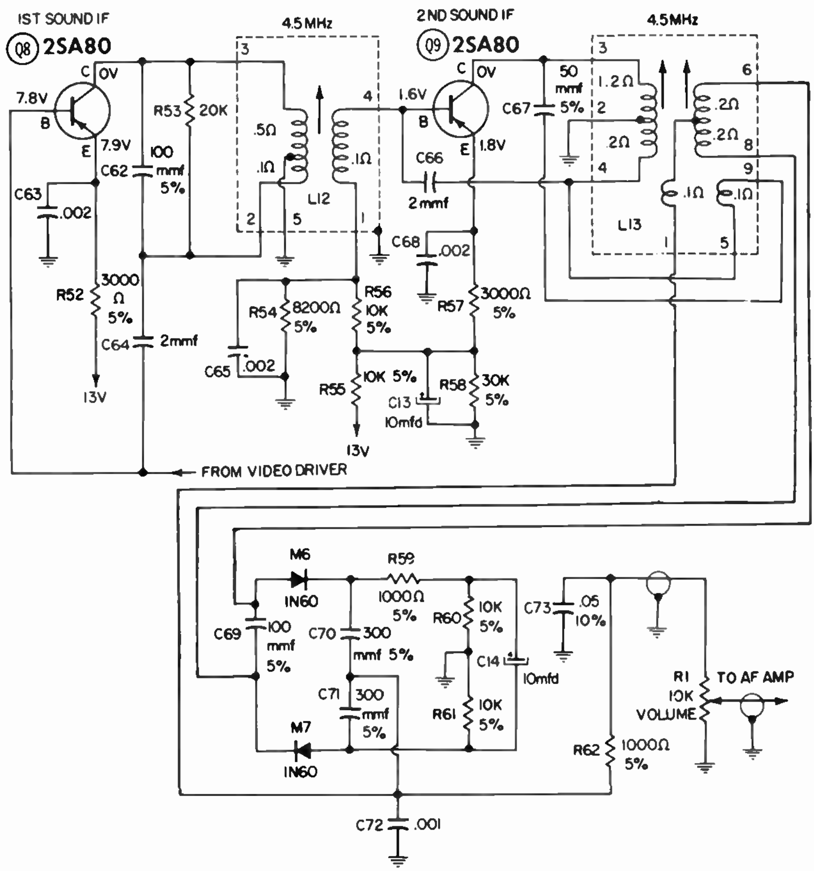


Fig. 13-3. Typical transistor sound IF configuration.

dary windings of transformer T are tuned to the center frequency of the intercarrier sound signal. Because a discriminator has very little ability to reject amplitude modulation (such as noise pulses), the last IF stage is operated as a limiter.

The effect of limiting action on the incoming intercarrier sound signal is depicted in Fig. 13-8. Because a discriminator circuit uses a push-pull rectifier arrangement, the diodes conduct on alternate half-cycles of the signal waveform and produce a plus-or-minus output signal. The phase characteristics of the tuned cir-

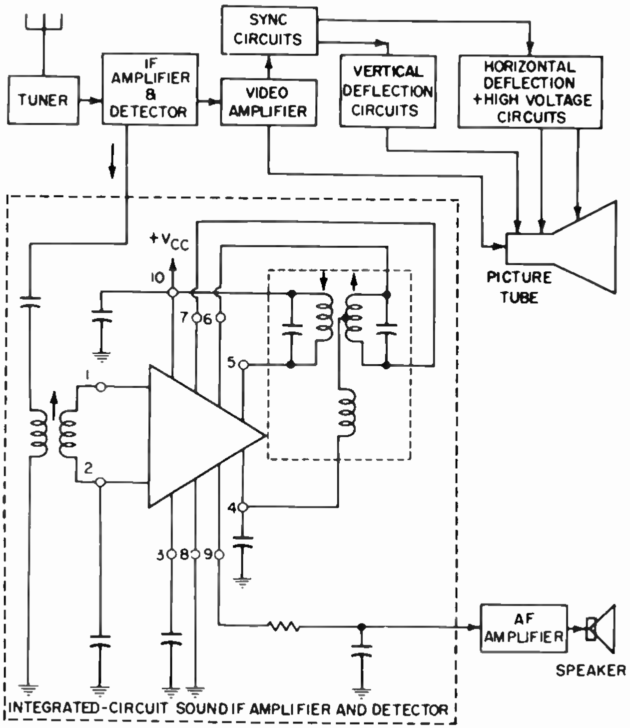


Fig. 13-4. Intercarrier sound system that uses an integrated circuit.

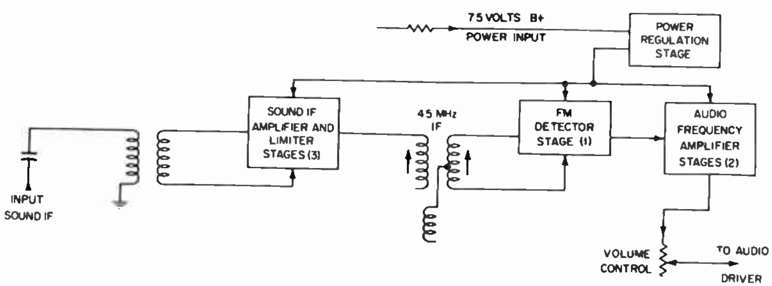
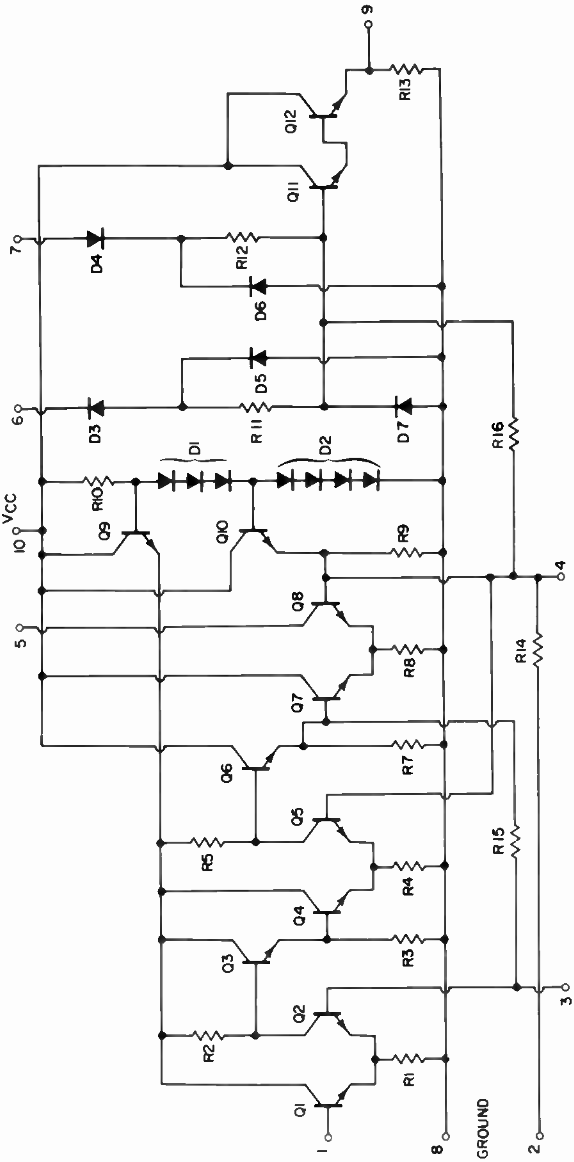


Fig. 13-5. Equivalent circuit of an integrated unit with



a block diagram showing stages contained.

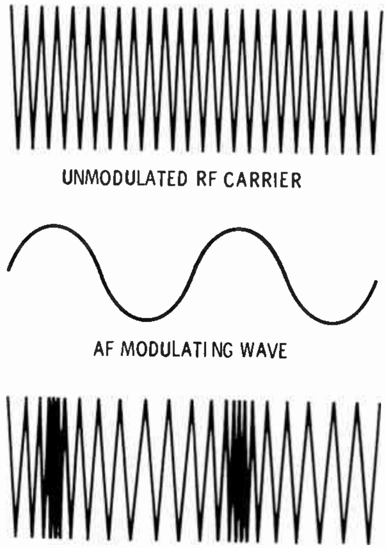


Fig. 13-6. Frequency modulator of a carrier wave.

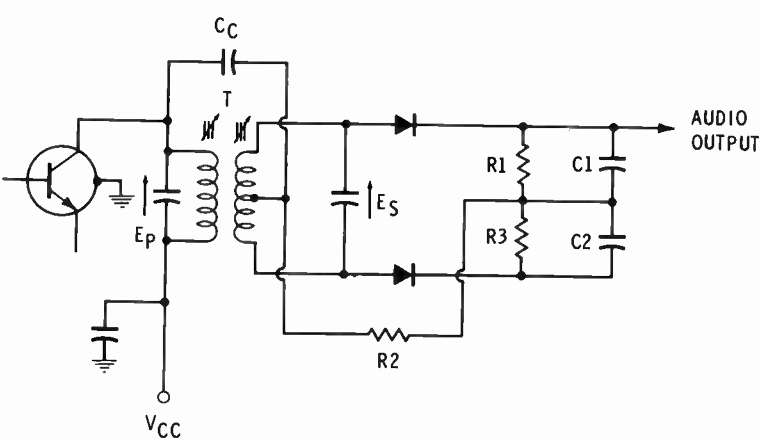


Fig. 13-7. Balanced phaseshift (Foster-Seeley) discriminator configuration.

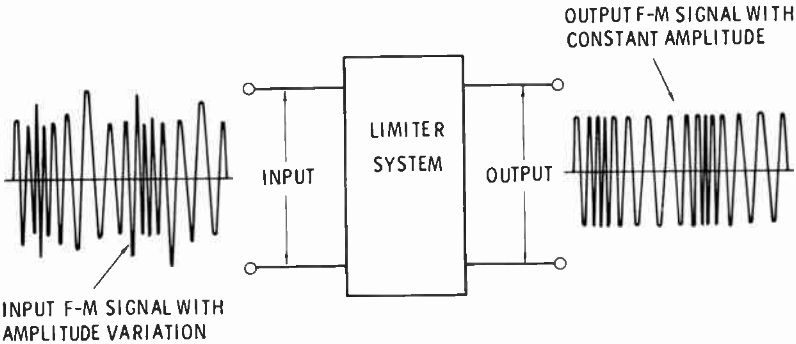


Fig. 13-8. Effect of limiting action on incoming intercarrier sound signal—an overdriven amplifier clips off the positive and negative peaks from the incoming signal.

cuits are such that a negative-output voltage is produced at frequencies below 4.5 MHz and a positive-output voltage is produced at frequencies above 4.5 MHz.

Next, consider the ratio-detector circuit shown in Fig. 13-9. This configuration has a general resemblance to a discriminator circuit, with an important difference: The rectifier diodes are polarized oppositely. As will be explained, this feature provides considerable self-limiting action in the FM detection process, and therefore receivers that use ratio detectors often do not operate the last IF stage as a limiter.

In a ratio detector, the two rectifier voltages are added alge-

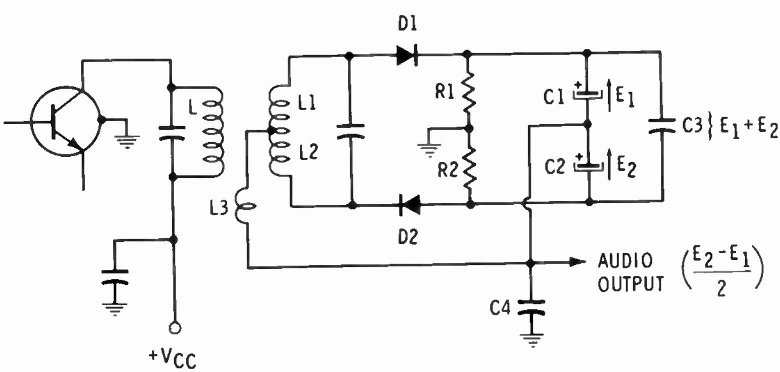


Fig. 13-9. Ratio-detector configuration.

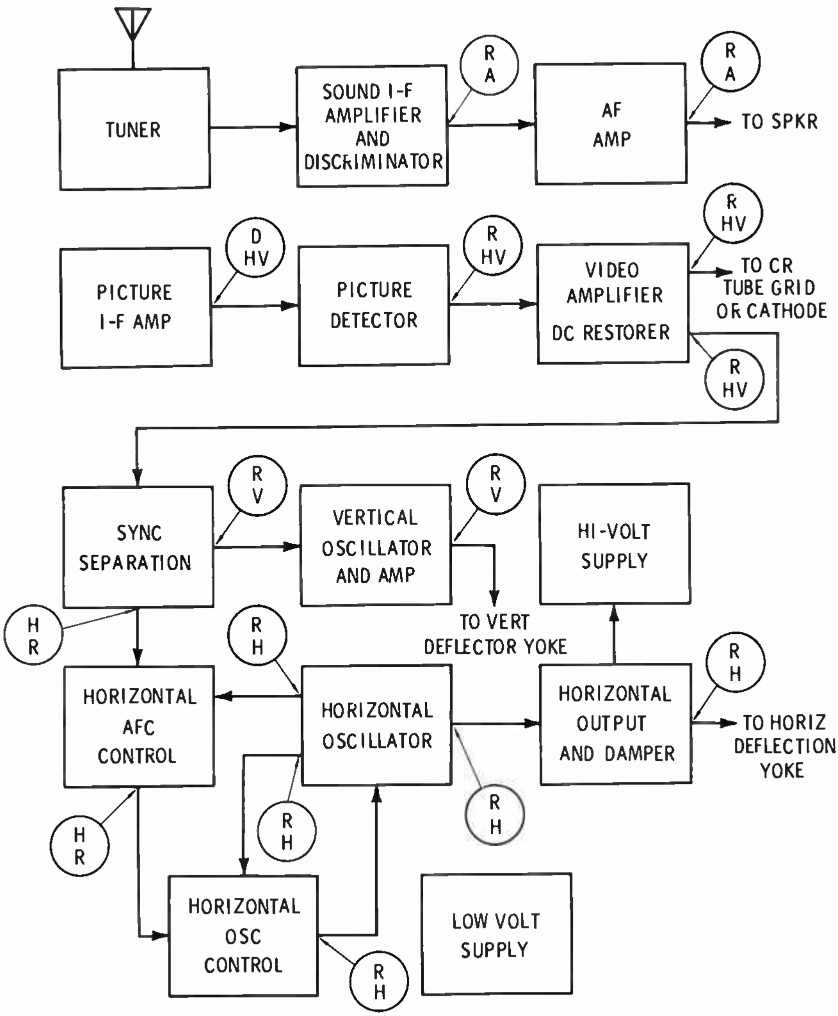
braically and the sum is held constant by a large electrolytic capacitor C3, which has a value of 5 μF in this example. It is this effectively constant charge on the electrolytic capacitor that rejects amplitude variations in the signal—the large capacitor tends to absorb any peaks or valleys that may be present in the intercarrier sound waveform.

Note that at the center frequency of 4.5 MHz, the voltages across C1 and C2 in Fig. 13-9 are equal and opposite, so that there is no output voltage. On the other hand, when the incoming signal swings below the center frequency, D2 conducts more than D1 and the output voltage swings negative; conversely, when the incoming signal swings above the center frequency, D1 conducts more than D2 and the output voltage swings positive. However, the voltage across C3 remains practically constant. It is helpful to note that the voltage across C3 tends to change somewhat from time to time, inasmuch as R1 and R2 function as bleeder resistors as well as load resistors. In practice, the change of voltage across C3 is more rapid for downward modulation of the incoming signal than for upward modulation.

Since sync-buzz pulses produce downward modulation of the intercarrier signal (in most cases), the ratio detector may not be able to completely reject high percentages of sync-buzz noise. Therefore, when this is a problem in receiver operation, the last IF stage is operated as a partial or complete limiter.

TROUBLESHOOTING

At this point, it is helpful to consider and summarize some basic troubleshooting principles. A simplified block diagram for a TV receiver is shown in Fig. 13-10, with basic oscilloscope test points indicated. If the sound IF amplifier and discriminator is checked with a sweep-frequency signal having a center frequency of 4.5 MHz, the output waveform from the discriminator normally appears as shown in Fig. 13-11. Note that this is an S curve, and that it is being "marked" at its center frequency of 4.5 MHz with an AM beat-marker signal. When alignment of any tuned circuits is required, the technician should consult the receiver service data and proceed accordingly.



PROBE	SWEEP FREQUENCY
R DIRECT D DEMODULATOR	H 7875 OR 15,750 Hz V 20, 30, OR 60 Hz A AUDIO TEST FREQUENCY

Fig. 13-10. Simplified block diagram of a TV receiver showing basic oscilloscope test points.

An RF signal generator and a VTVM are also basic troubleshooting instruments for sound IF and detector circuitry. Basic troubleshooting tests for sound IF and detector stages are depicted in Fig. 13-12.

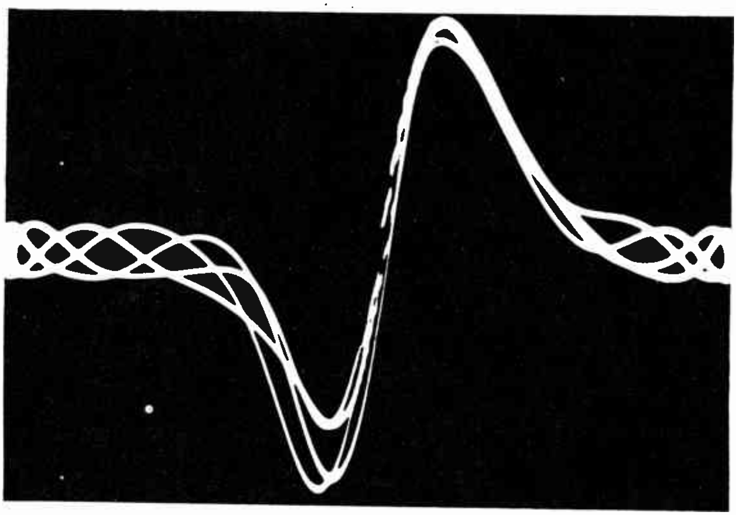


Fig. 13-11. Normal S curve for a discriminator with an AM center-frequency beat marker.

SUMMARY

The sound takeoff for modern intercarrier TV receivers must follow the video detector. The sound detector requires a definite amount of signal to provide a noise-free signal. The 4.5-MHz signal is coupled through a small capacitor from the video-detector output to the sound IF amplifier input. Sound takeoff point is generally in the output circuit of the video amplifier to take advantage of the gain supplied by the video-amplifier stage.

The sound IF system of the TV receiver is similar to the IF system of an FM radio receiver except the IF frequency for FM is at 10.7 MHz, whereas the sound IF for television receivers has

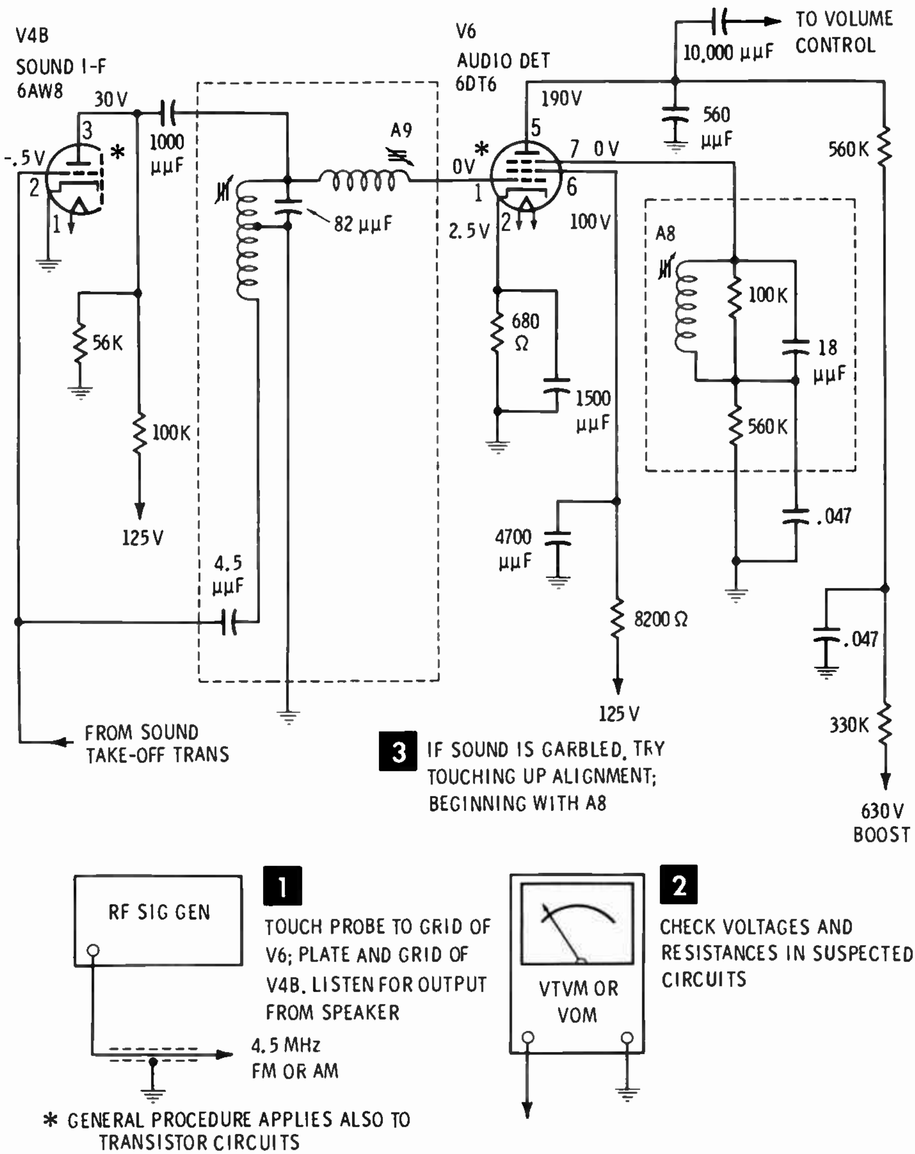


Fig. 13-12. Basic troubleshooting tests for sound IF and detector stages.

been standardized at 4.5 MHz. This is the frequency difference between the video and sound carriers and is held constant at the transmitter.

REVIEW QUESTIONS

1. What is the IF frequency for FM receivers? For television receivers?
2. What are the main differences between FM and television sound IF systems?
3. What part of the video IF amplifier is the sound takeoff section?
4. Name the basic demodulation circuits used in television receivers.

CHAPTER 14

Color Television

The development of color television was governed by two requirements: The color signal had to be inserted within the 6-MHz-channel bandwidth; and the color signal had to be compatible with the monochrome (black-and-white) television system. In other word, the signal must be such that it can be received on a monochrome receiver in black and white without any modification of the receiver. In addition, the part of the signal that conveys color must be transmitted in such a manner that it does not appreciably affect the quality or type of picture reproduced by the monochrome receiver tuned to the color signal.

The signal must represent the scene according to its color, and the colors must be transmitted in terms of the three chosen primaries: red, green, and blue. By some means, the three physical aspects of brightness, hue, and saturation must be conveyed by the signal for each color in the scene because the eye sees color in terms of these aspects. Figure 14-1 shows the basic plan of the color-TV system.

In order to make the color system compatible, the specifications of the standard monochrome signal had to be retained. This meant that such things as the channel width of 6 MHz, the aspect ratio of 3:4, the number of scanning lines per frame (525), the horizontal- and vertical-scanning rates (15,750 and 60 hertz, respectively), and the video bandwidth of 4.25 MHz had to remain the same within narrow tolerances. To these basic specifications, provisions had to be added to convey the color elements by means of a signal that will hereafter be known as the *chrominance signal.*

Fig. 14-1. Basic plan of the color-TV system.

Even if the same specifications were retained, the color system would not be compatible if the composite color signal did not contain a signal that would convey brightness. To satisfy this requirement, a signal that is representative of the brightness of the colors in the scene must be transmitted together with the chrominance signal. This brightness signal is very much the same as the video signal used in standard monochrome transmission, and it will be referred to hereafter as the *luminance signal.* It is transmitted by amplitude modulation of the picture carrier in such a manner that an increase in brightness corresponds to a decrease in the amplitude of the carrier envelope.

Putting a chrominance signal in the allotted channel of 6 MHz created a difficult problem since this chrominance signal had to be transmitted along with the luminance signal and had to be included without objectionable interference to the luminance signal. This was accomplished by proper placement of the chrominance signal within the band of video frequencies. The color-signal carrier has the relations shown in Fig. 14-2 to the picture- and sound-signal carriers.

The chrominance and luminance signals are included within the 4.25-MHz video band by an interleaving process. This pro-

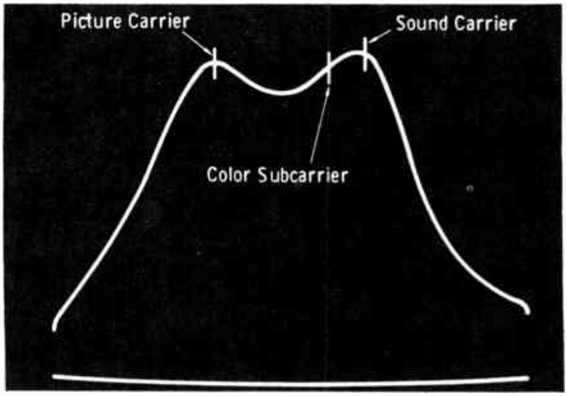


Fig. 14-2. RF frequency-response curve showing relations of color, sound, and picture carriers.

cess is possible because the energy of the luminance signal concentrates at specific intervals in the frequency spectrum. The spaces between these intervals are relatively void of energy, and the energy of the chrominance signal can be caused to concentrate in these spaces, as depicted in Fig. 14-3. The chrominance signal is conveyed by means of a subcarrier. The frequency of this subcarrier was chosen so that its energy would interleave with the energy of the luminance signal. The energy of each of these signals is conveyed by the video carrier. The subcarrier frequency is high enough in the video band that the subcarrier sidebands, when they are limited to a certain bandwidth, do not interfere with the reproduction of the luminance signal by a monochrome receiver.

The chrominance signal must convey energy that represents the primary colors. Color could be transmitted by three separate signals, each representing a primary color, but a channel width of at least 12.75 MHz would then be required. Since this would take away the idea of compatibility, color had to be represented in some other manner in order to utilize the standard 6-MHz-channel width.

Three signals—red, green, and blue—are obtained from the camera. Portions of these three signals are used to form the luminance signal, which leaves three signals that are referred to as

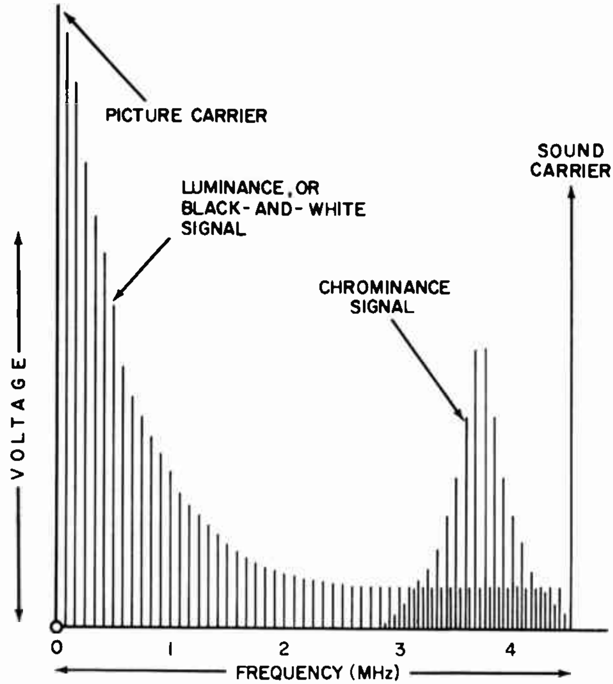


Fig. 14-3. Placement of the color signal.

color-difference signals. Two of these signals are proportionately mixed together to form two other signals that are used to modulate the chrominance subcarrier.

A method of modulation known as *divided-carrier modulation* may be employed in order to place two different signals upon the same carrier. The subcarrier is effectively split into two parts, and each portion of the subcarrier is modulated separately. Then the two portions are combined to form the resultant chrominance signal. The amplitude and phase of this signal vary in accordance with variations in the modulating signals. A change in amplitude of the chrominance signal represents a change in hue.

A reference signal of the same frequency as the subcarrier frequency is transmitted in the composite color signal. This reference signal, called the *color burst*, has a fixed phase angle and is employed by the color receiver in order to detect properly the colors represented by the chrominance signal. Figure 14-4 shows the appearance of the color burst. An expanded display of the color burst obtained with a triggered-sweep oscilloscope is shown in Fig. 14-5.

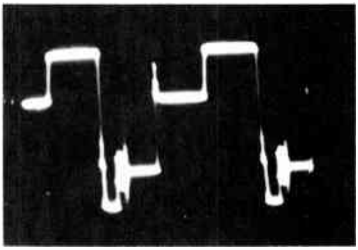


Fig. 14-4. Color burst is placed on the back porch of the horizontal sync pulse.

In the foregoing discussion, it has been stated that the composite color signal contains a luminance signal and a chrominance signal. A color-burst signal is also transmitted along with the conventional blanking and sweep-synchronizing signals. Let us now examine in greater detail the methods employed in making up the composite color signal.

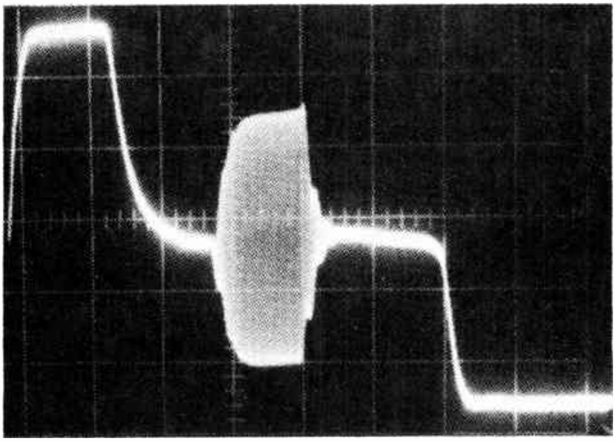


Fig. 14-5. Expanded display of the color burst as obtained with a triggered-sweep oscilloscope.

CHARACTERISTICS OF COLOR

In order to see, we must have a source of light, just as in the process of hearing, we must have a source of sound before we are able to hear. Obviously, if sound waves were not present, nothing would be heard. So, if a source of light were not present, nothing would be seen.

When we speak of light, we usually think of light coming from the sun or the light that is emitted from some artificial lighting source, such as electrical lighting. This type of light is referred to as *direct light*. Another type of light is *indirect*, or *reflected*, light, which is given off by an object when direct light strikes it. The difference between these two types of light is that the indirect light is dependent upon the direct light. When light is not shining upon an object, light will not be given off unless the object contains self-luminating properties.

Direct light falling upon an object is either absorbed or reflected. If all of the light is reflected, the object appears white. If the direct light is entirely absorbed, the object appears black. The larger the amount of light that is reflected by an object, the brighter the object will appear to the eye. In addition, the more intense the direct light source, the brighter the object will become. This can be demonstrated by casting a shadow upon a portion of an object and noting the difference in brightness of the two areas. The portion without a shadow will, of course, appear brighter.

Light is one of the many forms of *radiant energy*. Any energy that travels by wave motion is considered radiant energy. Classified in this group, along with light, are sound waves, x-rays, and radio waves. As shown in Fig. 14-6, light that is useful to the eye occupies only a small portion of the radiant-energy spectrum. Sound is located at the lower end of the spectrum, whereas cosmic rays are at the upper end; light falls just beyond the middle of the spectrum. Along the top of the spectrum shown in Fig. 14-6 is the frequency scale, and along the bottom is the angstrom-unit scale (10^{-8} cm). Wavelengths in the region of light may be designated in microns (1 micron = 10^{-4} centimeters). These units are also shown along the bottom of the spectrum in Fig. 14-6. Light is

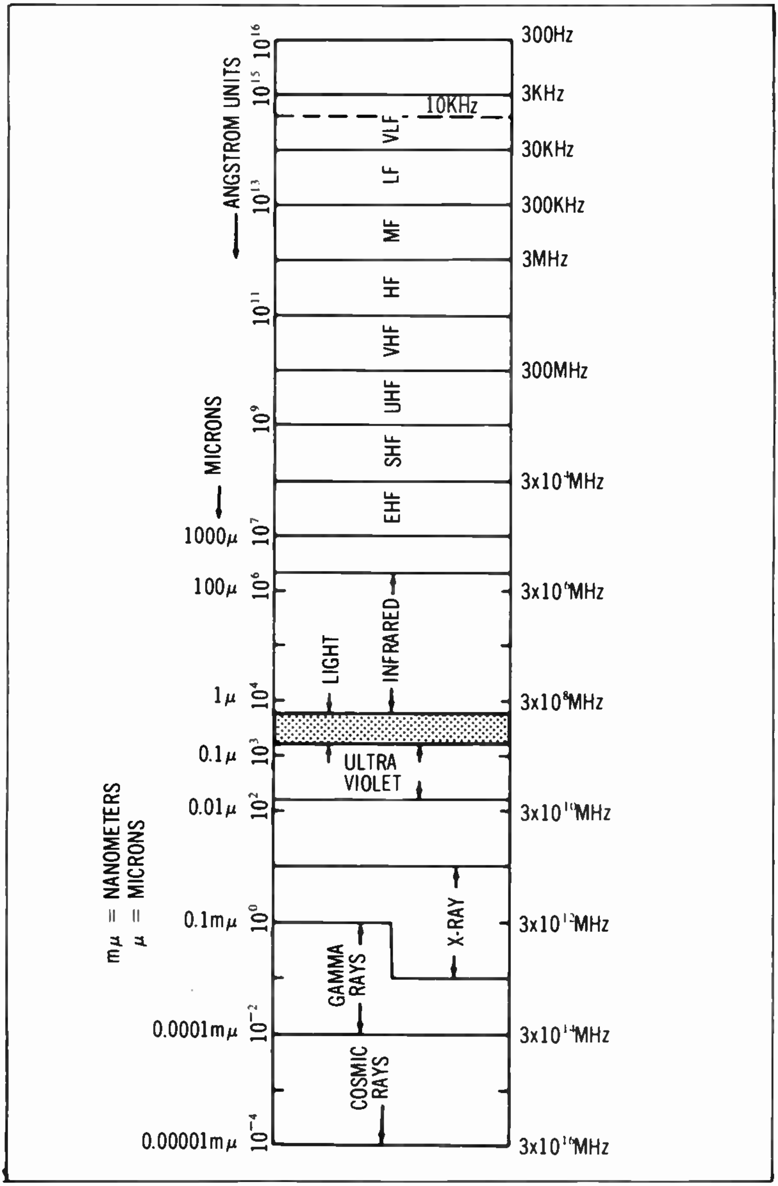


Fig. 14-6. Radiant-energy spectrum.

made up of that portion of the spectrum between 400 and 700 nanometers (nm).

When all wavelengths of the light spectrum from 400 to 700 nm are presented to the eye in nearly equal proportions, white light is seen. This white light is made of various wavelengths that are representative of different colors. This composition can be shown by passing light through a prism, as shown in Fig. 14-7.

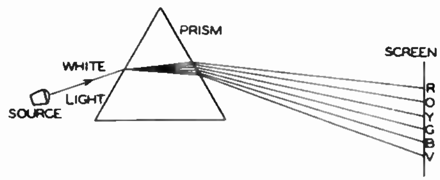


Fig. 14-7. White light dispersed by a prism.

The light spectrum is broken up into its constituent wavelengths, with each representing a different color. The ability to disperse the light by a prism stems from the fact that light of shorter wavelengths travels slower through glass than does light of longer wavelengths. Figure 14-8 shows the relationship of wavelengths

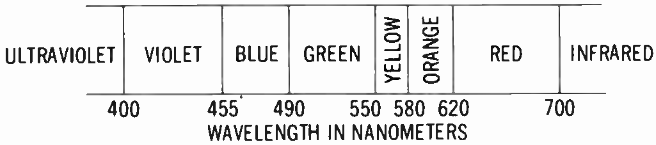


Fig. 14-8. Relationship between colors and wavelengths in the light spectrum.

and the colors of the light spectrum. The spectrum ranges from violet on the lower end to red on the upper end. In between fall blue, green, yellow, and orange. A total of six distinct colors is visible when passing light through a prism. Since the colors of the spectrum pass gradually from one to the other, the theoretical number of colors becomes infinite. It has been determined that about 125 colors can be identified over the visible gamut.

Three color attributes are used to describe any one color or differentiate between several colors: (1) hue, (2) saturation, and

(3) brightness. Hue is a quality used to identify any color under consideration, such as red, blue, or yellow. Saturation is a measure of the absence of dilution by white light and can be expressed with terms such as rich, deep, vivid, or pure. Brightness defines the amount of light energy contained within a given color and can be expressed with terms such as bright, dark, or dim.

We might consider an analogy between a color and a radiated radio wave. Hue, which defines the wavelength of the color, would be synonymous with frequency, which defines the wavelength of the radio wave. Saturation, which defines the purity of the color, would be synonymous with the signal-to-noise ratio, which defines the purity of the radio wave. Brightness, which is governed by the amount of energy in the color, would be synonymous with amplitude, which defines the amount of energy in the radio wave.

Brightness is a characteristic of both white light and color, whereas hue and saturation are characteristic of color only. Saturation and brightness are often visualized as identical or interrelated qualities of color, whereas they should be considered as separate qualities. It is possible to vary either one of the qualities without changing the other.

In nature, however, a change in saturation is usually accompanied by a change in brightness, which is exemplified by the fact that a pastel color generally appears brighter than a saturated color of the same hue when they are directly lighted by the same source. By changing the lighting on the pastel color (such as by placing it in a shadow), one can decrease the brightness of the pastel color; and it is conceivable that both colors can be made to have the same brightness. Thus, two colors of the same hue but of different saturation can have equal brightness levels.

Any given color within limitations can be reproduced or matched by mixing three primary colors. The additive process of color mixing used in color television employs colored lights for the production of colors. The colors in the additive process do not depend upon an incident light source. Self-luminous properties are characteristic of the additive colors. Phosphorescent signs that glow in the dark are good examples of this process. Cathode-ray tubes contain self-luminance properties, and so it is only logical that the additive process would be employed in color television.

The three primaries for the additive process of color mixing are red, green, and blue. Two requirements for the primary colors are that each primary must be different, and that the combination of any two primaries must not be capable of producing the third. Red, green, and blue were chosen for the additive primaries because they fulfilled these requirements and because it was determined that the greatest number of colors could be matched by the combination of these three colors.

The basic principle of the color-TV system is shown in Fig. 14-9. When the red camera is energized at the transmitter, the red gun in the color picture tube at the receiver is energized. Similarly, a signal from the blue camera results in an output from the blue gun, and a signal from the green camera results in an output from the green gun. Since three kinds of signals must be transmitted in a channel that normally accommodates only one signal, a multiplexing, or encoding, method of transmission must be used. This method involves modulating one carrier with two signals, as explained next.

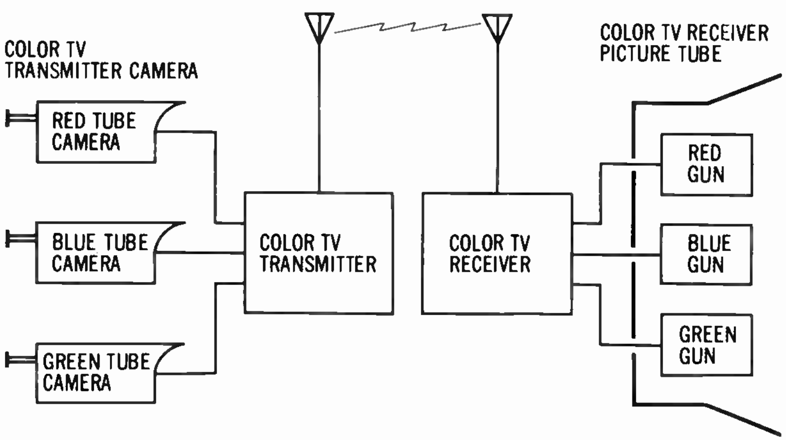


Fig. 14-9. Basic principle of the color-TV system.

DIVIDED-CARRIER MODULATION

It has been pointed out that, for purposes of color transmission, a chrominance signal is required; moreover, the chrominance signal must represent two color signals (saturation and hue) separable from each other. One subcarrier at a frequency of 3.579545 MHz above the picture carrier is available to convey both color signals. Consequently, some method of modulating one carrier with two signals must be utilized at the transmitter.

As can be seen in Fig. 14-10, a fundamental block diagram shows the manner in which one carrier may be modulated by two signals. A subcarrier generator produces a sine wave of constant frequency and amplitude. This subcarrier is then applied to two doubly-balanced modulator circuits, represented by blocks A and B. The subcarrier coupled to the modulator in block B has been subjected to a 90° phaseshift. One of the two modulating signals is applied to modulator A, and the other is applied to modulator B.

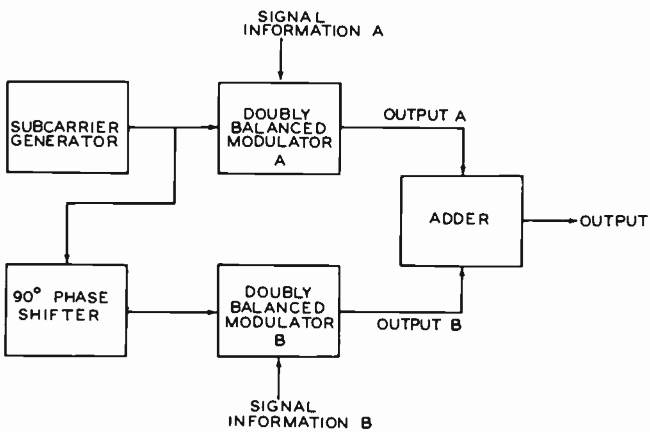


Fig. 14-10. Block diagram of divided-carrier systems of modulation.

In Fig. 14-10, there are two blocks representing doubly-balanced modulators. The modulator in block B operates in the same manner as the one in block A, with the exception that the subcarrier input is delayed 90°. This delay causes the output of modulator B to be displaced 90° in phase with reference to the output of modulator A. In this respect, it should be remembered that the output of modulator B can either lead or lag that of modulator A by 90°, depending upon the polarity of the modulating signal introduced into each balanced modulator circuit.

The voltages from the outputs of modulators A and B are combined in the adder stage. The output of this stage is a single waveform, which varies in amplitude and phase in accordance with the amplitude and phase of each of the two signals introduced to modulators A and B. Thus, two modulating signals are impressed upon a single subcarrier, and these two signals can be recovered by reversing the modulation process at the receiving end.

COLOR SYNCHRONIZATION

The chrominance signal changes phase with every change in the hue of the color it represents, and the phase difference between the chrominance signal and the output of the subcarrier generator identifies the particular hue at that instant. When the chrominance signal reaches the receiver, the receiver must have some means of comparing the phase of the signal with a fixed reference phase identical to that of the subcarrier generator at the transmitter. This reference phase is provided in the receiver by a local oscillator that is synchronized with the subcarrier generator by means of a color-burst signal transmitted during the horizontal-blanking period. The color burst consists of a minimum of 8 hertz at 3.579545 MHz.

As shown in Fig. 14-11, the color burst is place on the back porch of the horizontal-blanking pedestal. When located at this point the burst will not affect the operation of the horizontal-oscillator circuits because the horizontal systems used in existing receivers are designed to be immune to any noise or pulse for a short time after they have been triggered. (Remember, the horizontal oscillator will have been triggered at the start of the horizontal-sync pulse.) Since the average voltage of the color burst is the same as the voltage of the blanking level, the burst signal will not produce spurious light on the picture tube during the retrace period.

A color receiver is designed to extract the color burst from the transmitted signal. This reference signal is used to synchronize the color section of the receiver in much the same manner as the horizontal and vertical pulses are used to synchronize the

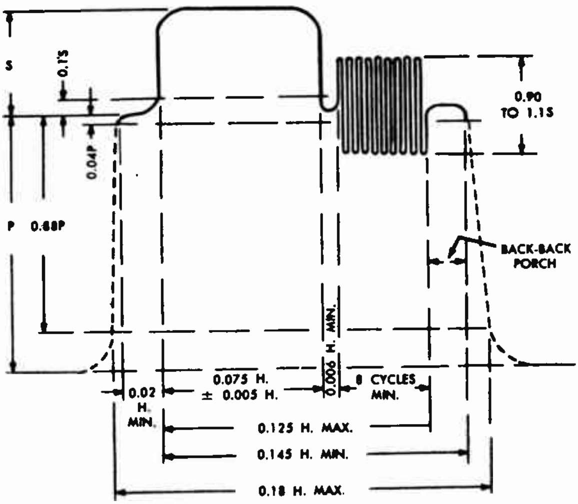


Fig. 14-11. Specifications for the color burst.

horizontal- and vertical-sweep sections. If the color burst is attenuated, the receiver is likely to loose color-sync lock (see Fig. 14-12).

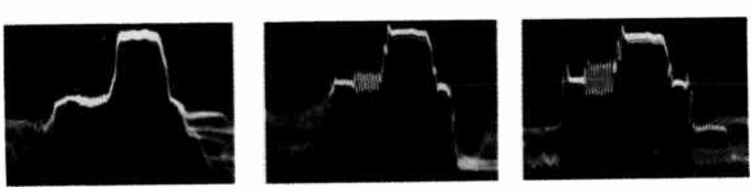


Fig. 14-12. Progressive attenuation of the color burst.

COLOR SIGNAL

As shown previously, the color-picture signal consists of two separate signals: luminance signal and chrominance signal. We shall now discuss the makeup of these two signals at the transmitter.

Shown in Fig. 14-13 is a drawing of the basic components of a tricolor camera that employs three camera tubes and two dichroic mirrors for the separation of light. Regular image orthicons may be used in this camera; however, newer tubes that have a response to light frequencies more similar to the human eye are also used. One of the camera tubes receives only the light frequencies corresponding to the color red and is called the *red camera tube*. Another tube receives only the light frequencies corresponding to the color blue and is called the *blue camera tube*. The third tube receives only light frequencies corresponding to the color green and is called the *green camera tube*.

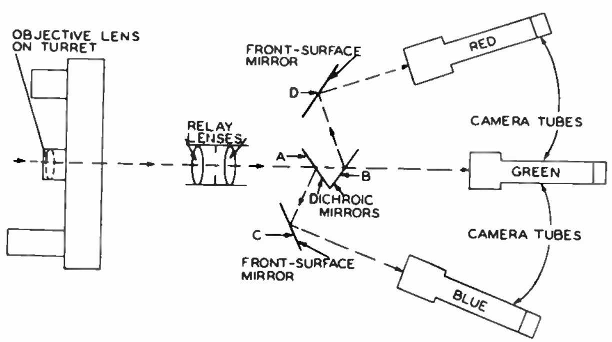


Fig. 14-13. Basic components of a tri-color camera.

To illustrate the operation, let us assume that the color camera is focused on a color scene. The light is broken up in the following manner: All the light frequencies pass through the objective lens, which is mounted on the turret, and through a pair of relay lenses. Then the light is affected by the dichroic mirrors. This type of mirror permits all the light frequencies of the spectrum to pass except those of the primary color which it is designed to reflect. By the use of this type of mirror, white light can be separated into the light frequencies of the three primary colors: red, green, and blue. This principle is depicted in Fig. 14-14.

Through correct placement, only two dichroic mirrors are needed in the color camera. The blue dichroic mirror is positioned at a point indicated by A in Fig. 14-13. When light arrives at this point, all the light frequencies except those representing the color blue are passed through the mirror. The frequencies representing the blue portion of the spectrum are reflected. The tilt angle of the mirror at point A is such that the mirror directs the blue light to a front-surface mirror at point C. Then the blue light is reflected onto the face of the blue camera tube.

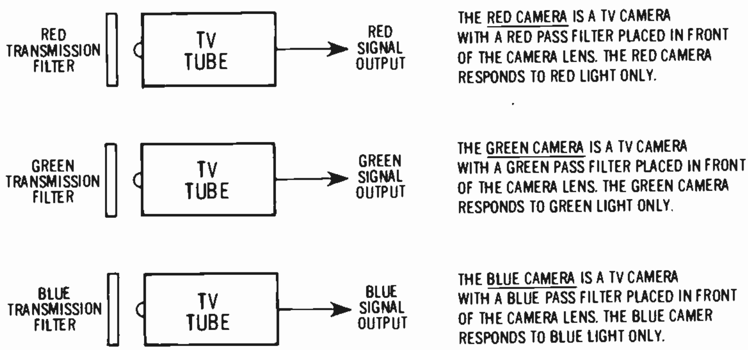


Fig. 14-14. Color filters permit only the primary colors to enter the color camera.

The light passed by the dichroic mirror at point A goes on to the red dichroic mirror, which is positioned at point B (Fig. 14-13). This mirror is designed to pass all the light frequencies except those which represent red. The red light is reflected to a front-surface mirror at point D, where it is again reflected so that it falls on the face of the red camera tube.

Both the blue and the red portions of the incoming light frequencies have been removed, and only the green portion remains, which is allowed to fall directly on the green camera tube. In this manner, the light is broken up into the three primary colors.

At the output of the color camera, there are three voltages that are representative of the three colors. From these voltages, the luminance and chrominance signals are formed. Figure 14-15 shows the plan of a basic color-TV transmitter.

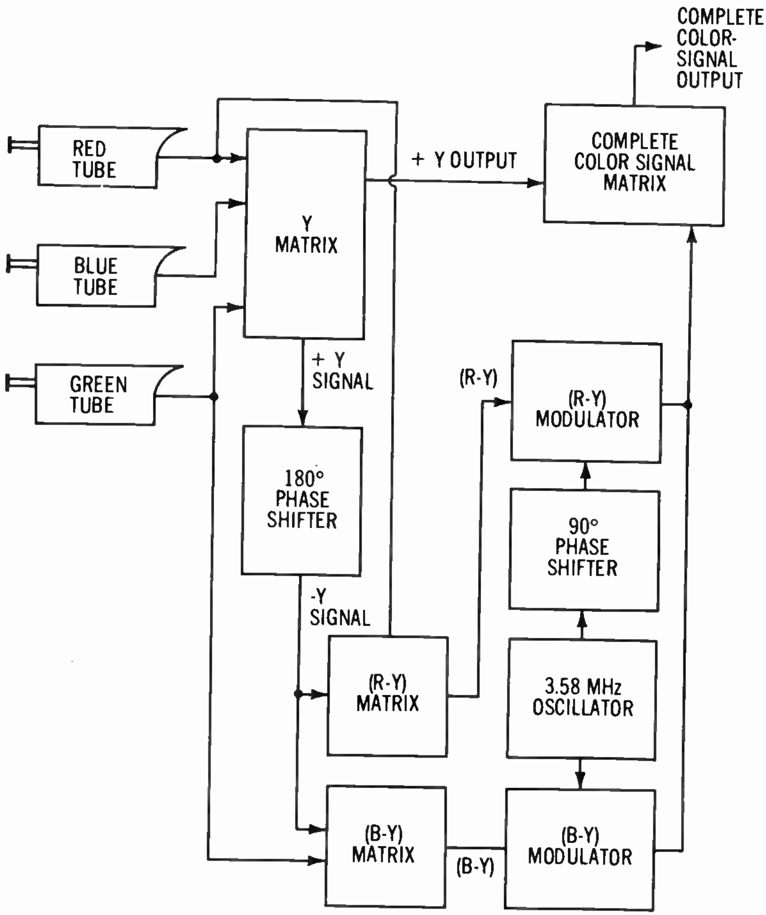


Fig. 14-15. Plan of a basic color-TV transmitter.

LUMINANCE SIGNAL

The luminance signal is the portion of the color-picture signal utilized by monochrome receivers. For this reason, the luminance signal must represent the scene only according to its brightness. It is very similar to the video signal specified for standard monochrome transmission.

The human eye does not see all colors equally bright. The specifications for the luminance signal take into consideration the sensitivity of the eye to light frequencies. Definite proportions of each of the color signals from the color camera are used to form the luminance signal. These proportions are: 59 percent of the green signal, 30 percent of the red signal, and 11 percent of the blue signal. Figure 14-16 provides a visualization of these facts.

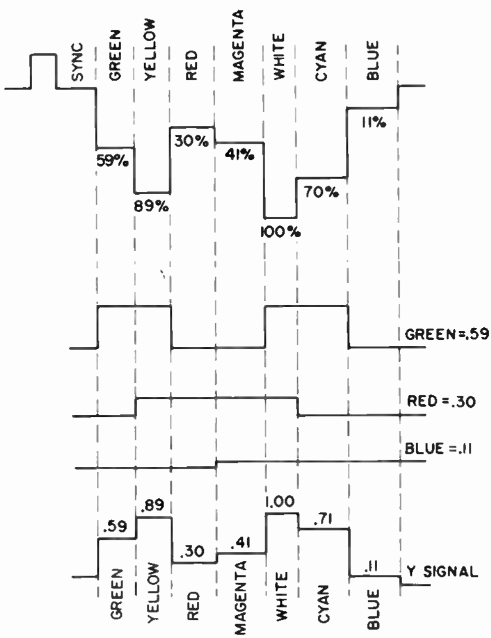


Fig. 14-16. Y component of the color-TV signal.

If an all-white portion of a scene is being scanned at the camera, the luminance signal will contain these proportions of the three color signals. The luminance signal is commonly called the Y signal. The proportions of the red, green, and blue signals do not change when brightness changes; only the amplitude of the Y signal changes. Figure 14-17 shows a display of the Y signal on an oscilloscope screen.

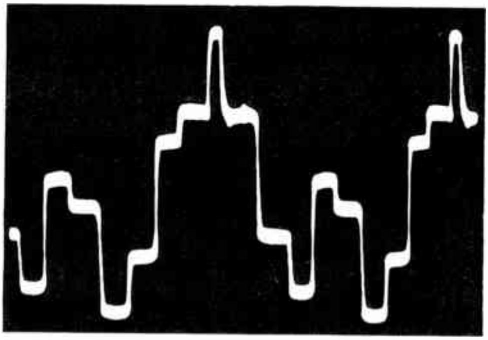


Fig. 14-17. Display of the Y signal on an oscilloscope screen.

CHROMINANCE SIGNAL

The chrominance signal must represent only the colors of a scene; therefore, the luminance signal is subtracted from each of the three output signals of the color camera. This results in three signals, which represent red minus luminance, green minus luminance, and blue minus luminance. These signals are denoted as the color-difference signals. When an all-white scene is being scanned, the color-difference signals are equal to zero so that no color information is transmitted; only luminance information is transmitted, as shown in Fig. 14-18. A display of a color-bar signal on an oscilloscope screen is shown in Fig. 14-19.

COLOR-RECEIVER CIRCUITS

A complete block diagram of a color receiver is shown in Fig. 14-20. The shaded blocks represent sections that are similar to those used in monochrome receivers. The unshaded blocks represent the new sections used only in color receivers.

From the block diagram in Fig. 14-20, it can be seen that the tuner, the video IF, and the sound IF sections of a color receiver

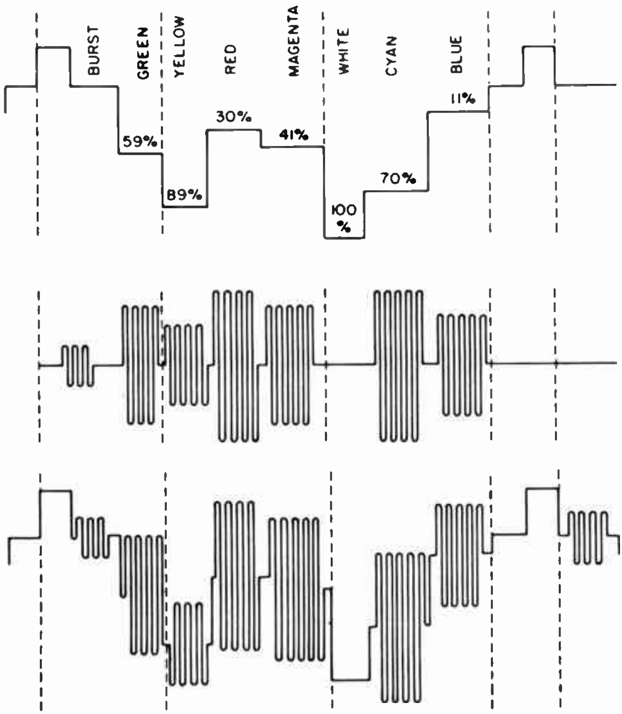


Fig. 14-18. Elements of TV color bars.

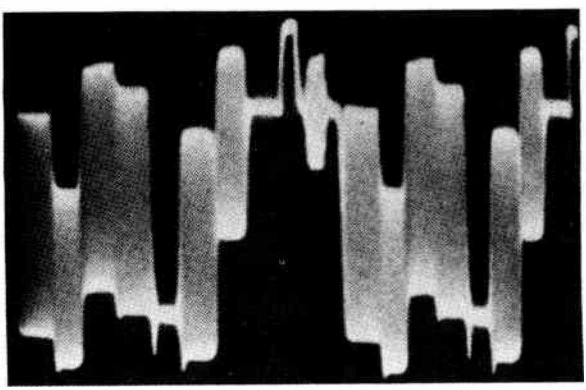


Fig. 14-19. Display of a color-bar signal on an oscilloscope screen.

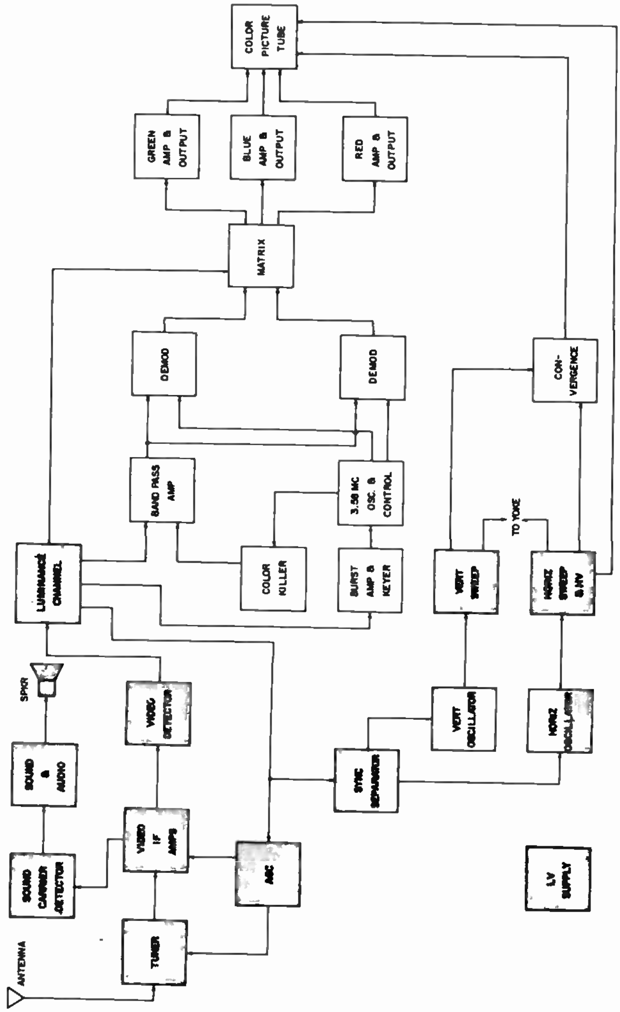


Fig. 14-20. Complete block diagram of a color receiver. Sections similar to those used in monochrome receivers are shaded; sections used only in color receivers are unshaded.

are not too different from those of a monochrome receiver. With the exception of the block representing the sound detector, this drawing could represent the RF, IF, and sound circuits of any television receiver; nevertheless, the following discussions about circuits show some important differences.

RF Tuner

The function of the RF tuner in a color receiver is the same as in monochrome receivers, and the physical appearance of the unit has not changed. However, the RF circuits in a color receiver must have one feature that is not necessarily required of the RF circuits in monochrome receivers. This concerns the allowable tolerance in the frequency response of the tuner.

It has been pointed out previously that a color picture signal is comprised of both a luminance and chrominance signal. As seen in Fig. 14-21, the bandwidth of this signal extends from 0.75 MHz below to 4.2 MHz above the picture carrier and falls to zero at 1.25 MHz below and at slightly less than 4.5 MHz above.

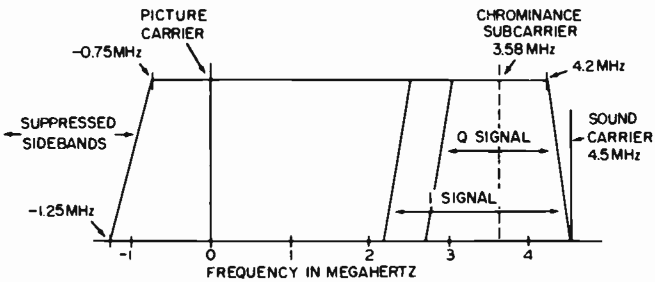


Fig. 14-21. Frequency distribution of the color picture signal.

If a tuner designed for a monochrome receiver were to be used in a color receiver, nonuniform amplification of frequencies might result and cause poor color reception. Although a tilt or sag in the response of the RF tuner might be compensated for in the IF amplifier section, it is necessary to provide uniform bandpass characteristics in the tuner for proper reception of color telecasts on all channels. An RF circuit that has a frequency response similar to that shown in Fig. 14-22 would produce excellent results in a color receiver.

A defective tuner that attenuates high frequencies might continue to provide satisfactory results during monochrome transmission; however, such a tuner would very probably cause poor reception during color transmission. Such a condition would obviously result in a complaint. When the tuner in a color receiver is serviced, particularly during alignment, the bandpass requirement of the tuner must be kept in mind. Many of the compromises that are in common practice in servicing tuners for monochrome receivers cannot be made in tuners for color receivers.

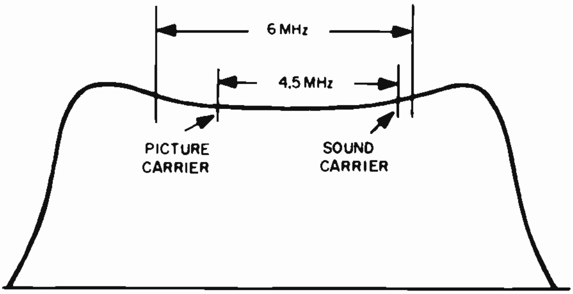


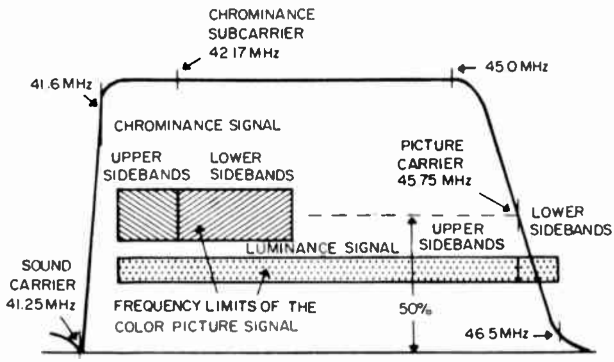
Fig. 14-22. Ideal frequency response of tuner used in color receiver.

Video IF Amplifiers and Video Detector

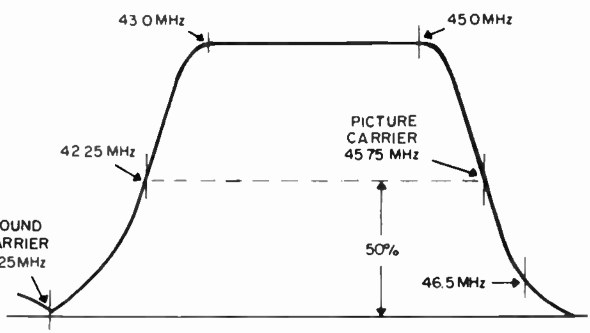
Although the bandpass characteristics of the video IF section are more restrictive in a color receiver, the function is essentially the same as in monochrome receivers. Before examining any circuits, let us consider what is required of the video IF section.

First, the purpose of this section is to provide amplification and selectivity to a specific band of frequencies. This band should extend from 0.75 MHz below to around 4.2 MHz above the IF picture carrier in order to include both the luminance and the chrominance signals. Ordinarily, four or five stages are needed for this function. The video IF strip should also attenuate the sound IF carrier much more severely than is common in monochrome receivers. An interference pattern will appear on the screen if the sound carrier and color subcarrier are allowed to beat together.

A curve illustrative of good overall frequency response through the RF and IF sections of a color receiver can be seen in Fig. 14-23A. Compare this curve to the one in Fig 14-23B, which is representative of the overall frequency response of late-model monochrome receivers. It can be noted particularly that the response of the color receiver is very critical in the region of the



(A) Color receiver.



(B) Late-model monochrome receiver.

Fig. 14-23. RF and IF frequency-response curves.

sound carrier where the slope of the curve is very steep. Frequencies only 0.35 MHz away from the maximum attenuation point at the sound-carrier frequency are provided with at least 90 percent amplification. The reason for this is that the upper sidebands of the chrominance subcarrier extend to this portion of the frequency curve.

For example, the frequency limits of the color-picture signal have been superimposed on the response curve of Fig. 14-23A. Although the frequency response indicated by the curve in Fig. 14-23B would produce good results during a monochrome transmission, it would severely attenuate the chrominance signal during color transmission. This loss of chrominance would result in poor color reproduction or a complete loss of color.

The video detector demodulates the IF signal so that the luminance, chrominance, and sync signals are available at the output of the detector circuit. A crystal diode with an IF filter is commonly used for this purpose. The video detector in a color receiver may employ a sound-carrier trap in its input. This trap attenuates the sound carrier and ensures against the development of an undesirable 920-kHz beat frequency, which is the frequency difference between the sound carrier and the color subcarrier. When the sound carrier is attenuated in this manner, the sound takeoff point is located ahead of the video detector.

A basic IF amplifier configuration is shown in Fig. 14-24. The third IF transistor operates at higher power than the other two transistors because the video detector requires appreciable power input. Transistor Q25 operates with a collector voltage of 15 volts and an emitter current of 15 mA. The collector-load impedance is about 1,000 ohms; however, T8 provides some stepup voltage transformation for the video detector. The power gain of this stage is about 18 db.

The first stage in Fig. 14-24 operates with a collector voltage of 15 volts and an emitter current of 4 mA. Q27 utilizes reverse AGC. The minimum collector current of Q27 under strong-signal conditions is about 50 μA. Q27 has a dynamic range of 40 db. Diode D12 is a clamp diode that becomes reverse-biased to prevent Q27 from being completely cut off at high AGC bias. Q27 is neutralized by the 1.5-pF capacitor connected from its base to T6.

Two traps are connected into the input circuit of Q27. The first trap is an inductively coupled trap, and the second is a bridge-T configuration. These are the accompanying sound and adjacent sound traps, respectively. The collector load for Q27 is a simple resonant circuit, with a tap to provide an out-of-phase neutralizing signal. Q26 is base-driven via capacitance coupling. This second IF stage is not AGC-controlled and operates continuously at maximum gain. The basic bias circuit for Q26 also provides some negative feedback to obtain a properly shaped response curve. The collector load for Q26 is a tuned bifilar transformer.

The third stage is neutralized by a 1.5-pF capacitor from the

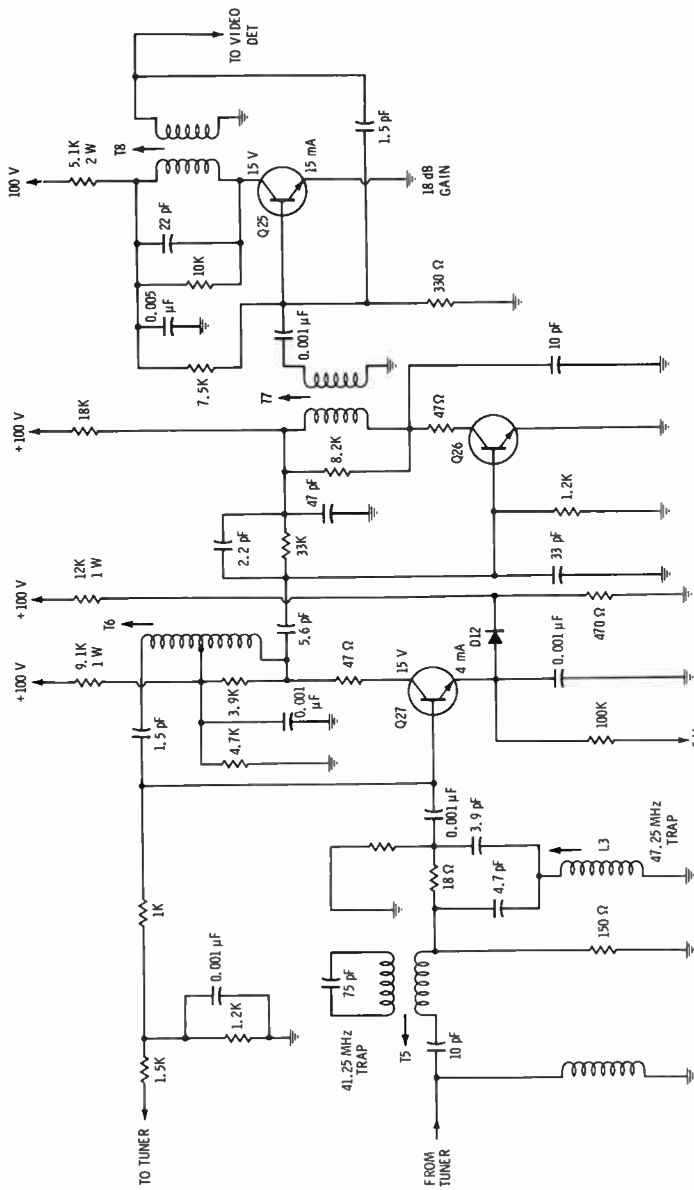


Fig. 14-24. Typical video-IF-amplifier configuration.

base of Q25 to the secondary of the collector-output transformer. A 0.005-μF capacitor is connected in the base bias network to prevent signal feedback from collector to base. This stage is not AGC-controlled and operates continuously at maximum gain. All of the collector loads are shunted by resistance to obtain proper bandwidth.

Sound IF and Audio Sections

With the exception of the separate sound IF detector, the sound IF and audio sections of color receivers follow conventional monochrome design. The reader who knows the theory of intercarrier operation should have little difficulty in understanding and working with these sections in color receivers.

It has been mentioned that the sound IF carrier is severely attenuated in the video IF strip; consequently, the output of the video detector contains virtually no 4.5-MHz beat signal. The sound signal must be obtained from a point ahead of the video detector. This takeoff point is usually the output of the final video IF amplifier. The signals available at this point are in the IF range, and in order to obtain the 43.5-MHz sound signal, a detector is necessary.

Video Amplifier

The main function of the video amplifier, often called the *luminance channel*, is to amplify the luminance portion of the video signal. This signal is comparable to a monochrome signal in that it represents the brightness variations of the image. From this standpoint, the function of the luminance channel can be compared with that of the video amplifier in a monochrome receiver. The luminance channel may use two or three stages so that the desired brightness signal may be obtained.

A secondary function of the luminance channel is to introduce a specific time delay in the brightness signal, which is necessary because all video signals undergo a time delay in reverse proportion to the bandpass limits of the circuits through which they pass. The time delay increases as the bandpass is narrowed. Since the luminance channel must pass a wider range of frequencies than the chrominance channel, the bandpass of the luminance channel is much wider than that of the crominance channel. Were it not for a special design, it would take a longer time for the chrominance signal to pass through the chrominance channel than it would for the luminance signal to pass through the luminance channel. The associated picture elements of these two signals must arrive at the picture tube at the same time; therefore, the luminance signal must undergo an extra time delay. This delay is accomplished through the use of a special delay circuit in the luminance channel.

A typical direct-coupled, video-amplifier configuration is shown in Fig. 14-25. A dc coupling diode is employed in the output stage. This diode tends to compensate for the drooping transfer characteristic of the output transistor when driven to maximum output. Blanking pulses are applied to the picture tube via C252. SC204 is the video detector and is followed by a low-pass filter comprising C232, L212, base-input capacitance of Q210, and L214. This low-pass filter removes IF feedthrough and also serves a peaking function.

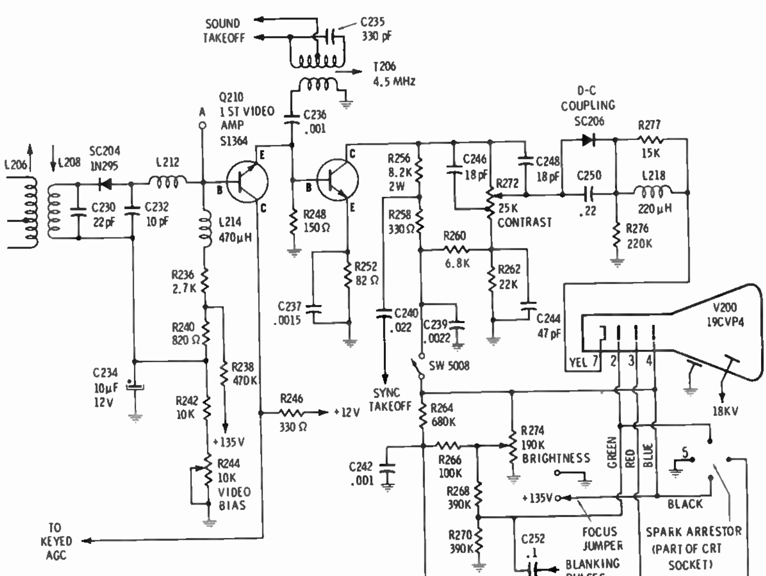


Fig. 14-25. Typical video-amplifier configuration.

The first stage operates in the common-collector mode and provides an impedance match to the output stage. This output stage operates in the common-emitter mode. T206 serves both as a sound-takeoff transformer and as a 4.5-MHz sound trap for the video amplifier. Note that 4.5-MHz interference causes sound "grain" in the picture, and a combination of 4.5- and 3.58-MHz interference produces a 920-kHz beat—a wormy effect that has the characteristic appearance shown in Fig. 14-26.

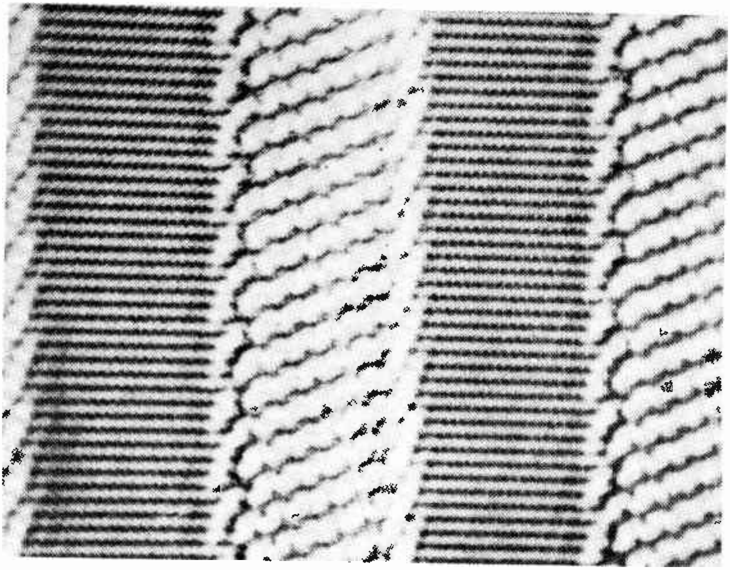


Fig. 14-26. "Wormy" effect produced by 920-kHz interference.

The AGC Circuit

Although conventional in operation, the AGC circuit plays an important part in the color receiver. This importance can be realized when it is considered that variations in the amplitudes of the incoming signal will affect the color as well as the brightness of the image. In order to stabilize the operation of the receiver, a good AGC circuit is a necessity.

The preceding material described the color-receiver circuits that correspond very closely to those found in monochrome receivers. We shall now discuss the circuits that deal with the proper reproduction of color. These circuits are represented by the unshaded blocks in Fig. 14-13.

In order to be utilized in the color receiver, the chrominance signal, which is in the form of a 3.58-MHz signal, must first be separated from the composite color signal. An amplifier stage having a frequency-limiting filter network is used for this purpose. This stage is called the *bandpass amplifier*. The chrominance signal is fed from the bandpass amplifier to two demodulators where two color-difference signals are extracted from the 3.58-MHz signal. In order for the latter function to take place, two continuous-wave (CW) signals are required by the demodulators. These CW signals are generated and controlled by a section referred to as the *color-sync section* of the receiver. A burst amplifier, keyer, 3.58-MHz oscillator, and control circuit are used in the color-sync section.

During the reception of a monochrome signal by the color receiver, a means of cutting off the chrominance channel is provided. This function is performed by the color-killer section, which automatically disables the chrominance channel when there is no color signal being received.

Bandpass Amplifier

The purpose of the bandpass amplifier is to separate the chrominance signal from the composite color signal and feed it to the demodulators. The signal at the takeoff point for a typical bandpass-amplifier section is the composite color signal, which includes the chrominance, luminance, burst, synchronizing, and blanking signals. The takeoff point for the chrominance signal is usually in the first video amplifier stage, but, depending on the gain in the bandpass amplifier, it can be anywhere in the video section.

Only the chrominance portion of the composite color signal appears at the output of the bandpass-amplifier circuit. Between the signal takeoff point and the input of the demodulators, any remaining 4.5-HMz signal has been attenuated, the luminance signal has been blocked, and the color-burst and synchronizing signals have been keyed out.

A typical bandpass-amplifier configuration is shown in Fig. 14-27. Diode CR205 functions as a bias-voltage regulator for Q206 to compensate for temperature drift. Diode CR206 operates as a rectifier to ensure that only a positive-going pulse is applied to the emitter of Q206 for blanking the chroma signal

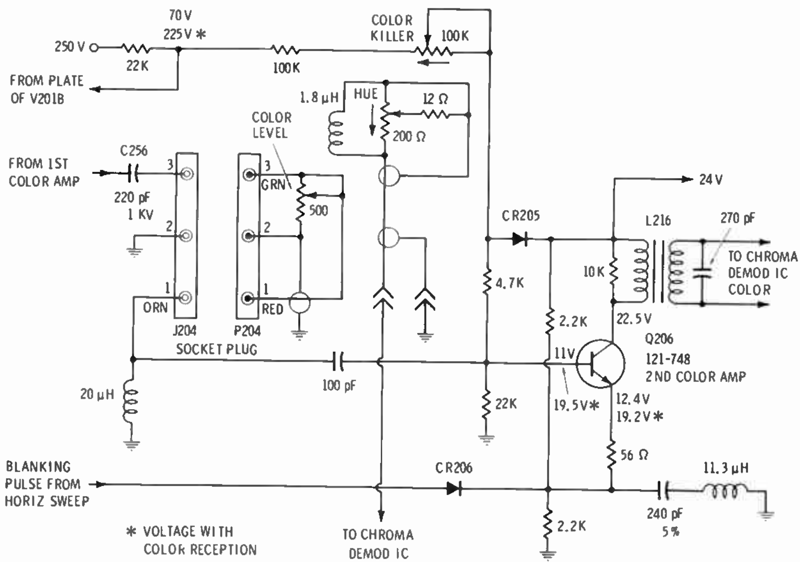


Fig. 14-27. Bandpass-amplifier configuration.

during horizontal retrace. Note that base and emitter voltages for Q206 are specified for both color and black-and-white reception. This change in base and emitter voltage is produced by color-killer action and often provides useful clues when troubleshooting bandpass amplifier malfunctions. Figure 14-28 shows the frequency-response curve of a typical bandpass amplifier.

The setting of the COLOR control in the bandpass amplifier determines the amount of chrominance signal applied to the demodulators as well as the saturation of the colors in the picture. This chrominance signal is coupled to the demodulator stages, where it is detected. The chrominance signal varies in both phase and amplitude. It is the function of the demodulator stages to detect correctly the differences between the phase and amplitude of the chrominance signal in order for the receiver to reproduce the proper colors.

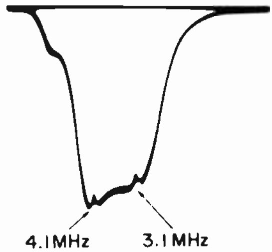
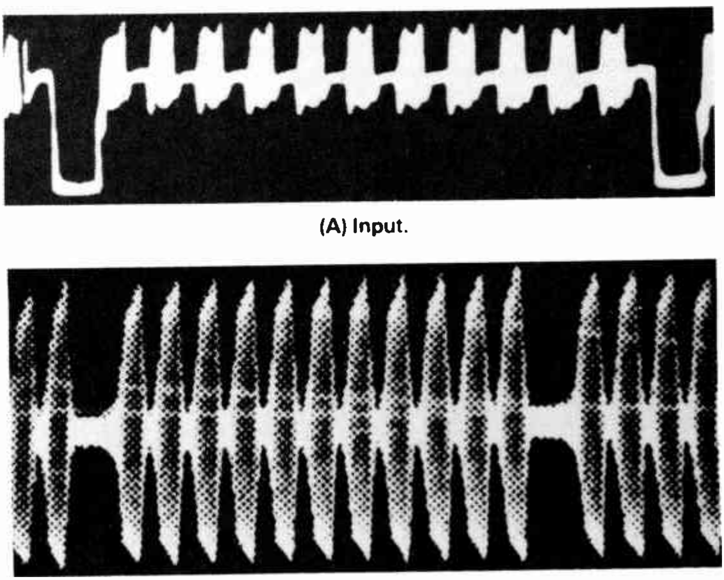


Fig. 14-28. Frequency-response curve of typical bandpass amplifier.

Normal input and output waveforms for the bandpass amplifier are shown in Fig. 14-29. The input waveform is a keyed-rainbow signal; it consists of a series of color bursts at a frequency of 3.56 MHz. Horizontal-sync pulses are included in the



(A) Input.

(B) Output.

Fig. 14-29. Input and output waveform for bandpass amplifier.

keyed-rainbow signal. After this standard test signal is processed through the bandpass amplifier, the bursts appear in amplified form, with the horizontal-sync pulses keyed out. Keyed-rainbow generators are discussed in Chapter 15.

Let us review briefly how the color signal varies in phase and amplitude. Figure 14-30 shows how the primary colors (red, green, and blue) and the complementary colors (magenta, cyan, and yellow) have different amplitudes and phases. The burst phase is at 0°; in turn, yellow has a phase angle of 12°, red has a phase angle of 76.5°, and so on. The relative amplitudes of yellow and red are 45 and 63 percent with respect to the amplitude of white.

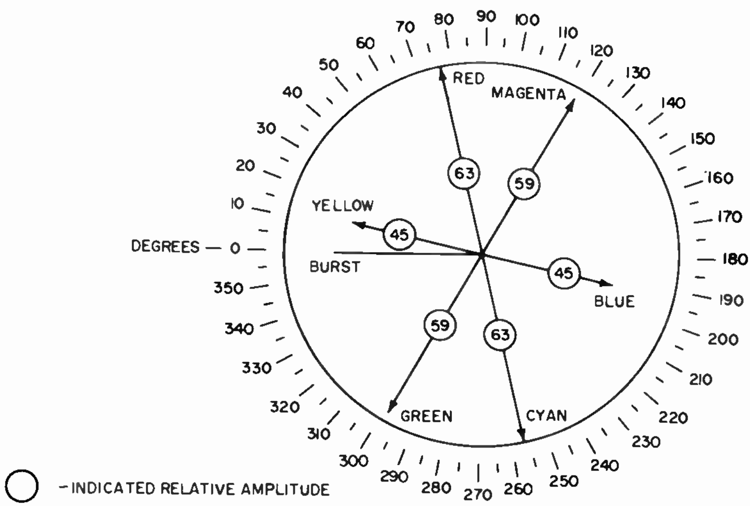


Fig. 14-30. Vector representation of relative phases of the TV color signal.

The chief chrominance signals that concern us at this point are R–Y, B–Y, and G–Y, as depicted in Fig. 14-31. Note that B–Y is 180° from burst; R–Y is 90° from burst. We observe that + (G–Y) is 300° from burst, and that –(G–Y) is 180° from + (G–Y). R–Y and B–Y are called *quadrature signals* because they are 90° apart. Similarly, G–Y ∠ 90° is a quadrature signal with respect to both + (G–Y) and –(G–Y). These chrominance signals are provided by standard color-bar generators.

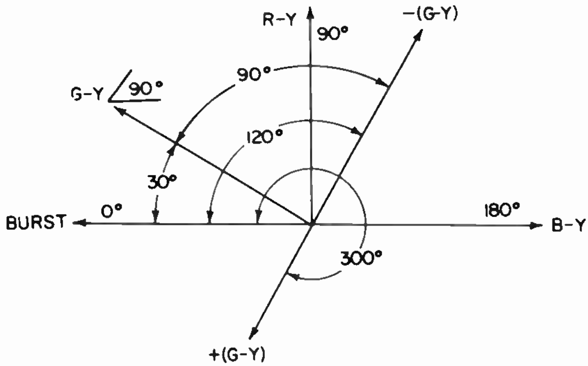


Fig. 14-31. Phases of G-Y, R-Y, and B-Y signals.

Figure 14-32 shows how the amplitude of a given chrominance signal varies for different colors. The amplitudes of the Y (black-and-white) signal are also indicated. For example, a green color is built up from 0.59Y, −0.59R-Y, −0.59B-Y, and 0.41 G-Y. Next, a yellow color is built up from 0.89Y, 0.11R-Y, −0.89B-Y, and 0.11G-Y. Therefore, when a color program is being transmitted,

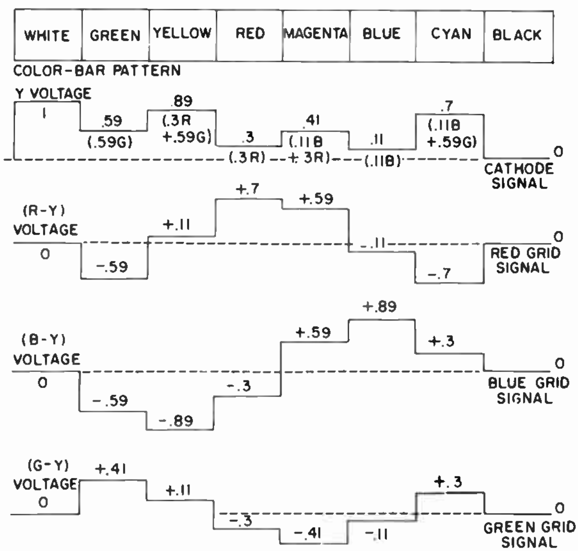


Fig. 14-32. Signal amplitudes for 100 percent saturated color-bar pattern.

the chrominance signal and the Y signal are varying rapidly in both phase and amplitude.

Color Synchronization

In order to reproduce properly the colors of a televised image, the modulation of the chrominance subcarrier at the transmitter must be reversed at the receiver. It may be recalled that the modulation process at the transmitter involves the use of a 3.58-MHz subcarrier. This subcarrier is applied in quadrature to two doubly-balanced modulator circuits. Simultaneously, the saturation signal is applied to one balanced modulator, and the hue signal is applied to the other. The 3.58-MHz subcarrier is cancelled, and the resultant output is the chrominance signal, which is a 3.58-HMz signal that varies in amplitude and phase.

Recovery of the color-difference signals in the receiver is accomplished by reversing the modulation process. This requires that a 3.58-MHz CW reference signal that is locally generated should be applied in quadrature to two demodulator circuits. Accuracy in the demodulation process is attained by regulating this reference signal so that a definite phase relationship with the subcarrier is maintained. It is the function of the color-sync section to generate the local 3.58-MHz reference signal and regulate its frequency and phase.

A circuit diagram of a typical color-sync, bandpass amplifier, and color-killer section is shown in Fig. 14-33; it is an example of a ringing-crystal, color-sync arrangement. In other words, the quartz crystal is shock-excited into 3.58-MHz oscillation each time that a color burst is applied. Although the ringing waveform tends to die out slightly between bursts, the crystal Q is very high, and the delay is small. Q6 operates as a limiter to provide a completely uniform output. The quartz crystal is energized by the output from the burst amplifier.

In normal operation, the burst-amplifier-output waveform appears as shown in Fig. 14-34. Note that the color killer operates as an electronic switch to turn the second bandpass stage on or off. The color killer is energized by the output from the subcarrier oscillator. Thus, if there is no color burst present, the second bandpass amplifier is disabled. The burst killer is energized from the horizontal-output transformer. It keys out the color burst from the signal in the bandpass amplifier, thereby preventing color contamination in the image from the color burst.

Color Killer

The purpose of the color killer in a color receiver is to prevent any signal from getting through the chrominance channel during the time a monochrome signal is being received. This prevents any signal other than the luminance signal from reaching the picture tube. Signals are prevented from passing through the chrominance channel by employing a color-killer stage to bias or to cutoff one or more stages in the chrominance channel.

Matrix and Demodulator Section

At this point in the discussion of color-receiver circuits, three video signals have been described: the luminance signal and two color-difference signals at the output of the chrominance demodulators. It is the function of the matrix section to combine these three signals in the correct proportions so that three color signals are produced. These color signals must correspond to those which appear at the output of the color camera: one for red, one for green, and one for blue. The color signals are amplified and applied to the picture tube, where they reproduce the hues of an image in terms of the three primary colors.

We shall find that various chrominance and demodulator arrangements are used in different models of color-TV receivers. In one basic arrangement, R–Y and G–Y signals are demodulated, as depicted in Fig. 14-35. However, the G–Y signal is recovered in a chrominance matrix. It can be shown that G–Y can be produced by mixing −0.51R–Y with −0.19B–Y. An R–Y signal is changed into a −(R–Y) signal by passing the R–Y signal through a phase inverter. The G–Y matrix is simply a mixer for the −(R–Y) and the −(B–Y) signals.

In order to understand how the colors of a scene are reproduced, it is necessary to know something about the picture tube. The tube used in the basic color receiver is known as the *tricolor picture tube*. Three separate electron guns are incorporated in

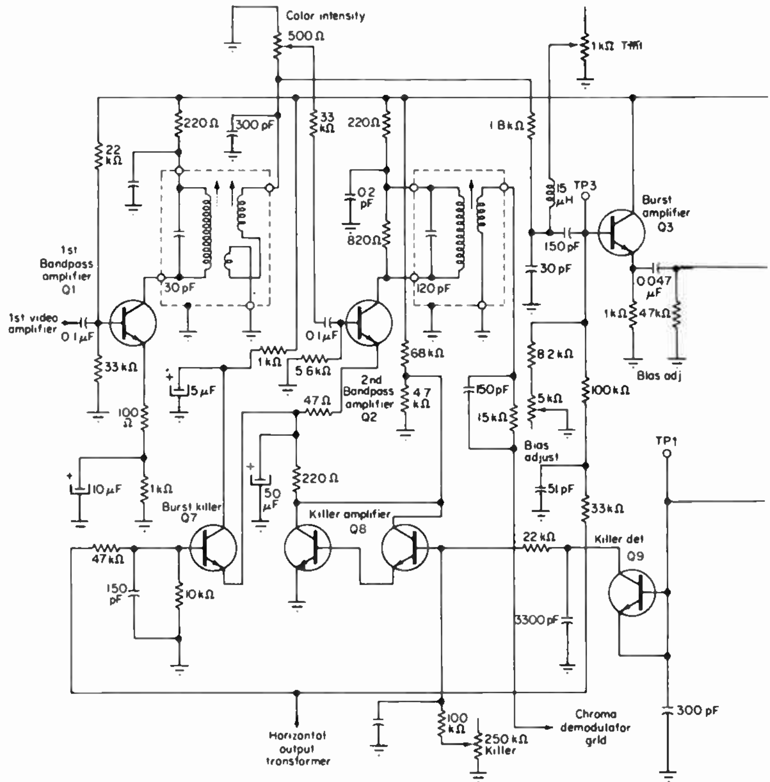
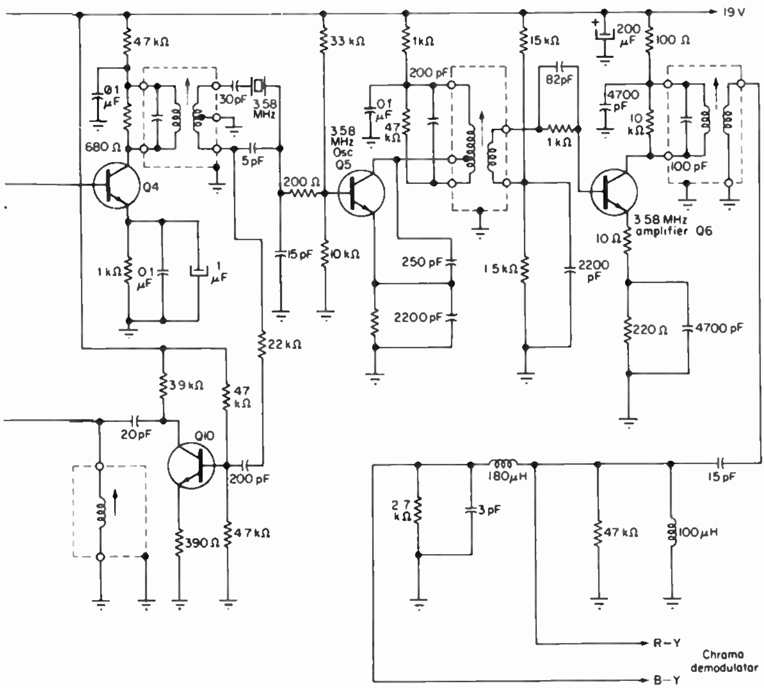


Fig. 14-33. Configuration of typical color-sync

this type of tube in order to accomodate the three color signals. The coating on the face of the tube consists of phosphor dots, which are arranged in triangular groups of three. One dot in each trio emits red, one emits green, and one emits blue light.

When operating properly, the electron beam from the red gun activates only the red dots, the beam from the blue gun activates only the blue dots, and the beam from the green gun activates only the green dots. The phosphor dots are closely spaced so that when more than one dot in each trio is activated, the total light emission will blend to form one color. For example, when the light emissions from all three phosphors are equal, the screen



bandpass amplifier and color-killer section.

appears white. If the red and green phosphors are activated equally, the resultant hue appears to be yellow. The blending into a single hue of the color dots on the picture-tube screen is based upon the principle that the human eye cannot resolve the separate colors at normal viewing distance. As a result, the total light emitted from the dot combinations appears as a single color. Figure 14-36 shows how the Y, R–Y, B–Y, and G–Y signals produce a red bar on the screen.

The foregoing information should be helpful in understanding the requirements of the matrix section. A detailed discussion of the picture tube will be presented later.

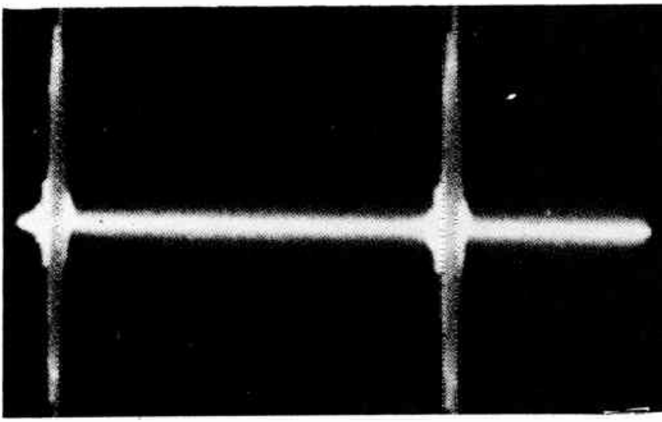


Fig. 14-34. Output waveform from the burst amplifier.

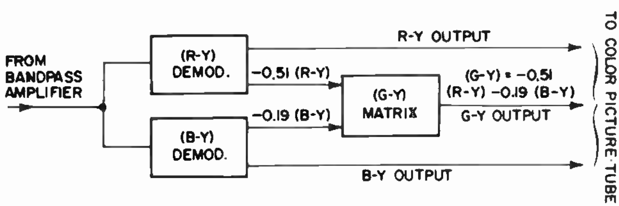


Fig. 14-35. Basic matrix arrangement.

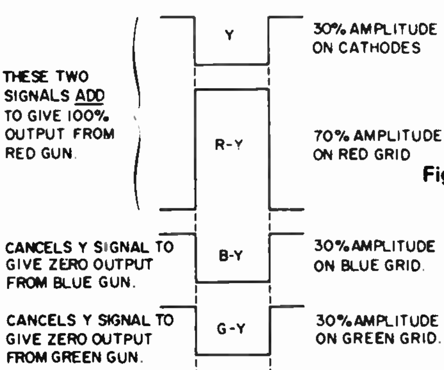


Fig. 14-36. Waveform amplitudes at the picture tube for a 100 percent saturated red bar.

In order to produce the colors of an image correctly, the matrix section must fulfill certain requirements. For instance, when a fully saturated red portion of the scene is to be reproduced, the amplitude of the video signal applied to the red gun must be at a maximum value and the amplitude of the signals applied to the green and blue guns must be zero. During the time when a fully saturated green is to be reproduced, the amplitude of the signals applied to the red and blue guns must be zero and that of the signal applied to the green gun must be at maximum value. The amplitude of the blue signal must be at maximum value, and those of the red and green signals must be at zero when a fully saturated blue is being reproduced. If white is to be reproduced, the amplitude of all three color signals must be at maximum values because white contain all colors.

Demodulation of the chrominance signal is the reverse of the modulation process at the transmitter. It could be accomplished by a mechanical switching action, but at a frequency of 3.58 MHz, a mechanical switch is impossible—switching tubes are used instead. Figure 14-37 shows the chief chrominance demodulator arrangement.

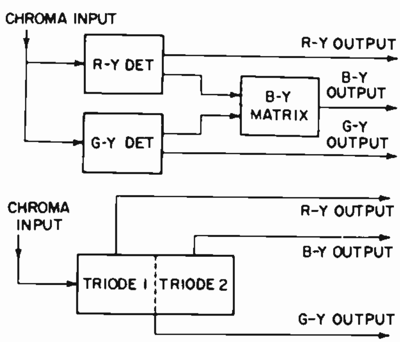


Fig. 14-37. Common demodulator systems.

A widely used chroma demodulator arrangement is shown in Fig. 14-38. Diode phase-amplitude detectors are utilized. The chroma-signal output from the bandpass amplifier is applied to the R–Y, B–Y, and G–Y demodulator diodes. Also, suitably phased subcarrier voltages from the subcarrier oscillator are applied to the diodes. Thus, the subcarrier voltage applied to the B–Y

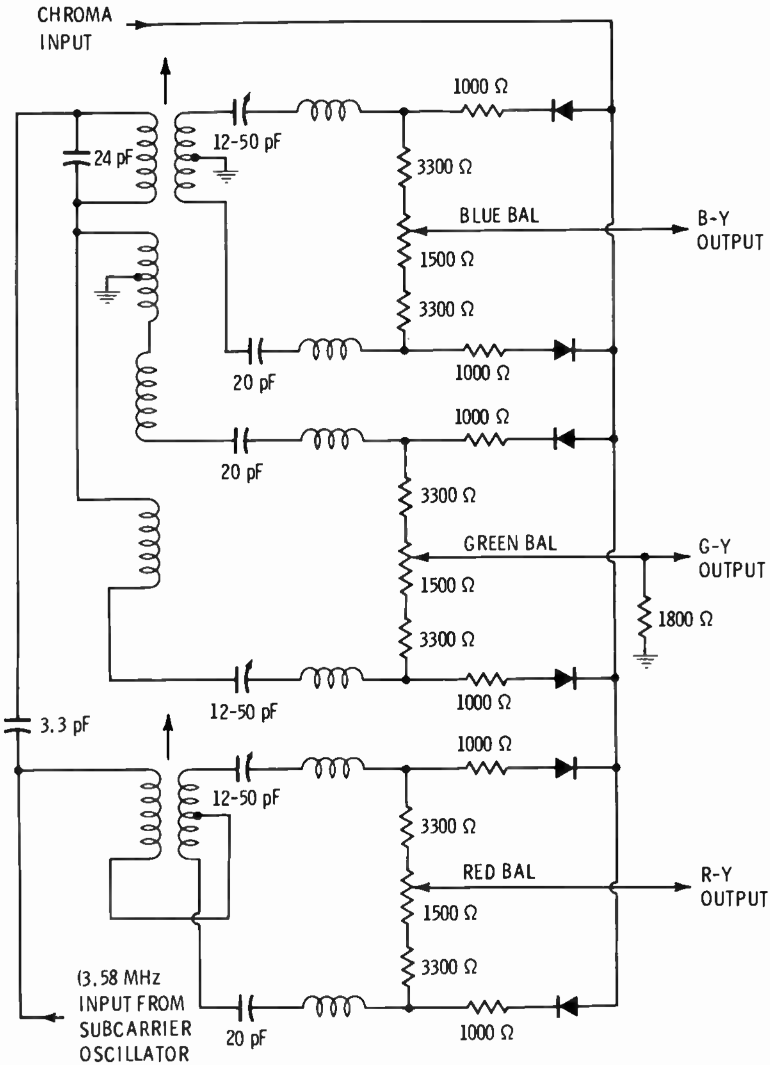


Fig. 14-38. An R-Y/B-Y/G-Y chroma-demodulator arrangement.

demodulator has the B–Y phase, that applied to the G–Y demodulator has the G–Y phase, and that applied to the R–Y demodulator has the R–Y phase. The diodes are turned on and off at suitable time intervals by the subcarrier voltage to pass the R–Y, B–Y, and

G–Y signals, respectively. At the same time, the subcarrier is reinserted into the three chroma signals, and they are demodulated by the rectifying action of the diodes. This process will be explained in greater detail in a following section.

CHARACTERISTICS OF THE THREE-BEAM PICTURE TUBE

Some of the characteristics of the three-beam tube are: (1) It has a phosphor-dot screen made up of three different phosphors; (2) it has a shadow mask to allow each beam to strike only the correct set of phosphor dots; (3) and it has three beams originating from three electron guns to energize each of the different phosphors.

There are therefore three major parts in a color picture tube: a phosphor viewing screen, a shadow or aperture mask, and an electron-gun assembly. A diagram showing the location of these parts appears in Fig. 14-39.

Let us investigate the characteristics of the three-beam color picture tube by first discussing the three major parts.

Phosphor Viewing Screen

The screen of the monochrome picture tube is made up of a mixture of phosphorescent material, which, when energized by

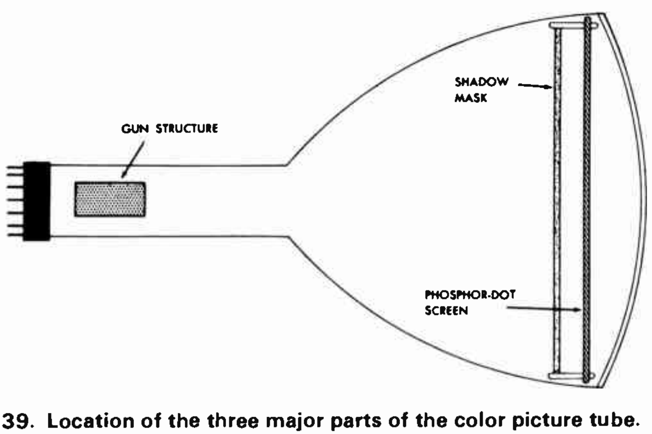


Fig. 14-39. Location of the three major parts of the color picture tube.

an electron beam, will emit white light. This material is placed on the face plate of the tube in the form of a solid screen. The viewing screen of a color picture tube is also made up of phosphorescent material, but since three different phosphors are used, the screen of the color picture tube is different from that of the monochrome tube. The phosphors are the type that will emit colored light when they are energized by electrons because color has to be reproduced on the screen.

Since three additive primaries are employed in color television, three different phosphors are used. The phosphors are deposited on the viewing surface in the form of dots in a set pattern. These dots are placed very close together, but they do not overlap or touch each other. One-third of all the phosphor dots emit red light, another third of them emit green light, and the other third emit blue light. When an electron beam strikes a red-phosphor dot in a triad, that dot will glow with a red light. The blue-phosphor dot will glow with a blue light when it is energized with a beam.

The characteristics of the human eye are such that the light emissions from the three phosphors cannot be distinguished separately at normal viewing distance. Instead, the eye blends the light from the three sources to give the appearance of a single color. For example, when the light outputs of all three phosphors are equal, each dot will glow with its respective color but the eye blends the three lights together so that the screen will appear to be white.

By controlling the energization of the phosphors, it is possible to produce a variety of colors that correspond to the hues in the visible light spectrum. For instance, when only the red and the green phosphors are energized, the two light sources are blended together by the eye and the color yellow is seen. If the green and blue phosphors are energized, the eye sees the color cyan.

Shadow, or Aperture, Mask

It has been stated that the color picture tube has three electron beams: One beam is used for energizing the red-phosphor dots, one for the green-phosphor dots, and the other for the blue-phosphor dots. These three beams must be made to strike their respective set of dots at all times. To make this possible, a *shadow mask* is placed in the path of the electron beams directly behind the phosphor screen.

The mask consists of a thin sheet of metal that has been etched with a series of very small holes by a photoengraving process. This mask is made large enough to cover the entire phosphor screen. There are as many holes in the mask as there are triads on the phosphor screen—one hole for each dot triad. The placement of the mask in respect to the phosphor dots is shown in Fig. 14-39. A red, green, and blue dot can be seen through each hole in the mask.

A drawing showing the relationship of the electron beams, aperture mask, and phosphor-dot screen is presented in Fig. 14-40. The blue beam is shown as originating from the source on the top, the red beam from the source on the lower right, and the green beam from the source on the lower left. The three beams are controlled in such a way that they converge and diverge at the same holes in the aperture mask as they are scanned across the screen, and therefore each beam strikes only its respective set of color dots. The blue beam hits the blue-phosphor dot of the particular triad indicated in Fig. 14-40, and the red and green beams hit their respective dots in this triad.

This triad of dots can be likened to the spot produced on a monochrome tube as the electron beam strikes the phosphor

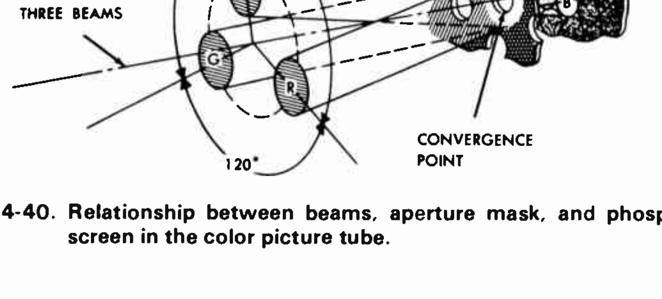


Fig. 14-40. Relationship between beams, aperture mask, and phosphor screen in the color picture tube.

screen. Just as the brightness of this spot can be controlled in the monochrome tube by varying the intensity of the beam, the brightness of the triad in the color tube can be changed by controlling the total intensity of the three beams. In addition, however, the beams can be controlled individually, which makes possible the reproduction of any desired hue.

Electron-Gun Assembly

As stated previously, the color picture tube employs three electron guns. Each is a complete unit in itself, and all three guns are identical in physical appearance and operation. Each gun contains a heater cathode, and grids Nos. 1 to 4. Grids Nos. 1 and 2 serve the same purpose as they do in a monochrome picture tube, No. 1 being the control grid and No. 2 the accelerating anode. Grid No. 3 in the color tube is the focus electrode. The focus electrodes of the three guns are electrically connected. The high-voltage anode of the color picture tubes consists of the inside coating to which the aperture mask and phosphor are connected.

The three electron beams are aligned so that they are equidistant from each other and from the central axis of the gun structure. In order to obtain this result, each beam is acted upon by a separate beam-positioning magnet, which is mounted outside the neck of the tube. By proper adjustment of the three magnets, each beam is positioned with respect to the other two beams.

With the three beams correctly aligned with respect to each other, the entire system of beams has to be oriented with respect to the central axis of the tube. This is accomplished by a purity coil, or magnet, which is placed around the neck of the tube and affects all three beams equally. The adjustment of this control will move all three beams the same amount until they are properly aligned with the central axis of the tube.

The three beams are brought into focus by the action of the No. 3 grids. These grids are electrically connnected, which means that all three grids will have the same potential with respect to ground. After being focused, the beams enter a convergence field, which causes them to cross over (converge) at the aperture mask and strike the dots of the correct color. In the latest color tubes, this convergence field is obtained through the use of electromagnets, which are mounted around the neck of the tube. During horizontal and vertical deflection of the three beams, they will converge at the center of the screen but not at the edges. To eliminate this condition, dynamic convergence coils are positioned around the neck of the tube. These coils are powered by currents from the horizontal and vertical output stages. The waveforms of these currents are adjustable so that convergence can be obtained over the entire screen.

Another type of color picture tube is called the *in-line design*, or *Trinitron*. As shown in Fig. 14-41, the chief feature of this picture tube is an aperture grille instead of a shadow mask. Also, the three electron guns are mounted in line horizontally. Note that all three electron beams pass through the same slot in the grille at a given time, but they pass through at different angles. Therefore, the red beam strikes the red stripe.

The same chroma and Y waveforms are used with the aperture-grille picture tube as with the shadow-mask picture tube. However, the convergence arrangement is quite different. Note that

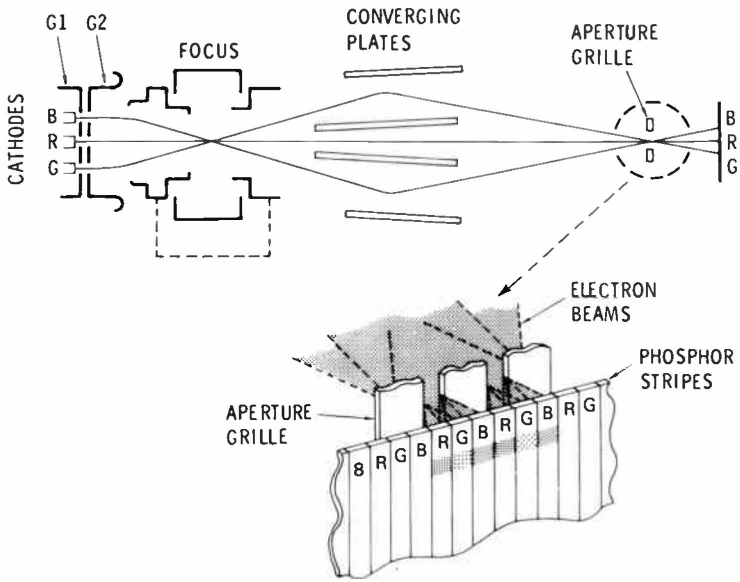


Fig. 14-41. Constructional plan of an aperture-grille picture tube.

there has been a trend toward the use of elaborated shadow-mask picture tubes that have their deflection yokes and convergence units permanently mounted on the neck of the picture tube. This type of picture tube is converged at the factory and does not require reconvergence during its useful life. When this type of picture tube is replaced, the yoke and convergence assembly are discarded with the defective picture tube.

TRANSISTOR COLOR-TV RECEIVERS

Transistor color-TV receivers use various circuits that are essentially the same as the circuits explained previously for transistor black-and-white receivers. However, the chroma processing circuits may be basically different from those in tube-type color receivers. Therefore, a typical chroma processing circuit used in a modern transistor color-TV receiver will be explained in this section.

It is helpful to start with a brief analysis of chrominance-signal demodulation, as depicted in Fig. 14-42. Note the following facts:

1. The subcarrier-oscillator voltage is injected into the R–Y demodulator in the R–Y phase.
2. The subcarrier-oscillator voltage is injected into the B–Y demodulator in the B–Y phase.
3. Conduction of the R–Y demodulator occurs briefly on the peak of the injected subcarrier voltage.
4. Conduction of the B–Y demodulator occurs briefly on the peak of the injected subcarrier voltage.
5. When an R–Y signal is applied to the demodulators from the bandpass amplifier, the R–Y signal is sampled on its peak by the R–Y demodulator. On the other hand, the R–Y signal is going through zero at the instant of sampling in the B–Y demodulator, and there is zero output from the B–Y demodulator.
6. When a B–Y signal is applied to the demodulators from the bandpass amplifier, the B–Y signal is sampled on its peak by the B–Y demodulator. On the other hand, the B–Y signal is going through zero at the instant of sampling in the R–Y

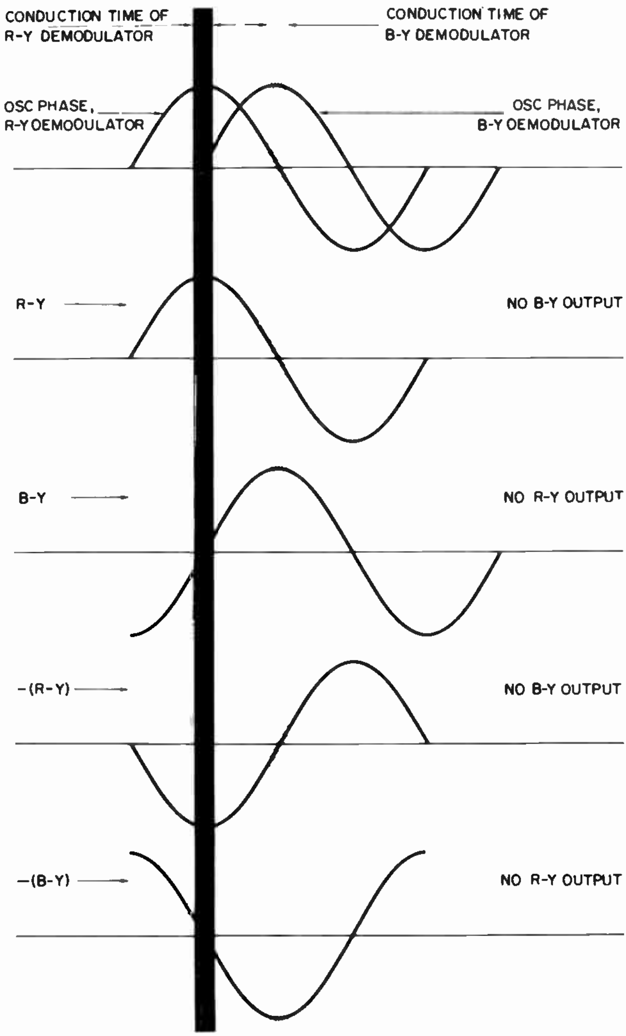


Fig. 14-42. Sampling the R-Y and B-Y signals.

demodulator, and there is zero output from the R–Y demodulator.

7. A minus (R–Y) signal is sampled on its negative peak by the R–Y demodulator and is going through zero at the instant of

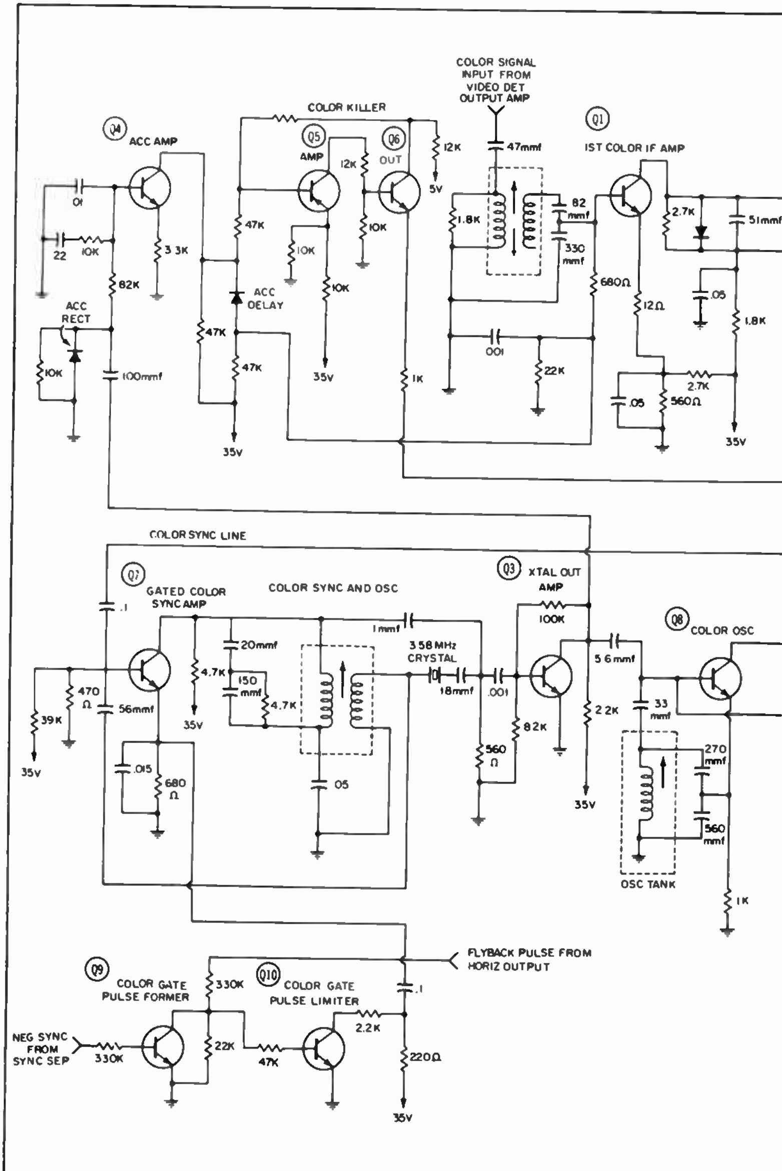
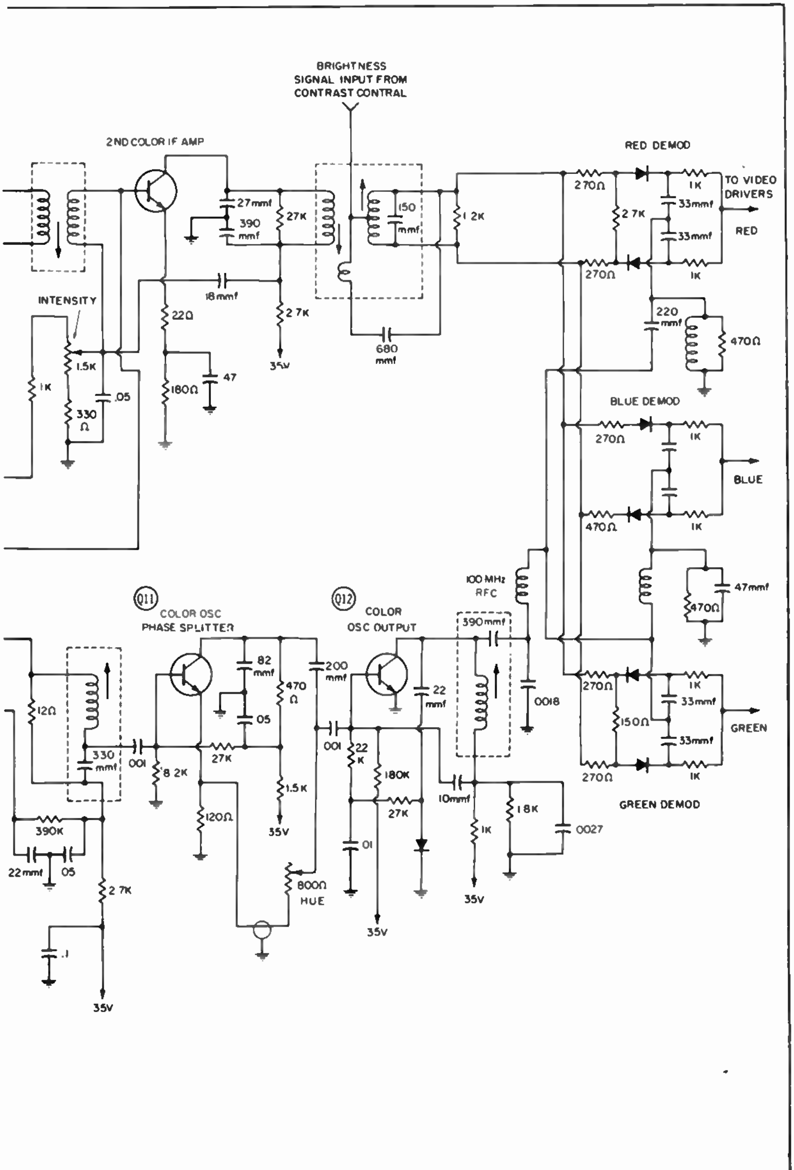


Fig. 14-43. Typical circuitry



for color stages.

sampling in the B–Y demodulator. There is a negative R–Y output from the R–Y demodulator and zero output from the B–Y demodulator.

8. A minus (B–Y) signal is sampled on its negative peak by the B–Y demodulator and is going through zero at the instant of sampling in the R–Y demodulator. There is a negative B–Y output from the B–Y demodulator and zero output from the R–Y demodulator.

Next, let us observe the chrominance demodulation arrangement depicted in Fig. 14-43. Note that the color signal is fed into the color IF amplifier from the video-detector output amplifier. In other words, the color IF amplifier operates in the same manner as the bandpass amplifiers discussed previously. After the chrominance signal is stepped up through two stages of amplification, it is mixed with the brightness (Y) signal from the contrast control. In other words, the red, blue, and green demodulators are energized by the *complete color signal*, as depicted in Fig. 14-44, which is a basic difference compared to the other demodulator arrangements described previously.

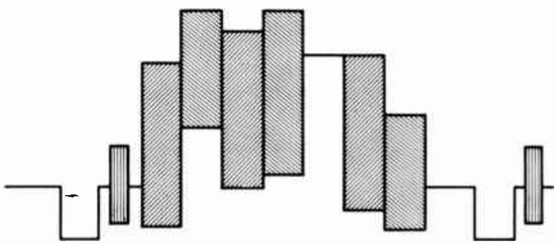


Fig. 14-44. The complete color signal.

Because the complete color signal is fed to the demodulators in Fig. 14-43, we find that a combined demodulation-matrixing action takes place. In other words, this system employs color demodulators instead of chrominance demodulators. Basically, the subcarrier oscillator injects the red phase into the red demodulator, the blue phase into the blue demodulator, and the green phase into the green demodulator, as shown in Fig. 14-45. Thus, matrixing is accomplished along with the demodulation process.

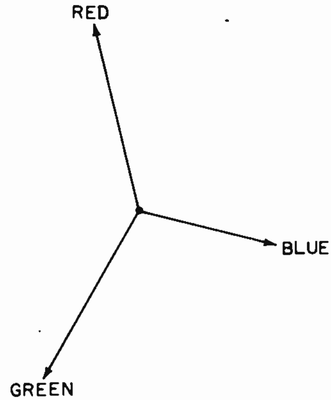


Fig. 14-45. Basic demodulation phases in color demodulators.

The red, green, and blue signals are then fed to video drivers and amplifiers and are finally applied to the cathodes of the color picture tube.

RGB demodulation entails a problem that is not encountered in conventional chrominance demodulation; that is, spurious pulses, called *blips*, are produced in a simple RGB demodulation system. Therefore, circuit means must be provided to cancel out the blip interference. This is done by reversing the polarities of the demodulator diodes in the green demodulator section, as seen in Fig. 14-43. In turn, we would obtain a magenta color-signal output from the green demodulator (Fig. 14-46) unless the injected

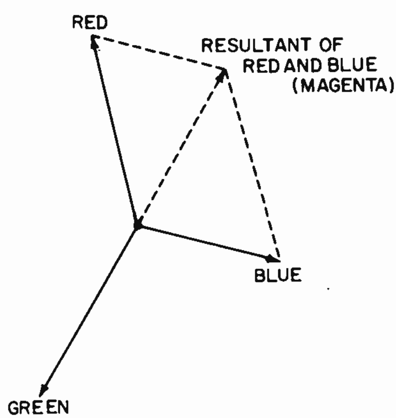


Fig. 14-46. Magenta is 180° from the green phase.

subcarrier phase is reversed. Therefore, the subcarrier is injected into the green demodulator in the magenta phase, and a green color-signal output is obtained owing to the fact that the diode polarities are reversed.

The automatic chroma control (ACC) section in Fig. 14-43 is simply an AGC arrangement to maintain the chrominance signal at a fixed level in case the incoming signal tends to fade. If the color burst decreases in amplitude, the color IF gain increases. The color killer operates as explained previously. Similarly, operation of the color sync and color oscillator (subcarrier oscillator) is the same as described previously.

SUMMARY

When color television was first developed, it had to meet two requirements: The color signal had to be compatible with the monochrome system; and it had be inserted within the 6-MHz-channel bandwidth.

Three color attributes are used to describe any one color or several colors: hue, saturation, and brightness. Hue is used to identify any color under consideration. Saturation is used to measure the absence of light and can be expressed as rich, deep, vivid, or pure. Brightness defines the amount of light energy contained within a given color and can be expressed in terms of bright, dark, or dim.

The color picture signal consists of two separate signals: luminance and chrominance signals. The luminance signal is the portion of the color-picture signal utilized by monochrome receivers. The chrominance signal must represent only the colors of a scene. Therefore, the luminance signal is subtracted from each of the three output signals of the color camera.

REVIEW QUESTIONS

1. What are the three basic primary colors?
2. What two basic requirements were needed in developing color TV?

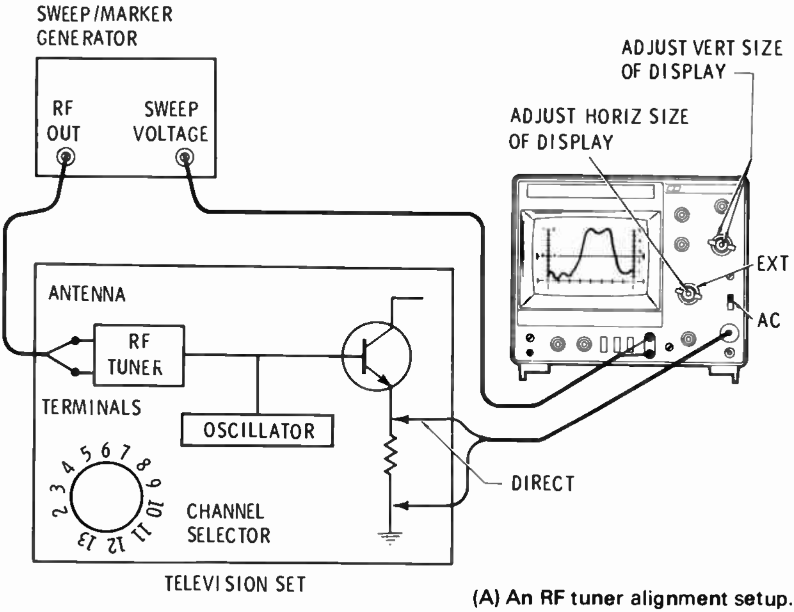
3. What is meant by the chrominance signal?
4. What are the three color attributes used to describe any one color or several colors?
5. Brightness is a characteristic of what two factors?
6. What are the two requirements for primary color for color mixing?
7. The color-picture signal consists of two separate signals. What are the two signals.?

CHAPTER 15

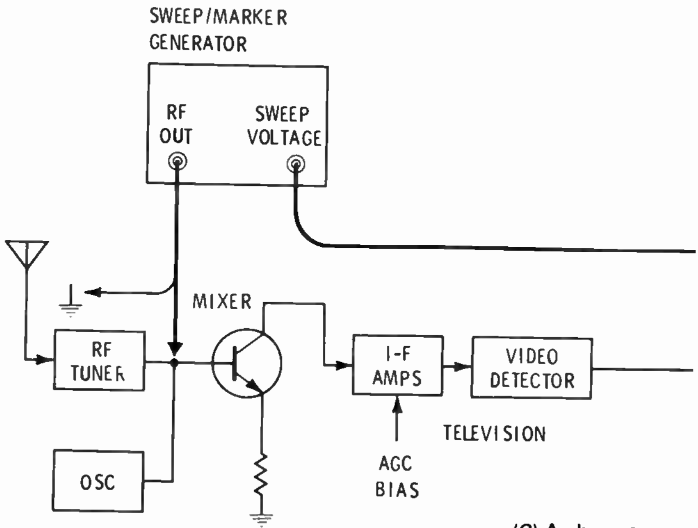
Television Alignment

Although each receiver is correctly adjusted at the factory, rough handling during transit and aging components may cause misalignment of the critical circuits. If picture and sound defects indicate that a realignment is necessary, the manufacturers' step-by-step procedure should be followed.

In order to better understand the following detailed alignment procedure, it is necessary to explain why this procedure has been prepared in this manner. Any receiver alignment problem may be classified as either *minor* or *major*. In other words, it is either only slightly out of adjustment and therefore requires minor adjustments of one or more of the coils; or some of the coil cores have been removed or are badly out of adjustment, requiring a thorough check of the entire circuit. A preliminary overview of basic alignment setups is shown in Fig. 15-1; typical coils with adjustable cores are shown in Fig. 15-2.

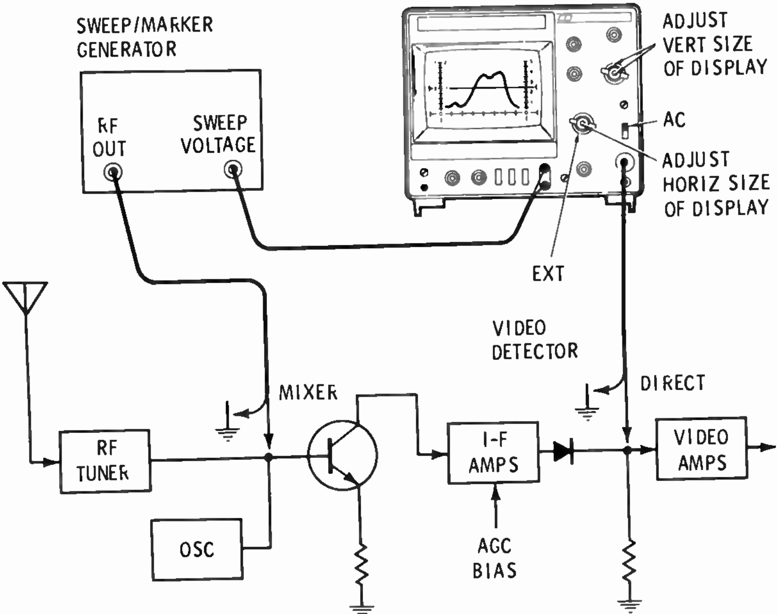


(A) An RF tuner alignment setup.

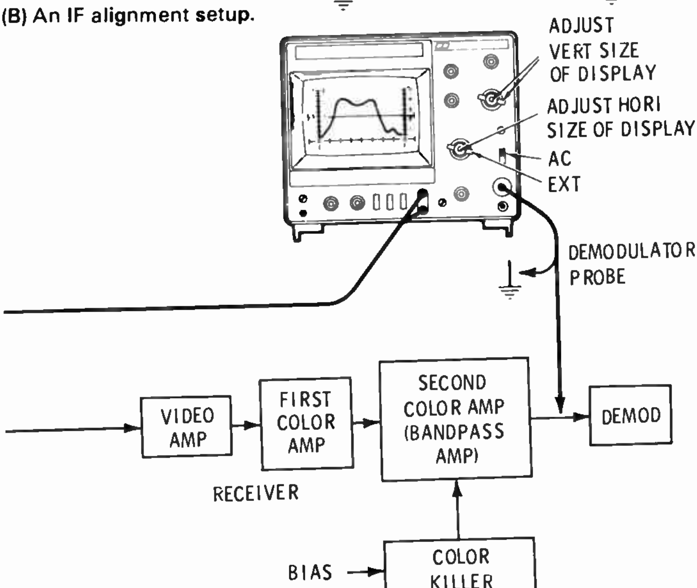


(C) A chroma

Fig. 15-1. TV-alignment



(B) An IF alignment setup.



setup.

Courtesy B&K Precision, Div. of Dynascan Corp.

Courtesy J. W. Miller Co.

Fig. 15-2. Coils with adjustable cores.

External noise and signals may be very troublesome during alignment. Therefore a stage-by-stage procedure is usually followed, during which the signal is injected just preceding the stage under alignment. If it is known that the set is not badly out of alignment, it may be possible and practical to abbreviate the procedure considerably by applying the input signal directly to the antenna input during the entire alignment procedure instead of applying it to the different stages as each individual stage is aligned.

One important point should be kept in mind when making all adjustments: All the individual coils must be aligned at the same frequency setting of the generator rather than changing the generator setting and having to reset the generator at the same frequency. For example, when making adjustments at 41.25 MHz, do not change the generator setting from the time of starting these adjustments until all adjustments on all coils that are to be aligned at this particular frequency have been completed, even though this means changing the point of signal injection. The exact frequency to which the coils are aligned is not as important as being sure that all coils of identical frequency are aligned at exactly the same frequency. The frequency tolerance of ±5% in signal-generator frequency can be tolerated if the coils are aligned at the identical frequencies.

Again it should be emphasized that all pertinent data relating to the set to be aligned should be available for reference, and the manufacturer's alignment procedure must be followed.

GENERAL ALIGNMENT PROCEDURE

To align a television receiver or any other receiver or device employing wideband circuits, a visual indication of the response of the circuit being aligned is required if the alignment is to be considered acceptable. Visual alignment is fast replacing the older, slower, point-by-point alignment method and is as rapid as it is effective. When combined with the use of accurately established marker frequencies, it is also precise.

If the amplifier under test happens to be a wideband IF amplifier, the sweep generator is normally connected to the stage preceding the second detector. The vertical-input terminals of the oscilloscope are connected across the detector, and the horizontal terminals are connected to a source of deflection voltage usually supplied by the sweep generator. When the sweep generator is tuned to sweep the band of frequencies accepted by the IF circuit, a trace representing the response characteristics of the circuit will appear on the oscilloscope screen.

A typical trace is shown in Fig. 15-3. From this trace, valuable information about the response can be obtained; but if the center frequency of the response and its bandwidth are to be determined to any degree of accuracy, a marker must be used.

When a source of marker frequencies is coupled to the input of the amplifier under test, a discontinuity, or "pip," will be observed on the trace, as shown in Fig. 15-3. If the marker generator is tuned exactly to the center of the passband accepted by the IF amplifier, then this marker pip will indicate the position of that frequency on the trace. Knowing the center frequency, the serviceman then adjusts the final tuned circuit for a trace that is of maximum amplitude and is symmetrical about the marker pip or has the shape recommended by the manufacturer of the equipment being aligned. Preceding stages are then adjusted progressively by moving the sweep-generator-output cable back, stage by stage, toward the input of the amplifier.

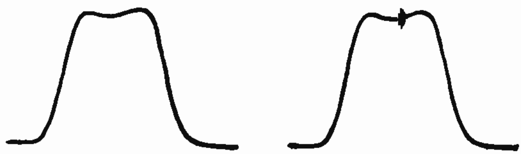
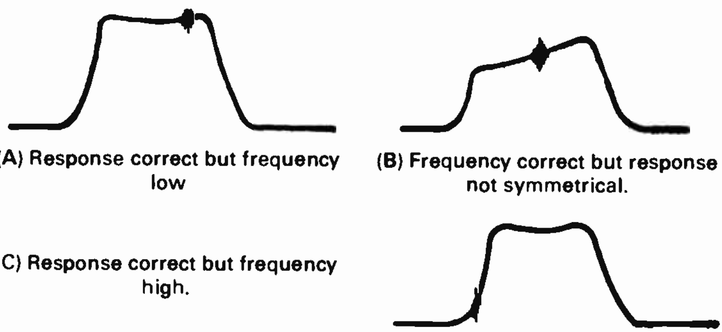


Fig. 15-3. Typical tuned-circuit response.

Figure 15-4 shows the position of the marker pip relative to the response for various conditions of misalignment. It must be emphasized that, once the marker generator is tuned to the correct frequency, the position of the response is incorrect and must be moved over under the marker pip by adjustments of the tuned circuits in the amplifier.



(A) Response correct but frequency low

(B) Frequency correct but response not symmetrical.

(C) Response correct but frequency high.

Fig. 15-4. Response of improperly aligned circuits.

The determination of the bandwidth of a particular response is another important function of marker generators. Figure 15-5 shows how this is performed. After the amplifier is aligned, the marker generator is tuned to a lower frequency so that the marker pip falls on the 70 percent response point on the low-frequency side of the response curve. The frequency at this point is read from the marker-generator dial scale; then the generator is tuned toward a higher frequency until the marker pip rests on the high-frequency side of the curve at the 70 percent response point. This response is also read from the dial scale. The difference

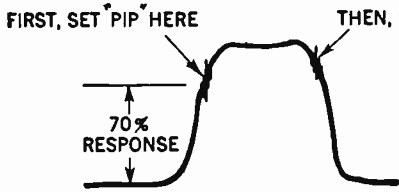


Fig. 15-5. Bandwidth measurement.

between the two frequencies is equal to the bandwidth of the amplifier at the 70 percent response points. (The application of marker generators to alignment problems has been discussed in a very general way to acquaint the reader with the technique.)

Since various models of television receivers employ different coupling and amplifier circuits, any one method of alignment, if described completely in this chapter, would be of little value to the television serviceman. In all cases, before alignment of any television receiver is attempted, the *manufacturer's alignment instructions should be consulted.* However, since the application of the television calibrator to alignment techniques in all cases is simply and clearly indicated, its use can be described in sufficient detail to cover all methods of alignment. Accordingly, in the following applications, we shall proceed with the assumption that the other equipment required is set up and operated in conformance with the *manufacturer's instructions* pertaining to the *particular receiver* under test and according to standard visual alignment technique.

Aligning Video IF Amplifier

The test equipment and the receiver are set up as shown in Fig. 15-6. When the sweep generator is tuned to sweep the passband of the video IF amplifier, a trace similar to that of Fig. 15-7 should appear on the oscilloscope screen. This trace is typical of the video IF response of modern television receivers. Since the intermediate frequencies for most television receivers are 45.75 MHz for picture and 41.25 MHz for sound, these frequencies are shown in their proper position in Fig. 15-7.

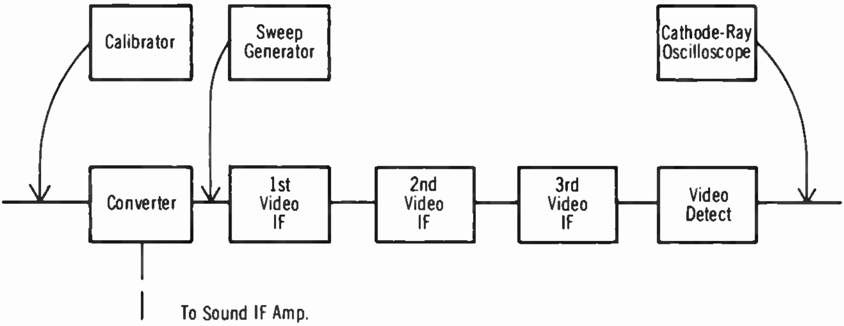


Fig. 15-6. Test equipment and receiver setup in alignment of video IF amplifier.

Fig. 15-7. Typical video IF response.

Typical Video IF Alignment

In the following description, we shall assume that the receiver under test employs standard intermediate frequencies, although under no circumstances does this assumption mean that receivers utilizing other intermediate frequencies cannot be aligned easily.

The instrument is employed as follows:

1. Couple the output cable of the calibrator loosely to the input of the mixer (see Fig. 15-6). Sufficient coupling is usually obtained when the ground lead on the output cable is connected to the receiver chassis and the *hot* lead is placed near the wiring of the mixer stage. Some television receivers, having comparatively low-gain IF amplifiers,

may require tighter coupling. Too much coupling is undesirable because detuning of the circuit may result. If the curve shape is altered when the marker signal is inserted, coupling is too tight.

2. Set the calibrator frequency exactly on 45.75 MHz. A marker pip should appear somewhere on the trace. If the oscilloscope used to observe the response curve has a wide-band video amplifier, the combination of marker pip and response curve may look like the curve shown in Fig. 15-8A. A sharper marker pip may be obtained when the high-frequency response of the oscilloscope vertical amplifier is decreased by shunting the vertical input terminals with a small capacitor (about 0.001 μF). The resulting trace is shown in Fig. 15-8B.

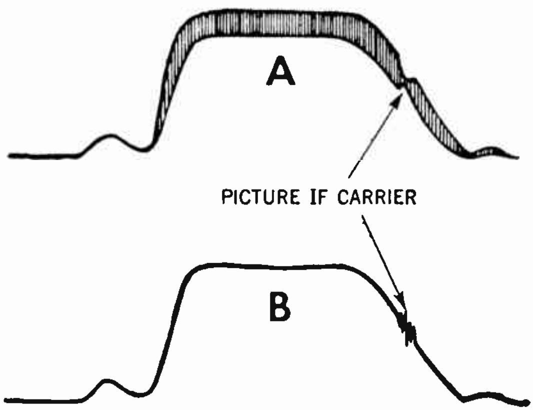


Fig. 15-8. Trace of video IF response as it might be seen on oscilloscope.

3. The position of the 45.75-MHz marker (picture IF carrier) should be approximately the 50 percent response point on the slope of the response curve, as shown in Fig. 15-8. The tuned circuits in the picture IF amplifier are adjusted so that the response curve is of the proper shape with the marker pip in the position shown in Fig. 15-8.

4. The position of any frequency in the response curve can be determined by placing the marker pip at that point and reading the frequency from the tuning-dial scale. One important frequency is that where the response just starts to drop off toward the sound-carrier frequency (see Fig. 15-9). If the variable-frequency oscillator of the calibrator is set and calibrated to the picture IF carrier and the external variable-frequency oscillator is set to a frequency that is the difference between the picture IF carrier and the frequency whose marker pip is shown in Fig. 15-9, two simultaneous markers will appear.

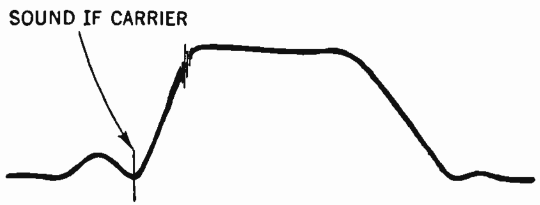


Fig. 15-9. Trace of video IF response with sound-carrier frequency marked.

These frequencies are most important in the alignment of picture IF amplifiers, and their marker pips may be kept in sight constantly to eliminate the necessity of returning and recalibrating the signal source.

Other important frequencies are the trap frequencies, shown in Fig. 15-10. Since the response of the amplifier is very low at the trap frequencies, the marker pip will disappear when it is placed

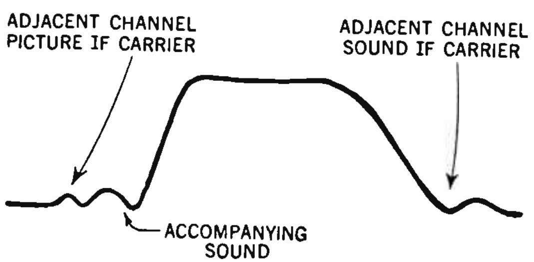


Fig. 15-10. Trace showing typical trap frequencies.

on these frequencies; however, these points can be determined on the response curve by placing the marker pip first on one side of the trap frequency, then on the other, and interpolating the center frequency.

During preliminary alignment, when the response of the amplifier at the trap frequencies has not been tuned to a minimum, a marker can be placed on the adjacent-channel sound IF carrier or adjacent-channel picture IF carrier. These markers can be obtained from a separate variable-frequency oscillator tuned to 1,500 kHz and connected to the MOD IN jack of the calibrator. With the variable-frequency oscillator of the calibrator set for a main marker at the sound or picture IF carrier frequency, markers will appear 1.5 MHz away from the main marker.

Two simultaneous marker pips may be provided by the calibrator—one at the sound IF carrier and the other at the picture IF carrier when the output of the variable-frequency oscillator is tuned to either frequency and the 4.5-MHz crystal oscillator output is used to modulate it. This may be accomplished by turning the calibrate selector to 4.5 MHz. It is advisable to maintain the RF OUT control near its maximum clockwise position whenever internal modulation is employed.

If the marker amplitude is still too high, it may be reduced by looser coupling to the amplifier input point. The size of the marker pip can be increased by turning the RF OUT control clockwise or by coupling the output cable closer to the amplifier under test, or both. Coupling that is too tight, however, may result in detuning of the IF amplifier and consequent distortion of the response.

Traps in the picture IF amplifier are adjusted by feeding the output of the television calibrator, tuned to the trap frequency, into the IF amplifier. Each trap is adjusted for minimum output, as indicated by a sensitive vacuum-tube voltmeter or digital voltmeter connected across the second detector. If the output of television calibrator is modulated by the internal audio signal, an oscilloscope may be used as an output indicator.

The general procedure in aligning picture IF amplifiers is first to set the traps and then to align the other circuits in the IF amplifier. Since any adjustment made on these other circuits in most cases will slightly detune the traps, they may have to be "touched up" during the picture IF amplifier alignment. The manufacturer's alignment instructions will again determine the exact procedure to follow.

Aligning RF Amplifiers

The radio-frequency stages of a television receiver should have a passband of about 6 MHz (see Fig. 15-11). The equipment for producing this is set up and operated according to the manufacturer's alignment instructions, and the output of the calibrator is fed into the receiver antenna terminals. Normally, the calibrator is tuned to the center frequency of the channel being aligned; then the tuning adjustments in the RF amplifier are adjusted to produce a response that is symmetrical on each side of the marker pip.

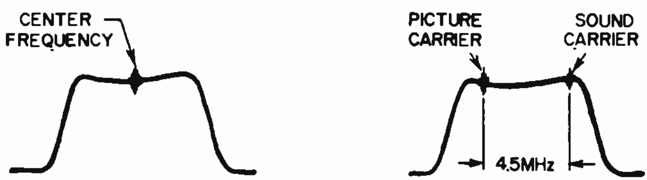


Fig. 15-11. Trace of typical RF response.

The output frequency of the calibrator is tuned to either the picture or sound carriers. When either of these frequencies is correctly marked on the RF response curve as seen on the oscilloscope, a marker pip appears at the other part of the curve if the output frequency is modulated by 4.5 MHz. To do this, the calibrate selector is set at the 4.5-MHz position, and two pips, one marking the sound carrier and the other marking the picture carrier, are seen on the response curve spaced exactly 4.5 MHz apart.

Aligning RF Oscillators

The local oscillator in the television receiver can be rapidly and efficiently aligned by feeding the sound-carrier frequency into the input of the receiver and adjusting the receiver oscillator to obtain zero output from the sound discriminator. This procedure can be followed only after the sound IF system has been correctly aligned. The procedure for a receiver using a discriminator is as follows:

1. Couple the output of the calibrator to the input of the receiver.
2. Connect a voltmeter to the output of the sound discriminator.
3. Set the calibrator to 215.75 MHz (channel-13 sound).
4. If the receiver has a fine-tuning control, it should be set at the center of its tuning range.
5. Adjust the channel-13 oscillator trimmer for zero output from the discriminator. Check this point by turning the trimmer through the correct setting. The discriminator output should be positive on one side of the proper adjustment and negative on the other.
6. Adjust the remaining channels in a similar manner. In each case, set the calibrator to the appropriate sound-carrier frequency. Since the order of alignment may differ in receivers of different makes, the manufacturer's instructions should be consulted before proceeding.
7. If the receiver uses a ratio detector, a VTVM can be connected across the stabilizing capacitor and the oscillator trimmers tuned for a maximum VTVM reading.

Aligning Sound IF Amplifiers

With the exception of the response-curve shape, the application of the calibrator to alignment of sound IF channels follows the same general procedure given in the previous paragraphs on picture IF channels. The alignment equipment is set up as shown in Fig. 15-12. The IF response, with the superimposed marker pip, is shown in Fig. 15-13 as being indicative of that to be expected from normal sound IF amplifiers.

The width of the passband can be determined as described under "General Alignment Procedure." The usual discriminator

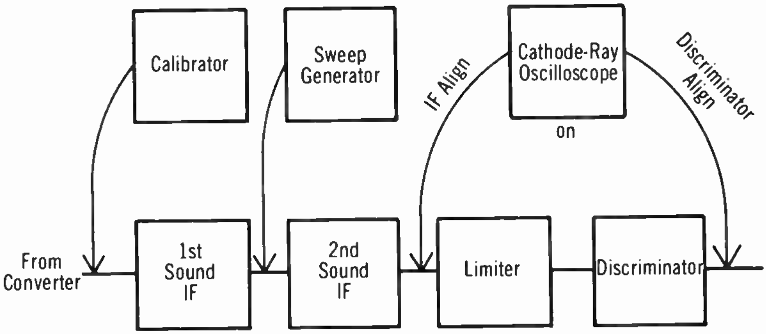


Fig. 15-12. Typical setup for sound IF amplifier alignment.

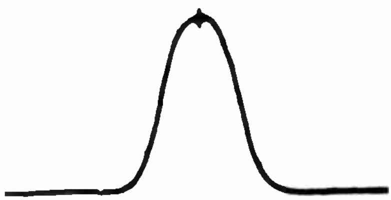


Fig. 15-13. Trace of sound IF response.

characteristic is shown in Fig. 15-14A. Figure 15-14B shows the usual discriminator response curve with the center frequency (sound IF) modulated by a 0.25-MHz frequency. Three simultaneous markers are provided by modulating the center frequency with the 0.25-MHz frequency. These marker pips are 250 kHz apart and are used to check discriminator bandwidth.

The center-marker pip may not be visible since it is at a point of zero voltage, and consequently the two visible pips will be 500 kHz apart. If the small capacitor previously shunted across the oscilloscope vertical input is removed, a trace like the one shown in Fig. 15-15B will appear. Using this trace, the serviceman can determine the important center frequency of the discriminator characteristic with relative ease. Figure 15-16 shows the various conditions of discriminator misalignment.

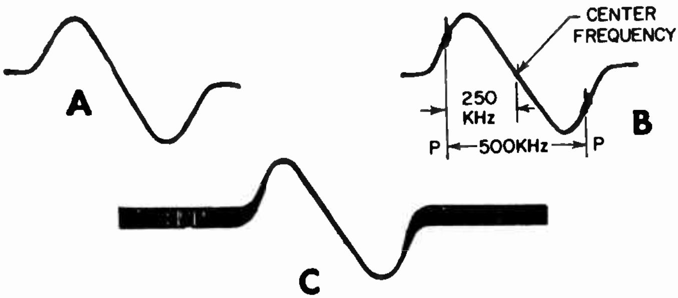
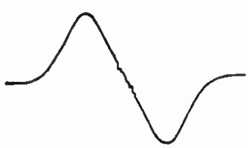


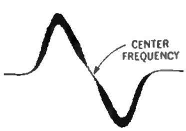
Fig. 15-14. Typical discriminator response.



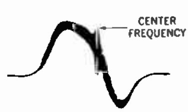
(A) With capacitor across oscillator input.

(B) Without capacitor.

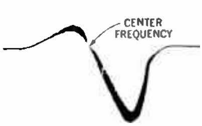
Fig. 15-15. Typical discriminator response.



(A) Correct response.



(B) Secondary resonant frequency high.



(C) Primary resonant frequency too high or resonant frequencies of other IF transformers too high.

Fig. 15-16. Response of improperly aligned discriminator circuit.

Another method of aligning the discriminator or ratio detector of television receivers is to obtain the usual response, as shown in Fig. 15-14A. The center frequency (sound IF) is then modulated by an audio frequency. An internal audio frequency is provided in many generators. When the discriminator or ratio detector has been properly aligned, the response curve seen on the oscilloscope will be similar to the one shown in Fig. 15-14A. When the center frequency is other than that provided by the generator, the response curve will be similar to that in Fig. 15-14C.

Television receivers employing intercarrier-sound IF stages may be aligned in a manner similar to the procedure described previously. Since all receivers of this kind use a sound IF frequency of 4.5 MHz, it is merely necessary to provide this frequency as the center frequency of the response curve. When the calibrator is set to 4.5 MHz, the RF output frequency is 4.5 MHz and its output may be controlled by the RF OUT control. This output is fed into the video amplifier ahead of the 4.5-MHz takeoff point. If additional markers are needed, they can be obtained by connecting the output of an ordinary variable-frequency oscillator the MOD IN jack of the calibrator.

Second-Detector and Video-Amplifier Response Check

This test portrays on the screen of an oscilloscope a trace that shows the response of, not only the video amplifier in a television receiver, but the second detector and its load as well. Equipment for the test is set up according to Fig. 15-17. The method follows:

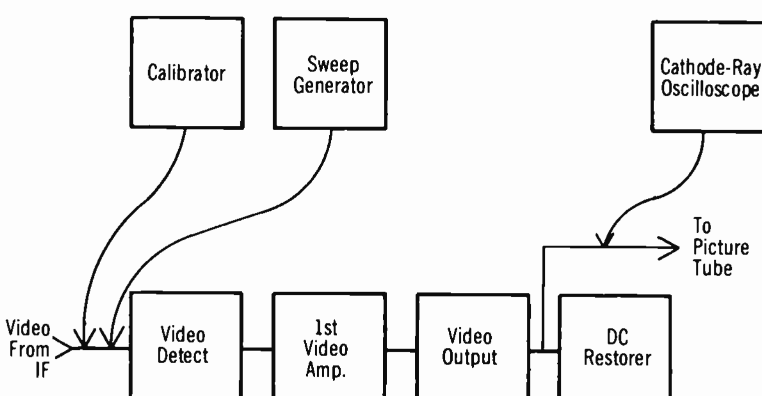


Fig. 15-17. Typical setup for second detector and video-amplifier response check.

1. Connect the outputs of the television calibrator and the sweep generator directly to the video detector stage.
2. Set the sweep generator to sweep an arbitrary band of frequencies, say 20 to 30 MHz. Tune the calibrator to 20 MHz. (These exact frequencies do not have to be used; it is necessary only to set the calibrator to a frequency that is included near the low-frequency end of the band swept by the sweep generator.) Rectification in the second detector will produce, across the detector load, a band of frequencies continuously swept from 0 to 10 MHz. This video sweep is used to check the video-amplifier response.
3. The detector probe of the oscilloscope is connected to the output of the video amplifier at the picture tube. If the oscilloscope is not equipped with a detector probe, then an external detector, using a diode or crystal rectifier, may be utilized. The detector should have, in addition to good 60-hertz, square-wave response, a low-input capacitance to preclude any detrimental effect on the video-amplifier response produced by capacitance loading of the amplifier output.

   When the picture tube is removed from its socket, the amplifier can be tested under more nearly actual conditions since the input capacitance of a well-designed detector closely approximates the input capacitance of the picture tube. If the oscilloscope has a wideband response, a detector probe will be unnecessary.
4. A trace similar to the one shown in Fig. 15-18 should appear on the screen of the oscilloscope. This trace represents the frequency versus amplification characteristic of the video amplifier and second detector. Particular frequencies along the response curve can be estimated since the length of the

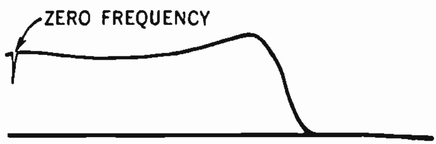


Fig. 15-18. Video-amplifier and -detector response.

entire trace is known to be representative of a video-frequency bandwidth equal to the sweep-width output of the sweep generator.

ALIGNMENT OF COLOR-TV RECEIVERS

Alignment of a color-TV receiver is much the same as for a black-and-white receiver except that the chroma section presents somewhat different requirements. With reference to Fig. 15-19, it

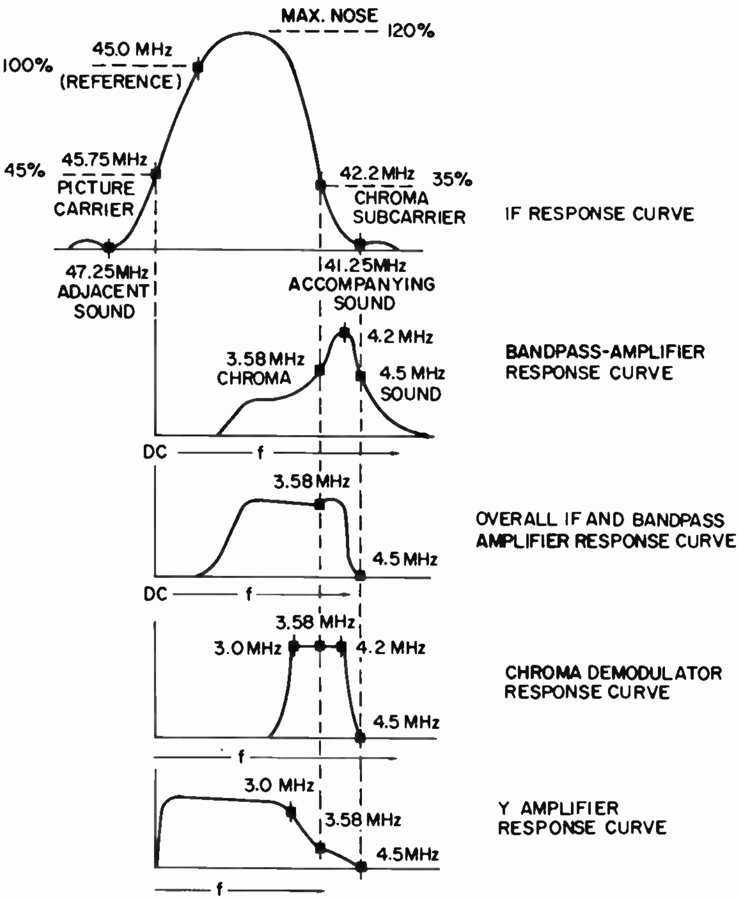


Fig. 15-19. Response of the video-signal channels.

is helpful to observe the relative frequency-response curves for the various video-signal channels of a typical color receiver. In this example, the chroma subcarrier falls at the 35 percent point on the IF curve. To compensate for chroma-sideband attenuation, the bandpass amplifier is aligned with a rising frequency response. In turn, the overall IF and bandpass-frequency response is substantially flat through the chroma-signal region.

The Y amplifier is checked in the same manner as explained previously for a video amplifier in a black-and-white receiver. Y-amplifier-response curves have different specifications for various color receivers. For example, one type of curve for a Y amplifier is seen in Fig. 15-19, whereas another receiver employs more extensive subcarrier trapping, as depicted in Fig. 15-20. Some color receivers have a picture-peaking control between the video detector and the video amplifier. The setting of this control will change the high-frequency portion of the response considerably.

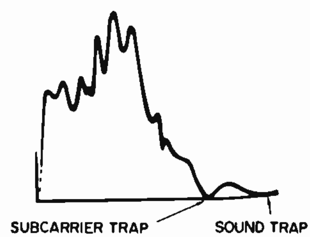


Fig. 15-20. Frequency-response curve for Y amplifier.

Figure 15-21 shows a typical chroma bandpass amplifier and a bandpass-response curve with absorption markers. The sweep-and-marker signals are applied at the video amplifier that drives the chroma-takeoff circuit. A scope is connected across the output of the bandpass amplifier (color saturation control in Fig. 15-21B). Either a low-capacitance probe or a demodulator probe can be used with scope. The frequency-response curve shown in Fig. 15-21A is an envelope display obtained with a demodulator probe. A circuit for a demodulator probe (sometimes called a *traveling detector*) is shown in Fig. 15-23.

Absorption markers may be provided in the video-frequency sweep generator, or an external marker-absorption box may be used (Fig. 15-24). The video-frequency sweep signal is passed through the marker box before it is applied to the receiver under

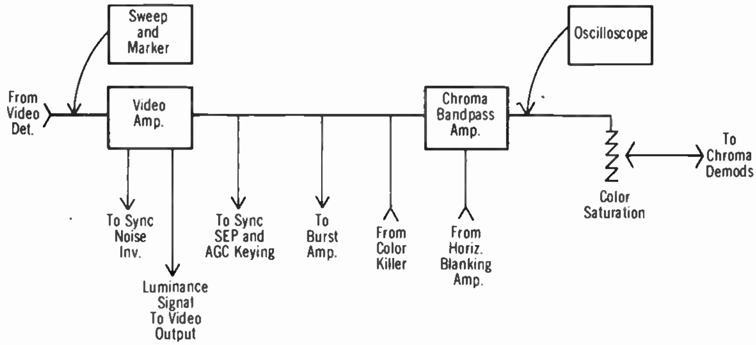


Fig. 15-21. Circuit diagram of typical bandpass amplifier.

test. Traps contained in the box (Fig. 15-25) produce notches in the frequency-response curve, as shown in Fig. 15-26. This is an envelope response, produced when a demodulator probe is used with the scope. If a low-capacitance probe is used with the scope, a video-frequency pattern appears, as depicted in Fig. 15-27. To the frequency of a marker "notch," the operator touches his finger to a terminal button (Fig. 15-24). In turn, body capacitance causes the associated notch to become more shallow and move on the pattern.

To summarize an important point, corresponding undemodulated and demodulated video-frequency-response patterns are

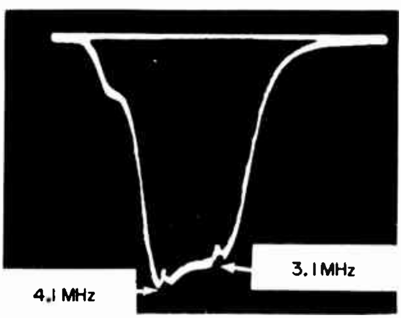


Fig. 15-22. Bandpass-response curve with comparatively little high-frequency rise.

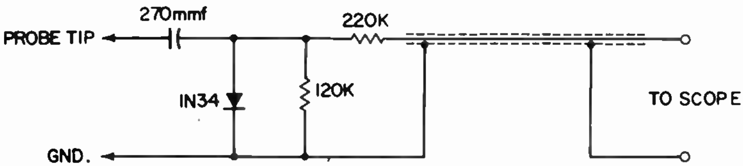


Fig. 15-23. Circuit for a demodulator probe.

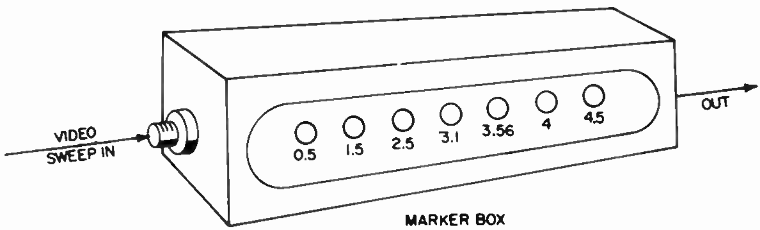
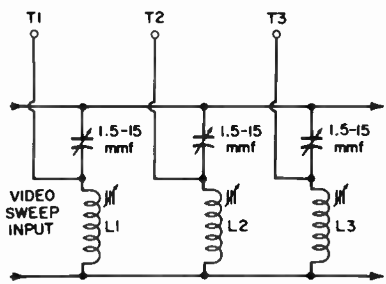


Fig. 15-24. Physical appearance of a marker box.

Fig. 15-25. Circuit configuration of a marker box for three markers.



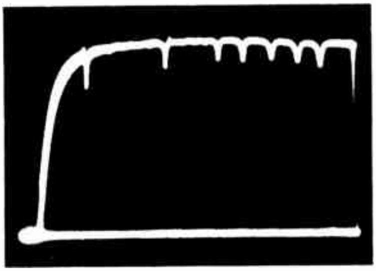


Fig. 15-26. Marker-demodulated video curve.

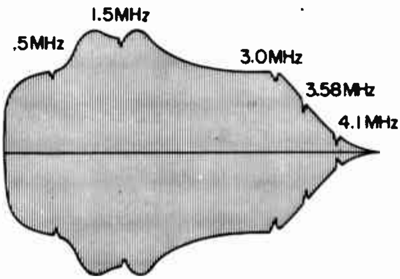


Fig. 15-27. Video-frequency pattern obtained with a low-capacitance probe.

shown in Fig. 15-28. The undemodulated pattern is obtained with a low-capacitance probe, while the demodulated response is obtained with a demodulator probe. The envelope of the response patterns is the same. If a narrow-band scope is used, a demodulator probe is necessary to avoid pattern distortion; on the other hand, if a 4-MHz scope is used, a low-capacitance probe may be employed if desired.

In the example of Fig. 15-21, three adjustments are provided to

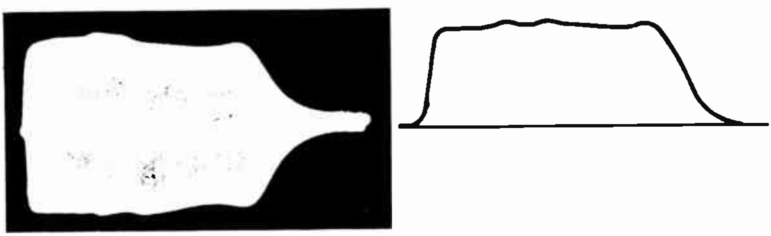


Fig. 15-28. Corresponding undemodulated and demodulated frequency-response patterns.

align the bandpass section. We observe that the curve shown in Fig. 15-21 has greater bandwidth than the one shown in Fig. 15-22. It is necessary to consult the service data for the particular receiver to determine the optimum bandwidth.

The burst amplifier has a narrow bandwidth; in other words, it is sharply tuned, with a peak frequency of 3.58 MHz. To align this stage, we simply use an unmodulated 3.58-MHz signal from a signal (or marker) generator and adjust for maximum output, as indicated by a scope or DVM. It is advisable to use a crystal-calibrated marker generator because the alignment of the burst amplifier is somewhat critical.

Figure 15-30 shows the chroma-reference oscillator and control sections. A color-bar generator is generally used for alignment. We proceed by disabling the burst amplifier so that the subcarrier oscillator is free-running. A DVM may be connected to indicate the amplitude of the subcarrier-oscillator signal, and the slug is adjusted for maximum DVM reading. This completes the first portion of the alignment procedure.

Next, we remove the short in the burst-amplifier circuit. If slug B has not been adjusted previously, it may be turned at this time to provide a maximum DVM reading, that is, aligned to resonance with the color-burst signal from the color-bar generator. Thus far, the subcarrier oscillator is only in rough alignment; in other words, the oscillator may be "pulling" appreciably, which is undesirable because the receiver will tend to lose color sync on weak incoming signals. Hence, we proceed to make a touchup adjustment of the subcarrier oscillator.

In this final step, we can connect the DVM to test point C in Fig. 15-29. It is very likely that either a positive or a negative voltage will be indicated. We adjust slug D to obtain a 0-volt indication on the DVM. A cross check can be made by reducing the output from the color-bar generator to a very low level. The color-bar display on the picture-tube screen should remain in sync. If the color bars break up into "rainbows" at a low signal level, the foregoing alignment procedure should be repeated. After the subcarrier oscillator has been checked out, we proceed to make a touchup adjustment of slug B in Fig. 15-29, if required. However, this involves the chroma demodulators, and this alignment procedure is explained subsequently.

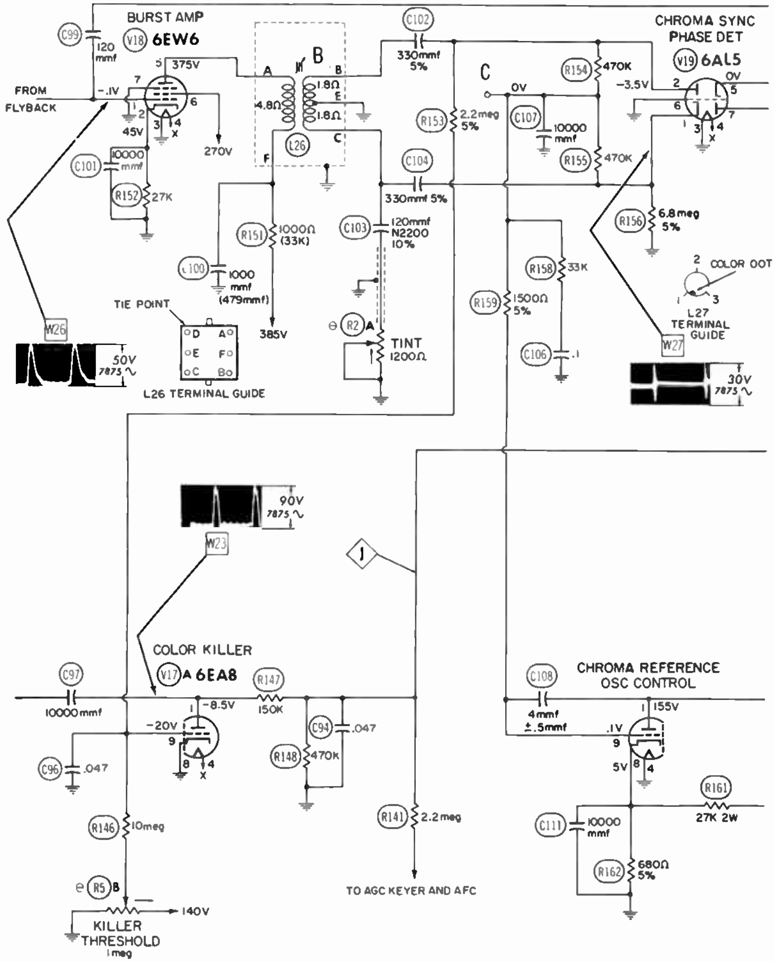
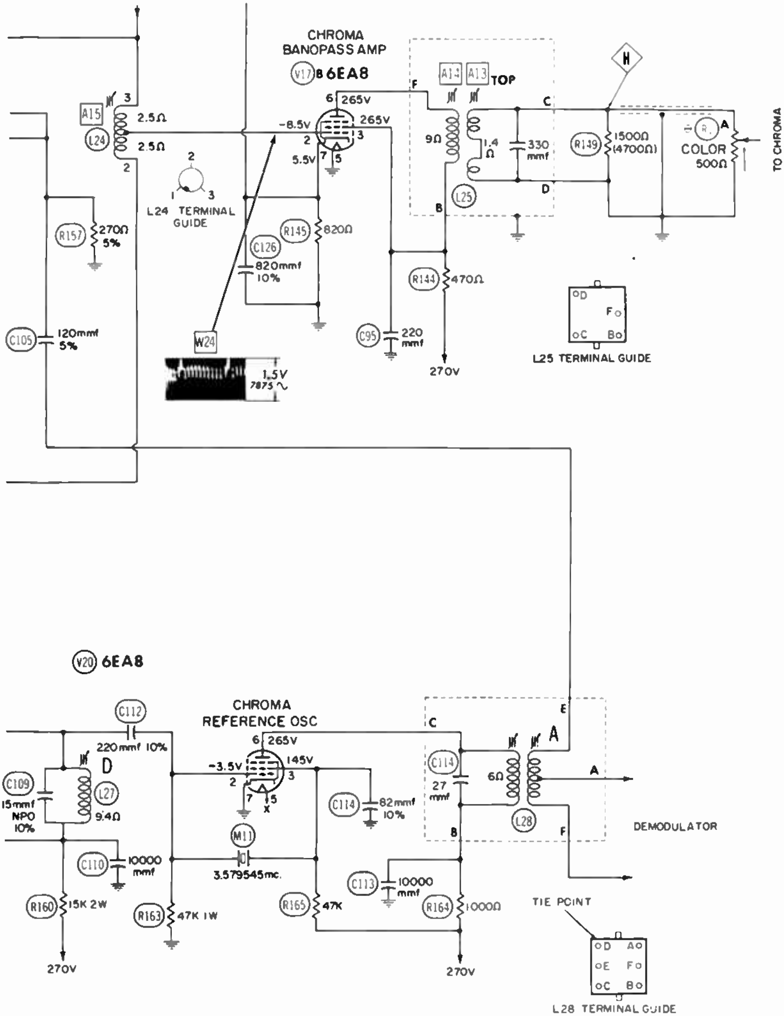


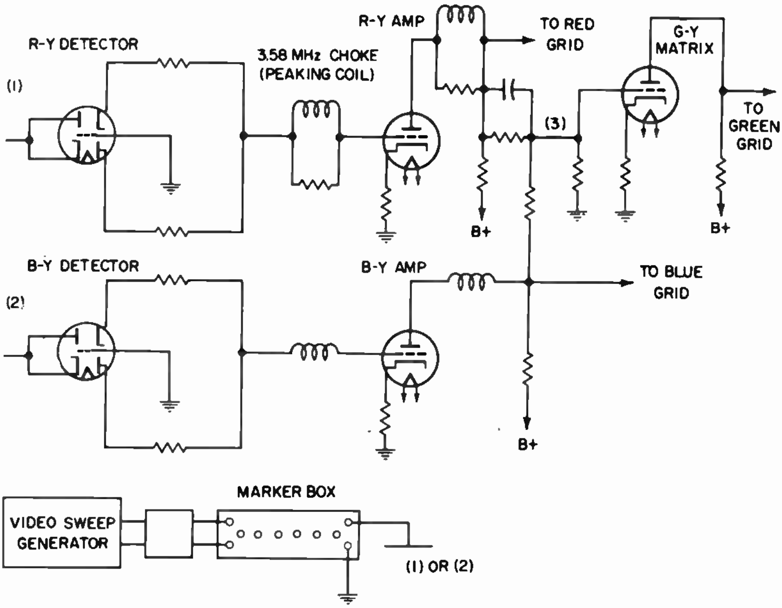
Fig. 15-29. Bandpass amplifier

Figure 15-30 shows a basic chroma-demodulator configuration. This is a simple arrangement in which the inductors are fixed-tuned. Therefore, if the frequency-response curve is not normal, there is a circuit defect, such as a faulty capacitor, off-

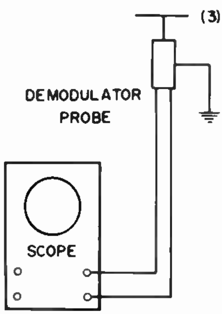


may be cut off by the color killer.

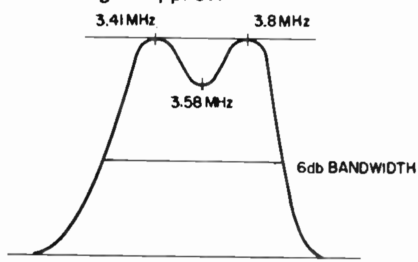
value damping resistor, or shorted turns in an inductor. It is desirable to disable the subcarrier oscillator when checking the frequency response of a chroma demodulator to avoid interference from the strong 3.58-HMz signal. Absorption markers are gener-



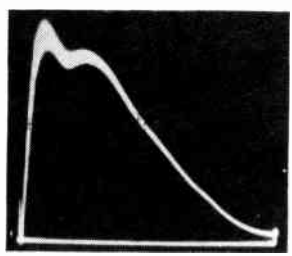
(A) Sweep and marker signal applied.



(B) Scope connected at demodulator output.



(C) Typical demodulator response curve.



(D) Display of a demodulator response curve on oscilloscope screen.

Fig. 15-30. Basic chroma-demodulator configuration.

ally used to check the bandwidth of the curve. Manufacturers of color receivers may not provide specified curves; in such a case, it may be possible to check against the curve from a receiver that is known to be in good working condition.

Phase-alignment checks are made with a color-bar generator. Most shops use a keyed-rainbow generator, which provides the signal shown in Fig. 15-31. The signal contains 11 bursts, the first of which is utilized by the color-sync section. The following 10 bursts produce color bars on the picture-tube screen, as shown in the diagram. Each burst advances in phase by 30° from the previous burst, as shown in Fig. 15-32. The color-bar signal is usually applied to the antenna-input terminals of the receiver, and a scope is connected at the output of the chroma demodulator, which is being checked for phase alignment.

Note that phase-alignment checks apply to chroma matrixes, as well as to chroma demodulators. In other words, if we are checking a G–Y signal channel, it makes no difference whether the G–Y

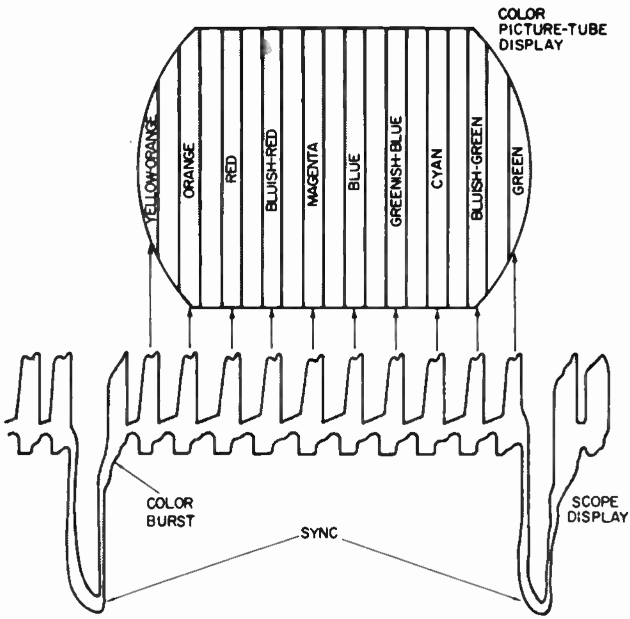


Fig. 15-31. Keyed rainbow and hues corresponding to each bar.

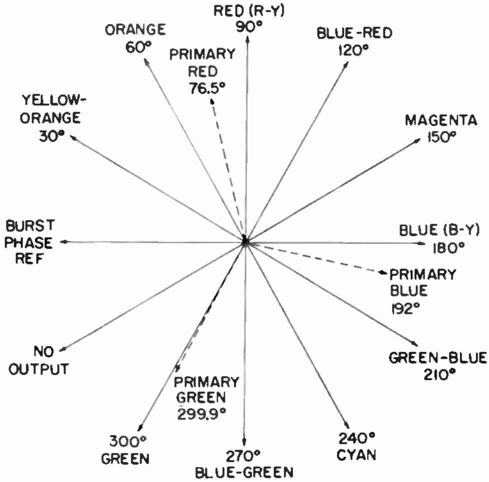


Fig. 15-32. Phase progression of rainbow signal.

signal is produced by a demodulator or by a matrix. The color picture tube is always driven by R–Y, B–Y, and G–Y signals. If the phase alignment is correct in these three channels, we observe scope patterns as depicted in Fig. 15-33. We count bars, or pips,

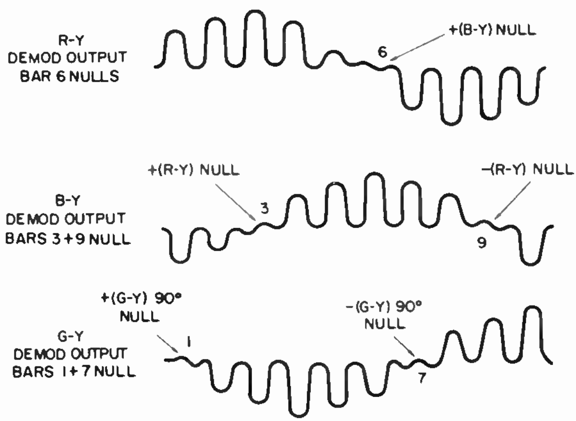


Fig. 15-33. Demodulator outputs using keyed-rainbow signal.

to check the null points. For example, an R–Y output signal should null on bar No. 6.

Occasionally, tuning slugs are provided for adjustment of phases of the injected subcarrier signals. Often, the circuits are fixed-tuned. As noted in the discussion of frequency-response curves, an incorrect pattern indicates a defective component, such as a faulty capacitor; that is, if one or more of the nulls in Fig. 15-33 occur at incorrect bars, we proceed to check the components in the associated circuit.

SUMMARY

A stage-by-stage procedure is usually followed during alignment due to external noise, which can be very troublesome. It should also be kept in mind that all pertinent data relating to the particular set to be aligned should be available for reference, and the manufacturer's alignment procedure must be followed.

The vertical-input terminals of the oscilloscope are connected across the detector, and the horizontal terminals are connected to a source of deflection voltage usually supplied by the sweep generator. When the generator is tuned to sweep the band of frequencies accepted by the IF circuit, a trace representing the response characteristics of the circuit will appear on the scope screen. The marker is used to obtain valuable information as to response and degree of accuracy.

The position of the picture IF carrier (45.75 MHz) should be at approximately the 50 percent response point on the slope of the response curve. If the marker generator is tuned exactly to the center of the passband accepted by the IF amplifier, then this marker will indicate the position of that frequency. Knowing the center frequency, the serviceman then adjusts the final tuned circuit for a trace that is of maximum amplitude.

REVIEW QUESTIONS

1. Why is the signal injected just preceding the stage under alignment?

2. How many hertz separate the sound and video IF?
3. Why should markers on response curve be observed?
4. What is the response point? What percentage?
5. What is the picture IF (in megahertz) in most TV receivers? The sound IF?

CHAPTER 16

Television Test Equipment

In the alignment and troubleshooting of a television receiver, a number of factors must be considered. The test equipment employed should be suitable for this type of work. All pertinent data relating to the television receiver to be aligned should be available for reference, and the manufacturer's alignment procedure must be followed closely.

TEST EQUIPMENT REQUIRED

At the outset it should be pointed out that no set of rules as to the number and exact specifications of the instruments required can be given here. Instead an effort will be made to give the most common type of equipment necessary in the average practice and also to explain how this equipment is used to accomplish its assigned function. (See Table 16-1.)

Table 16-1. Test Methods for Troubleshooting TV Receivers

Section	Primary Tests	Secondary Tests	
		1	2
Power supply	DVM or VTVM	Scope	- - - - -
Audio	Signal injection	DVM or VTVM	Scope
Video amplifier	Scope	DVM or VTVM	Listening test or signal injection
Vertical deflection	Scope	DVM or VTVM	6.3 VAC signal injection
Horizontal deflection	Scope	DVM or VTVM	Sawtooth signal injection
Horizontal AFC-OSC	Scope	DVM or VTVM	- - - - -
Video IF	DVM or VTVM	Signal tracing or injection	Alignment check
AGC	"Clamping" with bias supply	Scope	DVM or VTVM
RF tuner	DVM or VTVM	Signal injection	Alignment check
Sync	Scope	DVM or VTVM	- - - - -
Sound IF and FM detector	Signal injection	DVM or VTVM	Alignment check

The intelligent servicing of a television receiver requires, first, a knowledge of the operation of the receiver and, second, a knowledge of the normal waveforms to be expected in the circuits of the particular equipment. The pieces of test equipment necessary for alignment and effective troubleshooting usually found in the average television service shop are as follows:

1. Oscilloscope
2. Sweep generator
3. Signal generator
4. Digital or vacuum-type voltmeter
5. Miscellaneous test equipment

The Oscilloscope

Few instruments are of greater utility in television receiver testing than the oscilloscope. A cathode-ray oscilloscope is necessary when alignment is performed with a sweep oscillator. It can also be employed with a modulated signal generator to align wave traps and other narrow-band circuits. It is also used in the sync and sweep circuits of the television receiver to observe the fidelity of the various waveforms and ascertain their presence at various points. The amplifiers, particularly the vertical amplifier, determine the utility of any particular oscilloscope in television-receiver testing. A typical oscilloscope is illustrated in Fig. 16-1.

The best criterion of satisfactory operation is the faithful reproduction of a square pulse at a repetition rate of from 100 to 15,000 hertz/sec. Defined in terms of frequency response, which does not take into account phase discrepancies, this is roughly uniform response from 30 to 150,000 hertz.

Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 16-1. Typical triggered-sweep oscilloscope.

The synchronizing of the oscilloscope to that of the waveform being observed is accomplished through a switching arrangement from two or three possible sources: external, internal, or 60 hertz. Each switch position connects the sweep generator in the oscilloscope to the respective sources. The external position allows injection of sync through a BNC connector on the front of the instrument, which allows any pulse (whether actually derived from the trace under observation or not) of the correct frequency to synchronize the trace. It is thereby possible, through the use of a phase-shifting network, to vary the portion of the pattern at which the trace begins and so change its position on the screen. A 60-hertz sync is usually internationally provided because a larger portion of the traces encountered are some multiple or submultiple of this frequency. Internally, the signal synchronizes itself since a portion of the signal is extracted from the vertical amplifier and injected into the sweep generator.

A complete treatise on the use of the oscilloscope is beyond the scope of this chapter. However, some few basic operational procedures have been included, which may serve as a guide to the serviceman who has not used the instrument extensively.

Controls—The following controls are normally found on the oscilloscope:

1. Focus
2. Intensity
3. Vertical centering
4. Horizontal centering
5. Sync-selector switch
6. Volts/div
7. Sec/div
8. Triggering

The meaning of these labels is doubtless self-evident. Proficiency in their use, particularly in connection with 6 to 8, comes only with practice. Perhaps the greatest difficulty that will be experienced, aside from the proper interpretation of the reproduced trace, will be obtaining stability of the trace—a function of the three aforementioned controls.

Perhaps the most outstanding cause of failure to consistently obtain a stable pattern lies in the use of excessive synchronizing potentials, which may cause irregular synchronization and the loss of a portion of the desired sweep trace. In adjustment, it is improper to vaguely set the timing (sweep-repetition rate) controls and to attempt final stabilization by greatly advancing the sync control. Instead, the sec/div should be first adjusted to a moderate value and the picture stabilized by adjusting control. Should insufficient sync then be had, as evidenced by inability to "stop" the picture, then the triggering control may be advanced slightly.

It should be remembered that, for a single cycle of reproduction, the oscilloscope sweep-repetition rate must be equal in frequency to that of the waveform being observed. For two cycles of reproduction, it must be one-half. Most waveforms presented in service manuals and in manufacturers' literature show two cycles of the signal.

Necessary Characteristics—The characteristics of a test oscilloscope must of necessity be considered prior to its use for alignment and troubleshooting of a television receiver. Some of these characteristics will now be discussed.

Frequency Response: Generally commercial oscilloscopes, depending upon the particular design, have a low-frequency limit somewhere between 10 and 100 hertz and a high-frequency limit of between 100,000 hertz and 5 MHz. If the vertical-interval test signal (VITS) is to be displayed, triggered sweep is required in addition to 4.5-MHz response. (See Fig. 16-2.)

It is sometimes erroneously contended that since video frequencies in excess of 4 MHz are encountered, the oscilloscope must be responsive to this limit. Stress is placed upon the wide passband of some instruments in promotion literature. In laboratory usage, there are instruments extending as high as 60 MHz that are advantageous in specialized applications. At the same time, there are instruments giving practical satisfactory performance with response extending only to 15 MHz.

It should be realized that in general testing and servicing of monochrome receivers, it is of no advantage to observe the higher-frequency component of the video signal. These are the impulses that reproduce the fine detail of the image and that can only be interpreted from the face of the picture tube itself; their presence in the oscilloscope reproduction of the video signal means nothing.

Secondly, limited high-frequency response will cause a

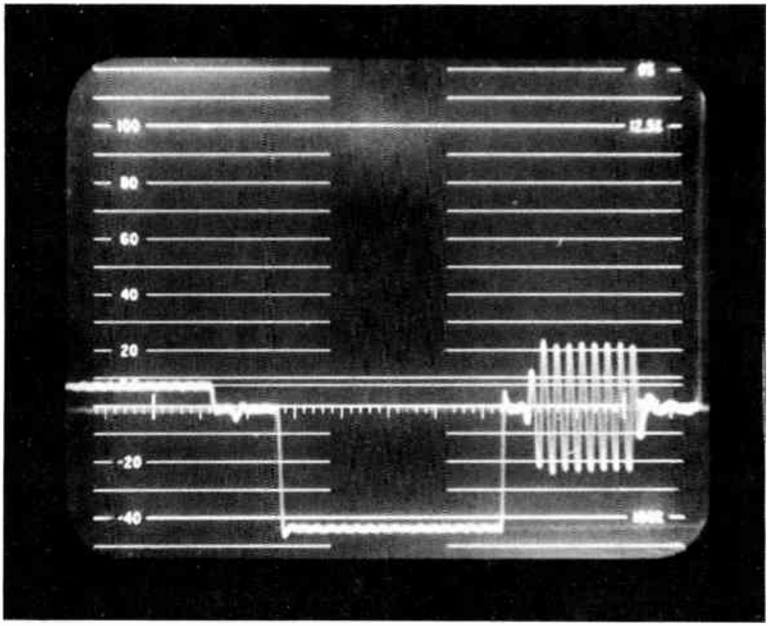


Fig. 16-2. Display of front porch, sync tip, back porch, and burst.

rounding-off of the sync pulses; therefore the question is primarily how high it will be necessary to go in order to satisfactorily reproduce them. In design and laboratory applications, it is often necessary that exactly true visualization of the wavefront be obtained, and that harmonics in the order of 120 or more be present. Receiver testing, however, permits some distortion and, furthermore, the high-frequency response of the sync circuits themselves are quite low. A typical circuit may use a plate-load resistor of 68,000 ohms and have a lumped capacity to ground of 50 μF, which gives a high-frequency cutoff of

$$f = \frac{1}{2\pi RC} = \frac{1}{6.28 \times 68{,}000 \times 50 \times 10^{-12}} = 46{,}800 \text{ hertz}$$

From this it follows that it would be of no particular advantage to use an oscilloscope with a frequency range extending to 5 MHz in such an application.

High-frequency response in the vertical-deflection amplifier might well be, for general testing and servicing, essentially flat to 100 kHz. Beyond this, the added cost is not justified by increased utility.

In the servicing of color receivers, it is sometimes necessary to observe signals at the color subcarrier frequency of 3.58 MHz. An oscilloscope response of 15 MHz is necessary.

Low-frequency response is often neglected in considering the oscilloscope, and yet it may be such that distortion is introduced. With poor low-frequency response resulting in a large amount of distortion, it is naturally impossible to judge the circuit being tested, and therefore the reproduced pulse values are of no value.

Input Cable: The input cable should always be of as low capacity as possible. Ratings are in a given number of microfarads per foot of length. The impedance of the cable is of no consequence when working at the signal frequencies encountered. It is to be anticipated that high impedance and low capacity are inseparable; but in any given cable of 100-ohms impedance, various capacities are represented. The choice of a cable should therefore be on the basis of capacity only and should not be excessively long.

Oscilloscope Loading: Quite often, it is desirable to expand the horizontal sweep so that it extends far beyond the limits of the screen. This calls for an amplifier capable of developing sweep potentials greatly in excess of that necessary to the 3 to 5 in. of active screen. Then there is the likelihood of overload and compression of the sweep at either or both ends. This may or may not be apparent by mere observation of the trace, but it may be determined definitely by placing a signal upon the vertical plates. (For a simple test, this signal could be simply placing a finger on the vertical-input terminal.) The horizontal amplifier should be such that this overloading condition is not apparent with horizontal sweep at its maximum and the horizontal positioning control rotated to extreme limits.

Testing the Oscilloscope: If it is desired to test the vertical response of an instrument prior to purchase or to determine its true operation in application, this may be done readily by applying to the vertical input the output of a variable-frequency, square-wave generator. Provided that the generator output is a true square wave, any departure therefrom on the screen is indicative of faulty operation. Frequencies should be between 30 and 15,000 hertz.

Should there be no distortion whatsoever, the vertical amplifier response is acceptable. By *distortion* is meant that the reproduction should not depart from the square wave; that is, the leading and lagging edges should be fairly straight, the corners square, and the baseline straight.

Other Features: Other features of the oscilloscope are more or less optional. It may have a 3- or 5-in. screen, although those with 3-in. screens are usually somewhat limited in other necessary requisites due to economic considerations.

Some instruments have provisions for internal sync at 60 hertz and an associated phasing device permitting the pattern to move along the frequency or time axis. These may be provided readily, however, by external devices of simple construction. It is immaterial whether the tube deflection plates are brought out to external connections since they have little application in receiver testing.

Also, the so-called Z axis is of little consequence in television-testing work. This is a connection, either directly or through an amplifier, to the control grid of the oscilloscope tube. Its function is to cut off the beam at some desired time; for example, one of the two traces obtained from sweep-generator operation may be eliminated by the application of a negative potential to this grid during the time of one of the traces. Most sweep generators now provide this blanking function internally.

After becoming thoroughly familiar with the operation of a conventional scope, the technician may wish to investigate the facilities provided by a triggered-sweep scope, shown in Fig. 16-3. For example, an expert operator can use this type of scope to pick a color burst out of a waveform and expand the burst display on the scope screen. This is a useful procedure when checking out a color-bar generator, for example. However, it must be emphasized that the most elaborate scope will be of little use to a technician who lacks an understanding of circuit action and waveform analysis. The ability to interpret waveform distortions can be gained only by persistent study and experience.

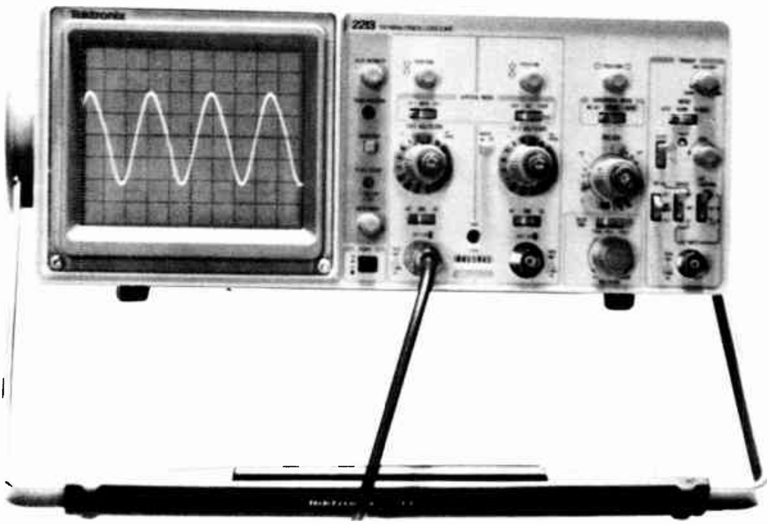


Fig. 16-3. Tektronix 2213 dual-trace, delayed-triggering oscilloscope.

Sweep Generator

In television testing and alignment, the requisites of the sweep generator are far more stringent than in other types of work owing to the higher frequencies and increased sweep width required. A typical sweep generator is shown in Fig. 16-4.

Center Frequency—The requisite for *center frequency* is that the generator should cover at least to the highest intermediate frequency of television receivers, that is, slightly under 50 MHz. This is a minimum requirement, and preferably it should extend also to the RF ranges of 220 MHz.

Sweep Width—The sweep excursion must be somewhat in excess of the greatest bandwidth encountered in television, which is 6 MHz. A sweep width of not less than ±4 MHz (8 MHz overall) with ±8 or 10 MHz being a more desirable range. Should the sweep excursion be too narrow, then the reproduced traces will be excessively broad and may not include the adjacent-channel frequencies at which traps are sometimes placed. As a

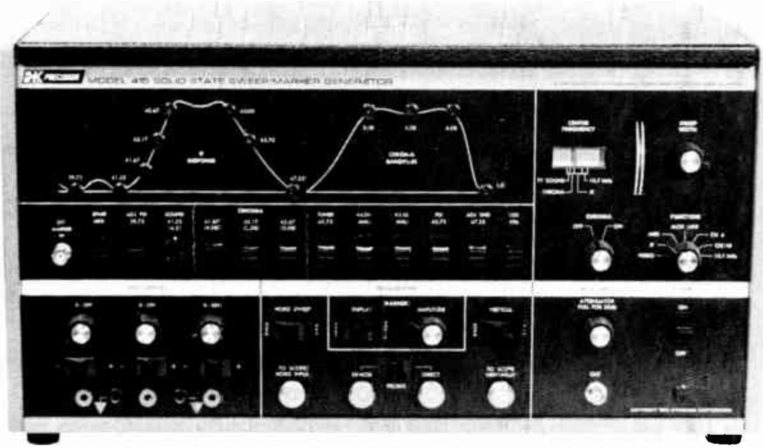
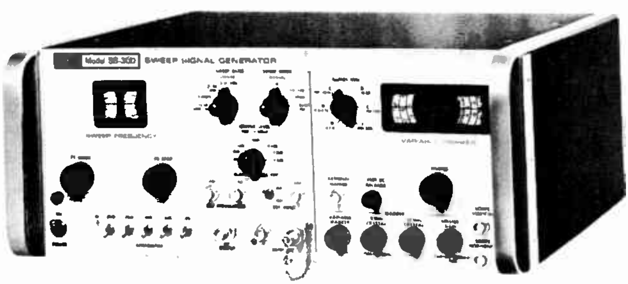


Fig. 16-4. B&K model 415 sweep/marker generator.

consequence, the two reproduced traces will merge into one where the sweep is very inadequate. A comparatively elaborate sweep generator is shown in Fig. 16-5.

Signal Generator

If the sweep generator does not incorporate internal marker circuits, it will be necessary to employ a separate signal generator (without modulation) as a means of identifying frequencies



Courtesy Jerold Electronics Corp.

Fig. 16-5. Lab-type sweep generator.

within the reproduced trace. As such, its calibration must be quite accurate. In fact, it is recommended that a crystal calibrator be used frequently since the calibration of most service-type signal generators changes from time to time. A crystal controlled calibrator is shown in Fig. 16-6.

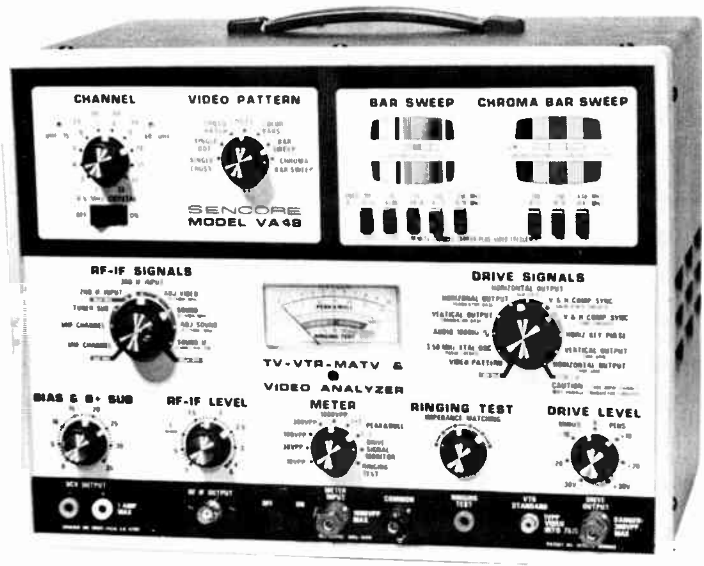


Fig. 16-6. Sencore video analyzer.

In television servicing the frequency range of the generator should be great enough to include all television channels so that the generator can be used to supply test signals at the picture and sound-carrier frequency for each television channel on which receivers will have to be adjusted. The commercial FM broadcast ban of 88 to 108 MHz should also be included. If the frequency range of the generator is restricted, it may be possible to use harmonics of the output signal for the higher frequencies. Actually, many signal generators use harmonics of a lower range to provide frequencies in the highest range.

Signal tracing through the receiver circuit may be carried out with this generator as in conventional receivers, working back toward the antenna, stage by stage, to localize a defective stage. When employing the 400-hertz output in the audio and video stages and the modulated RF signal in the IF and RF stages, the indication of normal operation is a steady tone from the loudspeaker in the sound channel while horizontal bars are produced on the screen of the picture tube for signals in the picture channel.

The audio test signal is also useful when nonimage methods of testing scanning linearity must be employed to produce horizontal bars in the picture for checking vertical linearity. A test-signal frequency of about 157.5 hertz can be used to check horizontal linearity.

Aside from frequency range and stability of calibration, there are two other points to be considered: First the output should be about 1 volt at a maximum, and attenuation down to almost zero, or about 1 μV, should be provided. Leakage is checked by connection to a sensitive receiver operating at full gain and then reducing the generator attenuator. The signal should then reduce to an imperceptible level. Second, the oscillator should be quite stable when used as a marker. Any factor that leads to instability of the oscillator within the signal generator leads to unsatisfactory results.

Marker Systems—Specifically, a marker system consists of an accurately calibrated signal source, which can be internal or external to the sweep generator. This calibrated source may take the form of a crystal oscillator of various frequencies, which can be switched in and out, permitting the calibration of the curve; or it can be a continuously variable accurately calibrated signal generator.

There are numerous marker generators on the market. When properly designed, it is a precision instrument, the function of which is to produce highly accurate marker pips to show specific frequency locations on a tuned-circuit-response curve on the oscilloscope.

The need for an accurately calibrated marker system will be seen by the fact that any response waveform, as reproduced on the oscilloscope screen, is only approximately calibrated. The center of such a trace represents the center frequency at which the sweep generator has been set. Without a marker system, extremities of the sweep can be approximated only by adding and subtracting from the center frequency the maximum frequency deviation for which the sweep generator has been adjusted.

MISCELLANEOUS TEST EQUIPMENT

Following are additional items necessary for television-receiver maintenance and troubleshooting:

Tube Tester—The *tube tester* should be preferably of the dynamic type, checking mutual conductance (Gm) of all types used, including the miniature types.

Digital Voltmeter—A *digital voltmeter* (DVM), reading volts, ohms, milliamperes, etc., should be of the high-impedance type (Fig. 16-7)—20,000 ohms/volt or better—and may be used also in

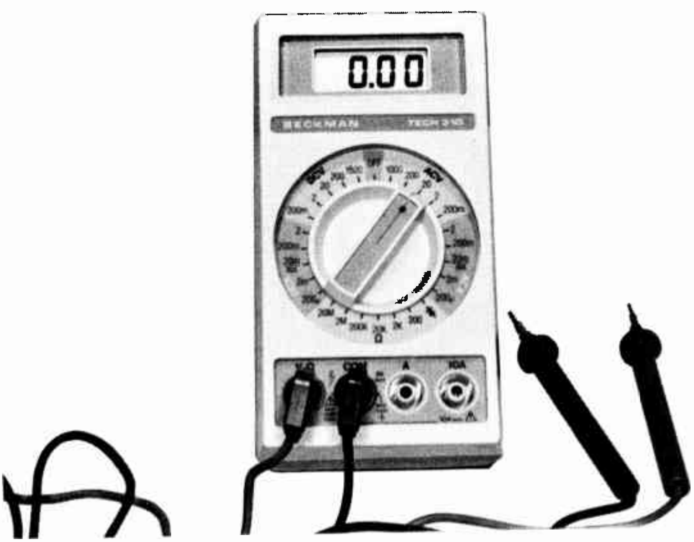


Fig. 16-7. Beckman 310 digital voltmeter.

reading high voltage by applying a multiplier. There are available high-voltage cables and test prods that have built-in multipliers to extend the range of the meter to any reasonable value. (See Fig. 16-8.)

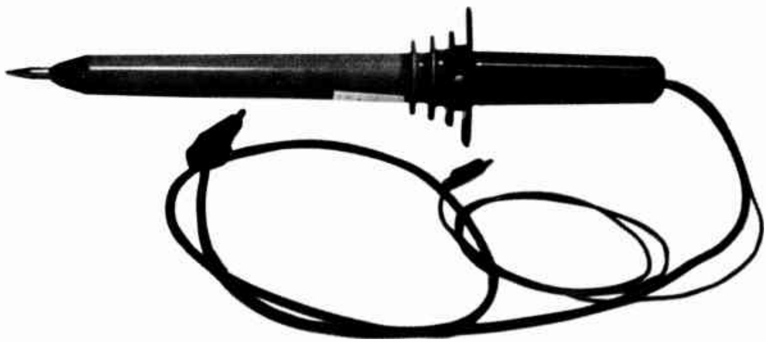


Fig. 16-8. High-voltage probe.

CRT Testers—There are many *CRT testers* on the market. These give a simple "good-bad" indication based on amount of cathode emission. Many of these instruments also provide a means of "rejuvenating" the CRT to extend its useful life.

Monochrome Picture Tubes—Monochrome picture tubes have acceleration potentials approaching 16,000 volts, which should be the minimum requirement in high-voltage meters. Color receivers will use up to 30 kV.

It must be borne in mind that even 50-μA drain (at full scale in the meter) may drop the high voltage appreciably. This may be ascertained by observing change in picture size. If the picture materially increases in size as the reading is being taken, some allowance must be made for reduction under test. The only true measure, in such a case, is by an electrostatic dc voltmeter, an instrument usually restricted to the laboratory due to cost factors.

Variable-Voltage Transformer—A variable-voltage transformer is necessary for proper voltage control. Picture size and brilliance are dependent upon line voltage, and changes are more apparent in some receivers than in others. Also, it has been noted that the line voltage in most service areas is variable over wide limits. Therefore, in adjusting the receiver, there should be some means of simulating the actual operating conditions encountered in the field. The transformer should be at least of 5 ampere size and should be the isolating type with no connection between primary and secondary. The use of an isolating transformer eliminates the shock hazard during servicing of ac-dc chassis, which have one side of the line connected directly to the chassis.

Small Tools—Small tools, including alignment tools, are essentially the same for any type of receiver, whether AM, FM, or television.

Mirror—In servicing television receivers, a mirror is often used for observation of the picture screen while making adjustments at the rear of the chassis. To prevent breakage, this may be a metallic sheet, possibly a ferrotype plate, obtainable at any photographic supply house.

Detector Probe—In checking operation or alignment in a single IF or RF stage, detection must be had before application to the oscilloscope. The detector probe may contain a tube or crystal, as long as it does not seriously introduce capacity into the circuit.

COLOR TEST EQUIPMENT

All the aforementioned test-equipment items are applicable to the servicing of color receivers. A few special pieces of test equipment are intended specifically for color servicing.

White-Dot Generator—The white-dot generator produces white dots on the screen of the receiver to permit adjustment of CRT convergence. An alternative output is a crosshatch of white lines. These outputs are available as a video signal (to be injected into the video-amplifier circuit) or as an RF signal (to be injected into the antenna terminals). Many instruments of this type also produce color bars.

Color Bar Generator—The final check, after serving a color receiver, is to see that it reproduces colors correctly. The color-bar generator produces on the screen a series of vertical bars of different colors. If the receiver reproduces these in the proper sequence (both saturation and hue), the color circuits are working properly. A typical color-bar generator is shown in Fig. 16-9.

WAVEFORM AND VECTORSCOPE GRATICULES

A *graticule* is a ruled transparency placed over the CRT face to facilitate waveform analysis. The graticule may also provide filtering for better contrast under ambient lighting conditions. For example, scope graticules are often green transmission filters.

Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 16-9. Digital IC color generator.

Some graticules are edge-lighted so that the rulings are clearly visible in low ambient lighting. Figure 16-10 shows a basic *vectorscope* graticule ruling. Only X and Y coordinates may be ruled on the graticule, or chroma values may be indicated along the vertical axis, as seen in Fig. 16-11.

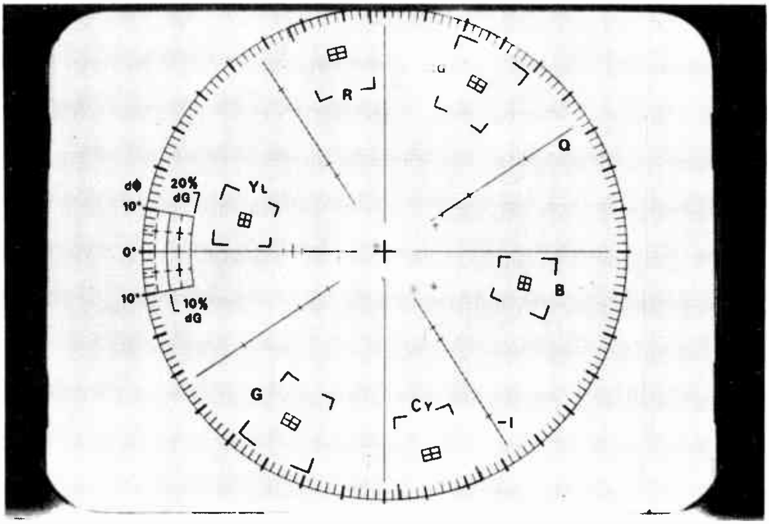


Fig. 16-10. Graticule markings of a vectorscope.

When an NTSC color-bar signal is used, the vectorscope graticule is ruled as shown in Fig. 16-12. Phases are indicated for burst, yellow, red, magenta, blue, cyan, and green. The small circles are also spaced from the center of the graticule to show the normal relative amplitudes of the color signals. Note that the burst phase will not be indicated in a vectorgram display if the burst is blanked out prior to chroma demodulation. This depends on the design of the color-TV receiver. In some receivers, the burst passes through the chroma demodulators and is indicated in the pattern. When the burst is blanked prior to demodulation, the residue of the blanking pulse is displayed. However, this residue has an arbitrary phase and does not denote the burst phase as such.

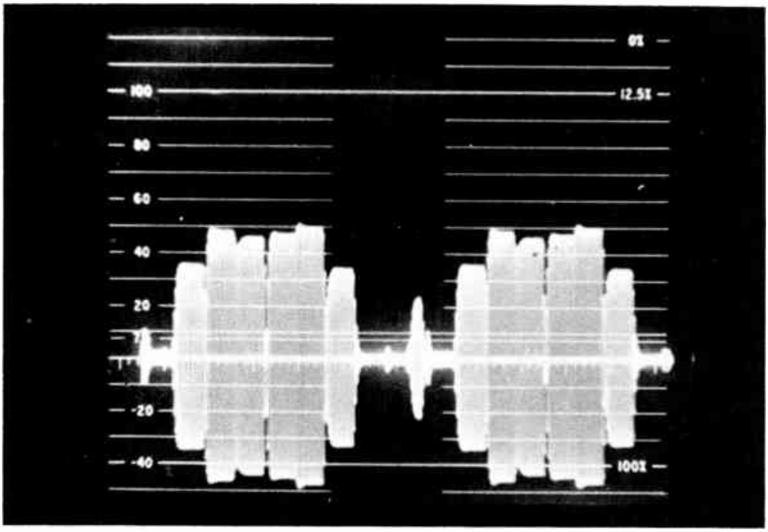
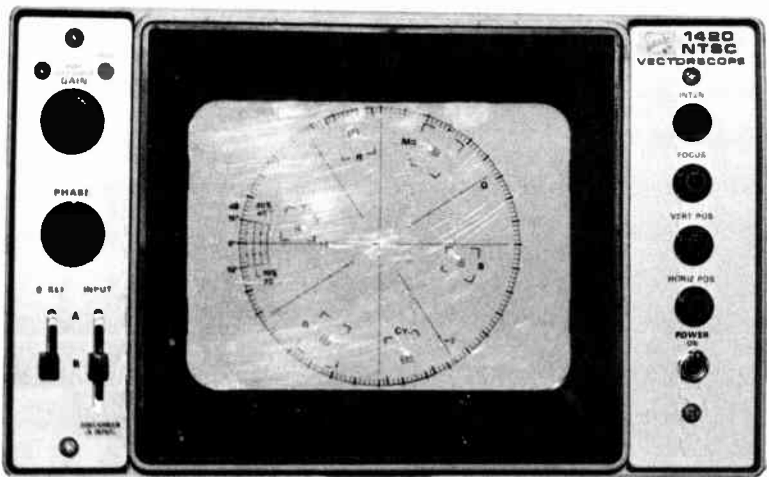


Fig. 16-11. Chroma values displayed by a waveform monitor.



Courtesy Tektronix

Fig. 16-12. Tektronix vectorscope.

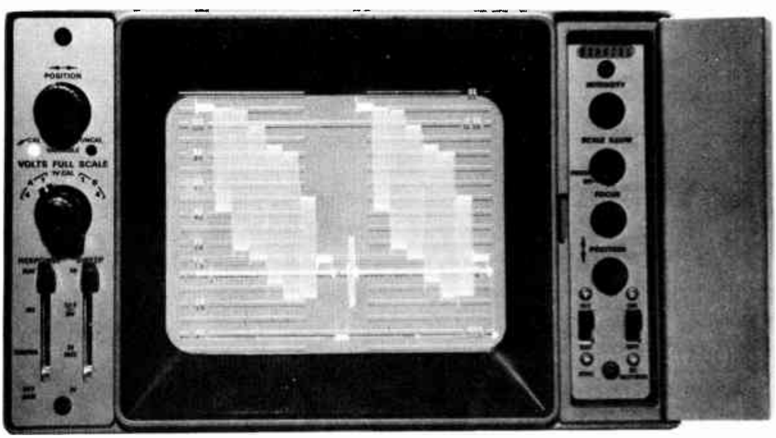
Figure 16-13 shows a waveform monitor with an NTSC color-bar signal displayed. This same display can be obtained on an oscilloscope.

SUMMARY

Test equipment necessary for alignment and effective trouble-shooting the average television in the shop are the oscilloscope, sweep and signal generators, and a vacuum-tube or digital voltmeter. The oscilloscope is used many times in many different operations, such as alignment, and in the sync and sweep circuits to observe various waveforms.

The frequency range of the generator should be great enough to include all television channels at the picture and sound carrier frequency. The commercial FM broadcast band of 88 to 108 MHz should also be included. White-dot and color-bar generators are instruments that must be included to service color-television receivers.

Meters that read volts, ohms, and milliamperes should be the high-impedance type (20,000 ohms/volt) and may be used to



Courtesy Tektronix

Fig. 16-13. Tektronix waveform monitor.

read high voltage with the use of a multiplier. Dynamic-type tube testers should be used to check the mutual conductance of all tubes, including the miniature type.

REVIEW QUESTIONS

1. What two instruments are necessary to align a television receiver?
2. What are the four basic instruments needed for trouble-shooting and the alignment procedure?
3. What are the low- and high-frequency responses of commercial oscilloscopes?
4. What should the frequency range of a signal generator be?
5. What are the requirements for a good VTVM? A good DVM?

Glossary

A glossary of television terms most commonly used is presented on the following pages. These terms will assist the reader in acquiring knowlege in interpretation of the function of the numerous components involved as well as to review the numerous technical terms used in the text.

Absorption Trap. A parallel-tuned circuit coupled either magnetically or capacitively to absorb and attenuate undesired frequencies.

Accelerator. The second anode of a cathode-ray tube. This anode, operated at a high positive potential with respect to the cathode, increases the velocity of the electron stream and is therefore referred to as an accelerating anode.

Accompanying Audio (Sound) Channel. The RF carrier frequency which supplies the sound that accompanies the picture. Also called co-channel sound frequency.

Active Lines. The lines which produce the actual picture, as distinguished from those which occur during the blanking time.

Adjacent Audio (Sound) Channel. The RF carrier frequency which carries the sound modulation associated with the next-lower-frequency television channel.

Amplitude Separation. Separation of signal components by virtue of their various amplitude excursions, usually accomplished by means of a clipper.

Aperture Mask. A thin sheet of perforated material placed directly behind the viewing screen in a three-gun color picture tube to prevent the excitation of any one color phosphor by either of the two electron beams not associated with that color. Also called Shadow Mask.

Aquadag Coating. A conductive coating formed by a colloidal solution of carbon particles on the surface of the glass envelope of picture tubes. It is also placed on the inside of the tube to collect secondary electrons emitted by the fluorescent screen. On the outside of the tube, it forms one plate (with the inner coating the second plate) of a capacitor for the high-voltage filter circuit.

Array. A combination of antennas.

Aspect Ratio. The ratio of the width to the height of a television picture. Under present television standards, the picture aspect ratio is 4 to 3.

Background. Average illumination of a scene.

Bands. This refers to a group of continuous frequencies occupying "room" in frequency space.

Bandpass Filter. An electrical network designed to transmit a band of frequencies and to reject all other frequencies.

Beam Current. The current in the stream of electrons in the cathode-ray tube. The beam current rarely exceeds 250μa and is normally less than 100μa.

Black Level. In the television receiver, the video signal is applied to the cathode-ray tube. Portions of this signal drive the tube to cutoff and produce the black portions of the picture. Those portions of the video signal which drive the tube beyond cutoff are said to be below the black level.

Blacker than Black. The region of amplitude excursion of the video signal which corresponds to levels lower than black in the picture. These are not seen on the picture tube when the background is correct. This region is occupied by sync signals.

Blanking. The process of applying voltage to the cathode-ray tube to cut off the electron beam during the retrace or flyback periods.

Blanking Pedestal. A voltage pulse used to drive the cathode-ray tube beyond cutoff during the time the spot is returning from right to left or from the bottom to the top of the picture. These blanking pedestals must be synchronized with the sweep circuits so that the beam is cut off at the right time.

Brightness. The intensity of the light produced at the screen of a cathode-ray tube.

Brightness Control. In the television receiver, the adjustment which varies the average illumination of the picture by varying the bias on the cathode-ray tube.

Brilliance. Same as brightness.

Cathode-Ray Tube. An electron tube which converts electrical energy into light by projecting a beam of electrons upon a fluorescent screen. The screen glows at the point where the electrons strike it, producing a spot of light. By deflecting the electron stream, the spot may be made to trace a pattern corresponding to the deflection voltage.

Centering. The process of moving the center of the image to coincide with the center of the cabinet opening which frames the picture.

Centering Control. An adjustment for moving the raster electrically in either a horizontal or vertical direction for framing the image.

Clamper. A circuit which establishes the DC level of a waveform (the baseline of an AC wave with a DC component). Clampers are also known as DC restorers.

Clipper. A circuit designed to remove all of a waveform above or below a given level.

Clipping Level. The amplitude level at which a waveform is clipped.

Contrast Control. An adjustment for increasing or decreasing the range of light intensities of an image by varying the amplitude of the picture signal. Contrast control in the television receiver corresponds to gain control in a sound receiver.

Composite Signal. A television signal whose waveform is composed of both video and synchronizing signals, each having different amplitude excursions.

Composite Sync. A signal composed of horizontal sync signals, vertical sync signals, and equalizing pulses.

Contrast. The total range of light intensities between the darkest and brightest portions of an image on the television screen.

Cutoff Frequency. A frequency beyond which no signals are transmitted or utilized. It may refer to an upper limit, a lower limit, or both.

Deflection. A process whereby an electron beam is deviated from its straight-line path by means of an electrostatic or electromagnetic deflection.

Deflection Coils. Coils placed around the neck of a cathode-ray tube to deflect the electron stream. The magnetic field created by the flow of current through the deflection coils causes the electron stream to deviate from its normal path. This system is electromagnetic deflection.

Demodulation. The derivation of a waveform having substantially the same form in time as the amplitude or frequency modulation of a carrier.

Differentiating Circuit. A circuit arranged to derive an output potential which is proportional to the time rate of change of the input current.

Dipole. A linear conductor whose length is approximately one-half the optimum wavelength of resonance, generally used as a television antenna. It is usually divided in the middle into two arms, where the impedance is lowest (72 ohms theoretically) for connection to a transmission line lead-in.

Director. A dipole placed in front of a dipole antenna, toward the transmitter, to narrow the angle of reception in order to obtain greater directivity. No connection is made to a director.

Dissector. A type of pickup tube used in the television camera, more properly referred to as an image dissector. The scene to be televised is focused through a system of lenses upon a photosensitive surface. The electron emission from every point on this surface is directly proportional to the intensity of the light falling upon that point. Since emission takes place simultaneously from all points on the surface, an electron image corresponding to the optical image is formed. This electron image is deflected in such a manner that a small portion of it at a time passes through a window or aperture, on the other side of which is an electron-multiplier tube. The output contains signal currents corresponding to the optical image.

Double-Tuned Circuits. These are circuits resonant to two frequencies, usually closely adjacent and coupled in such manner as to show two values of peak response, approximately equal, with a dip-response between.

Dynode. An intermediate electrode between the cathode and plate of an electron-multiplier tube. The dynode emits many secondary electrons for each incident electron striking it.

Echo. Usually a pulse signal of lower amplitude than the parent primary pulse from which it originates by reflection, and occuring at a later time than the primary pulse. An echo pulse usually exhibits some phase distortion.

EIA Signal. This is a composite signal composed of video signals and EIA sync signals. It has been standardized by the Electronic Industries Association.

Electron Gun. An arrangement of electrodes inside a vacuum tube which will direct electrons from many directions, falling upon one end of it into a beam emerging from the other end. The velocity of the emerging beam may differ from that of the entering electrons.

Electron Multiplier. A device arranged to receive electrons at an input and to deliver a greater number of electrons to an output. The increase in number is due to multiplication by secondary emission in one or more stages.

Electron Optics. This refers to the treatment of electric fields as lenses for electron beams, similar to treatment of ordinary lenses in ordinary optics in regard to ordinary light beams.

Electrostatic Scanning. The deflection of electrons from a straight-line path by means of an electrostatic field of force, which depends upon the force at a distance between electric charges.

Equalizing Pulses. Horizontal sync pulses occuring at twice line frequency and of half normal duration.

Field. The picture information produced by scanning the image from top to bottom in the standard interlaced scanning system. The odd and even lines are scanned separately, thus two fields are necessary to produce the complete picture.

Field Frequency. The number of fields scanned per second. Under present television standards, this frequency is 60 fields per second.

Field Repetition Rate. The number of fields transmitted per second.

Flyback. In cathode-ray tubes, the return of the spot between successive sweeps. Flyback is also known as retrace. In some oscilloscopes and in all television receivers, the cathode-ray tube is biased beyond cutoff during this period.

Fluorescent Screen. The face of a cathode-ray tube when the inside of the glass is coated with phosphor.

Focusing Control. The adjustment which varies the potential of the first anode in a cathode-ray tube. When it is properly adjusted, the stream of electrons converges to a sharp point at the exact instant it strikes the fluorescent screen.

Folded Dipole. A dipole antenna in which the outer ends of the two arms are connected together by a linear conductor, located at a small distance, one inch or so, away. Surge impedance is 300 ohms.

Frame. The total picture information contained in a scanned image. In the standard interlaced scanning system, one frame consists of two fields. The frame frequency is therefore equal to one-half of the field frequency, or 30 frames per second.

Frequency Band. A region of frequencies, extending between limits, each frequency being adjacent to another, without gaps.

Ghost. A duplicate image on the screen of a television receiver. The ghost image is caused by a reflected signal which arrives at the receiver a short time after the direct signal.

Halation. The glowing of a phosphor on the fluorescent screen, in a region immediately surrounding the scanning spot.

Height. The amplitude of a picture in the vertical direction.

High Voltage. A potential, usually above 500 volts, utilized usually in television equipment for accelerating or speeding up an electron beam. High voltages can be dangerous to life.

Hold Controls. The adjustments which control the free-running frequencies of the horizontal and vertical sweep oscillators in a television receiver.

Horizontal. Pertaining to the line structure of a picture in a directional parallel to the ground; normally it refers to the dimensions of width.

Horizontal Blanking. The application of cutoff bias to the cathode-ray tube during the horizontal retrace.

Horizontal Centering Control. The adjustment which permits the television image to be shifted in the horizontal direction so that it may be centered on the screen.

Horizontal Flyback. The return of the spot after each horizontal sweep. It is also known as horizontal retrace.

Horizontal Frequency. The number of times per second the spot sweeps across the screen in the horizontal direction. It is also referred to as the horizontal repetition rate. In standard television practice, the horizontal frequency is 15,750 sweeps per second.

Horizontal Resolution. The number of picture elements which can be distinguished in each line of the picture.

Horizontal Retrace. The return of the beam across the width of the image after the scanning of one line.

Iconoscope. A television pick-up tube consisting of a mosaic of photosensitive elements upon which an optical image may be projected through a window, and arranged to be scanned by an electron beam which releases the stored charges in the latent image on the mosaic and produces an electrical signal in time sequence with the scanning, at an output electrode.

Image Dissector. A device for dissecting an electron image, picture element by picture element, to derive therefrom an electrical signal arranged in a time sequence.

Image Orthicon. A television pickup tube which embodies the combination of dissector and orthicon principles to produce a very high level of light sensitivity.

Integrating Circuit. A circuit arranged to derive an output potential which is proportional to the stored value of the input current over each cycle.

Interlaced Scanning. A system of scanning in which only a fraction of the image is scanned during each field. In the standard interlaced scanning system, the odd lines and the even lines are scanned as separate fields. Each field therefore contains 262.5 or the total 525 lines.

Ion. An atom having more or less than its normal number of electrons. A balanced atom has an equal number of protons and electrons. If such an atom loses one of its electrons, it assumes a positive charge (positive ion). If the atom should gain additional electrons, it assumes a negative charge (negative ion)

Ion Trap. An arrangement of magnetic fields which will allow an electron beam to pass through but will deflect ions.

Keystone Distortion. A form of distortion which causes the television image to take the shape of a trapezoid even though the mosaic in the pickup tube is rectangular. Keystone distortion is due to the fact that the electron stream does not strike the mosaic at right angles. This distortion is normally corrected in the transmitting equipment.

L/R Circuit. A time-determining circuit in which the time constant depends on the ratio of inductance to resistance.

Line. One of the strips which make up a television image. The scanning path across the width of a television raster.

Linearity. The uniform distribution of picture elements over the total area of the image. Such uniformity can be achieved only if the sweep waveforms are linear.

Linearity Control. An adjustment in the vertical or horizontal sweep circuit which controls the linearity of the sawtooth and consequently the uniform distribution of the picture elements of the image. If the sawtooth is not linear, the spot sweeps across the screen at a varying rather than at a constant rate, with the ultimate result that the image is spread out near one edge of the picture and crowded toward the opposite edge.

Line Doubling. The technique of inserting line sync pulses at double frequency during the preparatory interval that precedes the field sync signal. The pulse width of the doubled pulse is cut in half so that integrating circuits will not store up too much energy in this period.

Line Sync. This refers to sync pulses at horizontal frequency.

Monoscope. A pattern-signal generating tube which produces in the proper circuit a time sequence of pulses equivalent to a fixed television signal. The pattern usually contains a resolution chart.

Mosaic. A photosensitive surface consisting of a large number of individual caesium-silver globules. (See Iconoscope.)

Negative Transmission. Modulation of the picture carrier in such a manner that the dark portions of the image cause an increase in radiated power and the bright portions cause a decrease.

Noise. The word noise has carried over from audio practice. It refers to random signals which produce a "salt-and-pepper" pattern over a picture which is called "noisy." Also called "snow."

Nonlinearity. The crowding of picture elements from side to side, or the crowding of lines at either top or bottom of the picture.

Odd-Line Interlace. This refers to a double interlace system in which there is an odd number of lines in each frame, and in which also, therefore, each field contains a half line extra.

Orthicon. A television pickup tube somewhat similar in structure to an iconoscope but with a translucent mosaic, a collector ring instead of a backing plate for deriving output signals, and operated on different principles whereby the scanning beam is at low velocity and always at right angles to the plane of the mosaic, which in practice avoids shading signals usually generated in the iconoscope.

Overcoupled Circuits. Usually two, resonant circuits tuned to the same frequency but coupled so closely as to exhibit two response peaks with a slight valley between, in order to obtain broad-band response with substantially uniform impedance.

Pairing. A partial failure of interlace in which the lines of alternate fields do not fall exactly between one another but tend to fall nearly on top of one another. The cause is usually improper timing of the field-deflection oscillator but is sometimes due to pickup of stray fields, and the result is a raster consisting of separated pairs of lines rather than with a continuous line structure.

Pass Band. A band of frequencies which is transmitted freely without intentional attenuation or reduction in amplitude of signals.

Peaking Coil. A small inductance placed in a circuit to resonate with the distributed capacitance at a frequency where it is required to develop peak response, as in a video amplifier near cutoff frequency.

Pedestal. A pulse, such as the blanking pulse, used in television systems. (See Blanking Pedestal.)

Phase Distortion. This refers to phase delays at different frequencies being of different magnitudes, which distorts peak values of the signal and spoils picture contrast and/or resolution.

Phosphor. The chemical coating deposited on the face of a cathode-ray tube. This chemical produces light when bombarded by electrons. Various chemicals are employed in practice to produce different colors.

Phosphorescence. Light given off by a phosphor after the exciting light or electron stream has ceased to act. The same as persistance and afterglow.

Photocell. A device for converting variations of light intensity or color into equivalent electrical variations.

Photoconductive. The name applied to a substance which changes its electrical conductivity under varying degrees of illumination.

Photoemissive. The name applied to a substance which emits electrons when struck by light. Caesium and rubidum are examples.

Pickup Tube. A tube used in the television camera for the purpose of converting the optical image into its electrical equivalent.

Picture Frequency. The same as frame frequency. In standard practice, the picture frequency is 30 per second.

Picture Element. An elementary area of an image field which represents one detail and is relatively uniform in illumination. The shape of a picture element in television is considered to be square, even though the aperture of scanning spot is round, because the lines are uniform and rectilinear. The ratio of the area of an image field to the area of a picture element is representative of the detail of a television image. For a 525-line television picture, the maximum detail which can be transmitted (with equal horizontal and vertical resolution, or square picture elements) is about 330,000 picture elements.

Polarity. This refer to the direction, plus or minus, of a potential peak of a voltage. Positive polarity of a video wave at the grid of a cathode-ray tube means that the potentials are in the right direction to give a positive or normal picture. In this case the pedestals, or blanking signals, have their peaks in the negative direction to cut off the beam current during the occurrence of black. Thus, in a positive picture, black is negative.

Polarization. This refers to the direction of vibration of the electric field of force in a radiated wave. The magnetic field of force is perpendicular to the electric, and so it also is defined.

Positive Transmission. Modulation of the picture carrier in such a manner that the bright portions of the televised scene cause an increase in radiated power, and the dark portions cause a decrease. Positive transmission is also called positive modulation.

Raster. The rectangular area scanned by the electron beam in the picture tube.

Reflections. This has two meanings in television; it refers to reflected waves from structures or other objects, and also to shadows in the picture produced by these reflected waves.

Reflector. A dipole placed behind a dipole antenna, away from the transmitter, to intensify the received signal. No connection is made to a reflector. It is usually spaced away at one-quarter wave-length for the desired signal.

Relaxation Oscillator. A relaxation oscillator is a generator of electric current waves whose amplitudes vary between negative cutoff and positive overload, as limits. In essence, a relaxation oscillator is a violently regenerative device for which many circuit arrangements exist in practice.

Retrace. The return path of the electron beam as it is swept back across the raster on the cathode-ray tube face after the completion of each scanning line and field trace.

RC Circuit. This refers to a time-determining network composed of resistors and capacitors in which the time constant is the product of resistance by capacitance.

Resolution. That quality of a television image which enables an observer to distinguish fine detail.

Resolution Chart. A test pattern containing a number of converging lines. The point on the screen where these lines seem to merge into one, determines the maximum resolution of the image. Resolution is normally indicated as the number of lines which can be distinguished as individual.

Return Time. This is the time required for retrace or flyback of the electron beam at the end of the scanning of the raster.

RF Response. This refers to the wide-band acceptance of signals in a television receiver and defines the selectivity for signals lying outside of the channel being received.

Retrace Ghost. An image produced during the retrace period. It may be due to improper blanking of the camera at the transmitter.

Return Period. The time required for the spot to return after each sweep. It is also referred to as return time.

Sawtooth. A voltage or current waveform which rises linearly to its peak value and then drops rapidly back to its starting level. The sawtooth waveform is used extensively for sweep or scanning in oscilloscopes and television equipment. If the sawtooth is not linear, the spot will move across the fluorescent screen at a varying rate and the pattern will appear to be crowded toward one side.

Scanning. The process of exploring an image, usually with an electron beam, in a predetermined pattern. In standard television practice, scanning of an image is accomplished in 525 horizontal lines.

Scanning Spot. This refers to an electrical window which scans an image field. Usually it refers to the size of the cross section of an electron beam used in a television pickup tube. In the image dissector it refers to the size of the aperture across which the extended electron image is scanned.

Separator. A clipping circuit used to remove a portion of a waveform by virtue of its amplitude. In the television receiver, a separator circuit is used to extract the synchronizing pulses from the composite signal.

Second Anode. This usually refers in television practice to the highest potential connection of a cathode-ray tube. Connections to the second anode supply the power for giving the electron beam its final, high level of energy.

Secondary Electron. An electron which has been knocked out of the surface of a metal during bombardment by other electrons, called primary electrons.

Secondary Emission. This refers to the phenomenon of knocking secondary electrons out of a surface by means of bombarding that surface with primary electrons.

Serrated Vertical Pulses. The wide vertical synchronizing pulse is divided into a number of narrower pulses in order to prevent loss of horizontal synchronization during vertical flyback.

Series Peaking. The technique of introducing a peaking coil in series with a resistor as the plate load of a vacuum tube to produce peaking at some desired frequency in the pass band.

Serrated Signal. This consists of serrated pulses for field synchronizing, plus a preparatory period in which line-doubling pulses are inserted in order to pass the integrating circuit ahead of time to give equal peaks on alternate pulses.

Shunt Peaking. The use of a peaking coil in a parallel-circuit branch to feed signals from the output load of one vacuum tube to the input load of a following tube, for the same purpose as a series-peaking circuit, but with the added advantage of splitting up the distributed capacitances of the two tubes.

Single Sideband. Transmission of a carrier and substantially only one sideband of modulation frequencies, usually the upper sideband in television practice.

Spectrum. The frequency band over which radiations are spread. It is usually used in connection with light frequencies, but may refer both to visible and invisible radiations.

Spot. This refers usually to the area on which an electron beam is focused.

Spot Size. This refers to the size of an electron beam.

Staggered Circuits. Circuits are said to be staggered when they are alternately tuned to two different frequencies, in order to obtain broad-band response. A complete stage of amplification in a staggered-circuit amplifier requires two vacuum tubes with output circuits tuned to different frequencies. The separation in frequency divided by the mean frequency of the two circuits is a coefficient of staggering and corresponds directly to coefficient of coupling in double-tuned circuits.

Staggered Tuning. Alignment of successive tuned circuits to slightly different frequencies in order to widen the overall response.

Sweep. Movement of the spot across the screen of a cathode-ray tube. Sweep is normally accomplished either by applying a sawtooth voltage to the deflection plates (electrostatic deflection) or by passing a sawtooth current through the deflection coils (electromagnetic deflection).

Sync. This is an abbreviation for synchronization and applies to a timing signal for determining the point in time at which an electrical oscillation or process will start.

Synchronization. Timing of an electrical action or waveform. In the television receiver, the horizontal and vertical sweep oscillators are synchronized or locked-in by the synchronizing pulses which accompany the transmitted signal.

Synchronization Clipper. A circuit designed to remove the synchronizing pulses from the composite signal.

Synchronization Pulses. Pulses transmitted along with the picture information and used to lock the frequency of the sweep generators in the receiver.

Synchronization Separator. Same as synchronization clipper.

Tearing. Splitting of the television picture due to improper synchronization.

Test Pattern. A fixed television image used to determine the quality and correctness of adjustment of a television system. See Resolution Chart.

Time Constant. The time required in an electrical circuit for potential or current to rise to approximately 63% of its steady, final value or to fall to approximately 37% of its initial value.

Time Delay. The time lapse between an electrical occurrence at the start of a transmission and the reproduction of this occurrence at a remote point.

Time-Determining Circuit. A circuit composed of energy-storage components having a time constant designed to introduce a predetermined amount of time delay.

Timer (Generator). An equipment designed to generate standard sync signals for synchronizing all components of deflection apparatus in a television system.

Trace. The path followed by the spot as it moves across the screen of a cathode-ray tube.

Trap. A tuned circuit used to eliminate a given signal or to keep it out of a given circuit. For instance, in the television receiver, traps in the video circuits keep the sound signal out of the picture channel. One type of trap is simply a tuned circuit which absorbs the energy of the signal to be eliminated.

Transmission Band. This refers to the band of frequencies utilized for transmitting information electrically.

Transmission Line. A two-conductor circuit having uniform characteristics for transmitting electrical signals.

UHF Waves. This refers to carrier frequencies in the ultra-high frequency spectrum between 300mc and 3000mc.

Vertical. This refers to the dimension of height in the picture.

Vertical Blanking. The application of cutoff bias to the cathode-ray tube during the vertical retrace.

Vertical Centering Control. The adjustment which shifts the image in the vertical direction so that it may be centered on the screen.

Vertical Hold. The adjustment which varies the free-running frequency of the vertical sweep oscillator in the television receiver. When this adjustment is properly set, the incoming synchronizing pulses will "lock in" the frequency of the vertical oscillator.

Vertical Resolution. This refers to the line structure of the image, that is, the number of lines or picture elements which can be resolved in the vertical direction.

Vertical Retrace. The movement of the spot from the bottom of the image to the top after each vertical sweep. The cathode-ray tube is biased beyond cutoff during this time.

Vertical Synchronization. Locking in of the vertical sweep oscillator by the incoming vertical synchronizing pulse. (See Vertical Hold).

Vestigial-Sideband Transmission. A method of transmission in which one set of sidebands is largely, but not completely, eliminated. This system is employed in commercial television practice.

Video Amplifier. The amplifier stages following the video detector in a television receiver. They are designed to have a flat response up to several megacycles.

Video Detector. The demodulator circuit which extracts the picture information from the modulated carrier.

Video Signal. This refers to a time sequence of electrical pulses generated at the signal plate of a television pickup tube.

Video Waveform. This refers to the portion of the waveform which corresponds to the light and dark values in the picture as they are transformed into an electrical signal, but does not include the synchronizing waveform.

Viewing Distance. This refers to the best distance to view a television picture from the standpoint of seeing all the detail which the picture is capable is resolving.

Visible Spectrum. That portion of the spectrum of electromagnetic radiations which is visible to the human eye.

Wave-Shaping Circuit. A circuit which alters the form of an electric wave to a different form.

Wedge. A convergent pattern of black-and-white lines equally spaced, and used as a television test pattern.

Width. The horizontal dimension of the television image.

Width Control. The adjustment which varies the horizontal size of the television picture. This is accomplished by controlling the amplitude of the horizontal sawtooth.

Yoke. An arrangement of deflection coils, usually including two sets of two coils each, for producing the magnetic deflection field for the electron beam in a cathode-ray tube.

Index

A

B

C

U

The Audel® Mail Order Bookstore

Here's an opportunity to order the valuable books you may have missed before and to build your own personal, comprehensive library of Audel books. You can choose from an extensive selection of technical guides and reference books. They will provide access to the same sources the experts use, put all the answers at your fingertips, and give you the know-how to complete even the most complicated building or repairing job, in the same professional way.

Each volume:

- **Fully illustrated**
- **Packed with up-to-date facts and figures**
- **Completely indexed for easy reference**

APPLIANCES

HOME APPLIANCE SERVICING, 4th Edition

A practical book for electric & gas servicemen, mechanics & dealers. Covers the principles, servicing, and repairing of home appliances. 592 pages; 5½x8¼; hardbound.
Price: $15.95

REFRIGERATION AND AIR CONDITIONING LIBRARY, 2nd Edition—2 Vols. Price: $30.90

REFRIGERATION: HOME AND COMMERCIAL

Covers the whole realm of refrigeration equipment from fractional-horsepower water coolers, through domestic refrigerators to multi-ton commercial installations. 656 pages; 5½x8¼; hardbound. **Price: $16.95**

AIR CONDITIONING: HOME AND COMMERCIAL

A concise collection of basic information, tables, and charts for those interested in understanding troubleshooting, and repairing home air-conditioners and commercial installations. 464 pages; 5½x8¼; hardbound. **Price: $14.95**

OIL BURNERS, 4th Edition

Provides complete information on all types of oil burners and associated equipment. Discusses burners—blowers—ignition transformers—electrodes—nozzles—fuel pumps—filters—controls. Installation and maintenance are stressed. 320 pages; 5½x8¼; hardbound. **Price: $12.95**

Use the order coupon on the back of this book.

All prices are subject to change without notice.

AUTOMOTIVE

AUTOMOBILE REPAIR GUIDE, 4th Edition

A practical reference for auto mechanics, servicemen, trainees, and owners. Explains theory, construction, and servicing of modern domestic motorcars. 800 pages; 5½x8¼; hardbound. **Price: $14.95**

AUTOMOTIVE AIR CONDITIONING

You can easily perform most all service procedures you've been paying for in the past. This book covers the systems built by the major manufacturers, even after-market installations. Contents: introduction—refrigerant—tools—air conditioning circuit—general service procedures—electrical systems—the cooling systems—system diagnosis—electrical diagnosis—troubleshooting. 232 pages; 5½x8¼; softcover. **Price: $7.95**

DIESEL ENGINE MANUAL

A practical guide covering the theory, operation and maintenance of modern diesel engines. Explains diesel principles—valves—timing—fuel pumps—pistons and rings—cylinders—lubrication—cooling system—fuel oil and more. 480 pages; 5½x8¼; hardbound. **Price: $12.95**

GAS ENGINE MANUAL, 2nd Edition

A completely practical book covering the construction, operation, and repair of all types of modern gas engines. 400 pages; 5½x8¼; hardbound. **Price: $9.95**

BUILDING AND MAINTENANCE

ANSWERS ON BLUEPRINT READING, 3rd Edition

Covers all types of blueprint reading for mechanics and builders. This book reveals the secret language of blueprints, step by step in easy stages. 312 pages; 5½x8¼; hardbound. **Price: $9.95**

BUILDING MAINTENANCE, 2nd Edition

Covers all the practical aspects of building maintenance. Painting and decorating; plumbing and pipe fitting; carpentry; heating maintenance; custodial practices and more. (A book for building owners, managers, and maintenance personnel.) 384 pages; 5½x8¼; hardbound. **Price: $9.95.**

COMPLETE BUILDING CONSTRUCTION

At last—a one volume instruction manual to show you how to construct a frame or brick building from the footings to the ridge. Build your own garage, tool shed, other outbuildings— even your own house or place of business. Building construction tells you how to lay out the building and excavation lines on the lot; how to make concrete forms and pour the footings and foundation; how to make concrete slabs, walks, and driveways; how to lay concrete block, brick and tile; how to build your own fireplace and chimney. It's one of the newest Audel books, clearly written by experts in each field and ready to help you every step of the way. 800 pages; 5½x8¼; hardbound. **Price: $19.95**

Use the order coupon on the back of this book.

All prices are subject to change without notice.

GARDENING & LANDSCAPING

A comprehensive guide for homeowners and for industrial, municipal, and estate grounds-keepers. Gives information on proper care of annual and perennial flowers; various house plants; greenhouse design and construction; insect and rodent controls; and more. 384 pages; 5½x8¼; hardbound. **Price: $9.95**

CARPENTERS & BUILDERS LIBRARY, 4th Edition (4 Vols.)

A practical, illustrated trade assistant on modern construction for carpenters, builders, and all woodworkers. Explains in practical, concise language and illustrations all the principles, advances, and shortcuts based on modern practice. How to calculate various jobs. **Price: $39.95**

Vol. 1—Tools, steel square, saw filing, joinery cabinets. 384 pages; 5½x8¼; hardbound. **Price: $10.95**
Vol. 2—Mathematics, plans, specifications, estimates. 304 pages; 5½x8¼; hardbound. **Price: $10.95**
Vol. 3—House and roof framing, layout foundations. 304 pages; 5½x8¼; hardbound. **Price: $10.95**
Vol. 4—Doors, windows, stairs, millwork, painting. 368 pages; 5½x8¼; hardbound. **Price: $10.95**

CARPENTRY AND BUILDING

Answers the problems encountered in today's building trades. The actual questions asked of an architect by carpenters and builders are answered in this book. 448 pages; 5½x8¼; hardbound. **Price: $10.95**

WOOD STOVE HANDBOOK

The wood stove handbook shows how wood burned in a modern wood stove offers an immediate, practical, low-cost method of full-time or part-time home heating. The book points out that wood is plentiful, low in cost (sometimes free), and nonpolluting, especially when burned in one of the newer and more effecient stoves. In this book, you will learn about the nature of heat and its control, what happens inside and outside a stove, how to have a safe and efficient chimney, and how to install a modern wood burning stove. You will learn about the different types of firewood and how to get it, cut it, split it and store it. 128 pages; 8½x11; softcover. **Price: $7.95**

HEATING, VENTILATING, AND AIR CONDITIONING LIBRARY (3 Vols.)

This three-volume set covers all types of furnaces, ductwork, air conditioners, heat pumps, radiant heaters, and water heaters, including swimming-pool heating systems. **Price: $38.95**

Volume 1
Partial Contents: Heating Fundamentals . . . Insulation Principles . . . Heating Fuels . . . Electric Heating System . . . Furnace Fundamentals . . . Gas-Fired Furnaces . . . Oil-Fired Furnaces . . . Coal-Fired Furnaces . . . Electric Furnaces. 614 pages; 5½x8¼; hardbound. **Price: $13.95**

Volume 2
Partial Contents: Oil Burners . . . Gas Burners . . . Thermostats and Humidistats . . . Gas and Oil Controls . . . Pipes, Pipe Fitting, and Piping Details . . . Valves and Valve Installations. 560 pages; 5½x8¼; hardbound. **Price: $13.95**

Volume 3
Partial Contents: Radiant Heating . . . Radiators, Convectors, and Unit Heaters . . . Stoves, Fireplaces, and Chimneys . . . Water Heaters and Other Appliances . . . Central Air Conditioning Systems . . . Humidifiers and Dehumidifiers. 544 pages; 5½x8¼; hardbound. **Price: $13.95**

HOME-MAINTENANCE AND REPAIR: Walls, Ceilings, and Floors

Easy-to-follow instructions for sprucing up and repairing the walls, ceiling, and floors of your home. Covers nail pops, plaster repair, painting, paneling, ceiling and bathroom tile, and sound control. 80 pages; 8½x11; softcover. **Price: $6.95**

HOME PLUMBING HANDBOOK, 2nd Edition

A complete guide to home plumbing repair and installation, 200 pages; 8½x11; softcover. **Price: $7.95**

MASONS AND BUILDERS LIBRARY, 2nd Edition—2 Vols.

A practical, illustrated trade assistant on modern construction for bricklayers, stonemasons, cement workers, plasterers, and tile setters. Explains all the principles, advances, and shortcuts based on modern practice—including how to figure and calculate various jobs. **Price: $24.90**

Vol. 1—Concrete Block, Tile, Terrazzo. 368 pages; 5½x8¼; hardbound. **Price: $12.95**

Vol. 2—Bricklaying, Plastering Rock Masonry, Clay Tile. 384 pages; 5½x8¼; hardbound. **Price: $12.95**

PLUMBERS AND PIPE FITTERS LIBRARY, 3rd Edition—3 Vols.

A practical, illustrated trade assistant and reference for master plumbers, journeymen and apprentice pipe fitters, gas fitters and helpers, builders, contractors, and engineers. Explains in simple language, illustrations, diagrams, charts, graphs, and pictures the principles of modern plumbing and pipe-fitting practices. **Price: $32.85**

Vol. 1—Materials, tools, roughing-in. 320 pages; 5½x8¼; hardbound. **Price: $11.95**

Vol. 2—Welding, heating, air-conditioning. 384 pages; 5½x8¼; hardbound. **Price: $11.95**

Vol. 3—Water supply, drainage, calculations. 272 pages; 5½x8¼; hardbound. **Price: $11.95**

PLUMBERS HANDBOOK

A pocket manual providing reference material for plumbers and/or pipe fitters. General information sections contain data on cast-iron fittings, copper drainage fittings, plastic pipe, and repair of fixtures 288 pages; 4x6 softcover. **Price $9.95**

QUESTIONS AND ANSWERS FOR PLUMBERS EXAMINATIONS, 2nd Edition

Answers plumbers' questions about types of fixtures to use, size of pipe to install, design of systems, size and location of septic tank systems, and procedures used in installing material. 256 pages; 5½x8¼; softcover. **Price: $8.95**

TREE CARE MANUAL

The conscientious gardener's guide to healthy, beautiful trees. Covers planting, grafting, fertilizing, pruning, and spraying. Tells how to cope with insects, plant diseases, and environmental damage. 224 pages; 8½x11; softcover. **Price: $8.95**

UPHOLSTERING

Upholstering is explained for the average householder and apprentice upholsterer. From repairing and regluing of the bare frame, to the final sewing or tacking, for antiques and most modern pieces, this book covers it all. 400 pages; 5½x8¼; hardbound. **Price: $12.95**

WOOD FURNITURE: Finishing, Refinishing, Repair

Presents the fundamentals of furniture repair for both veneer and solid wood. Gives complete instructions on refinishing procedures, which includes stripping the old finish, sanding, selecting the finish and using wood fillers. 352 pages; 5½x8¼; hardbound. **Price: $9.95**

ELECTRICITY/ELECTRONICS

ELECTRICAL LIBRARY

If you are a student of electricity or a practicing electrician, here is a very important ahd helpful library you should consider owning. You can learn the basics of electricity, study electric motors and wiring diagrams, learn how to interpret the NEC, and prepare for the electrician's examination by using these books.

Use the order coupon on the back of this book.

All prices are subject to change without notice.

WELDER/FITTERS GUIDE

Provides basic training and instruction for those wishing to become welder/fitters. Step-by-step learning sequences are presented from learning about basic tools and aids used in weldment assembly, through simple work practices, to actual fabrication of weldments. 160 pages; 8½x11; softcover. **Price $7.95**

FLUID POWER

PNEUMATICS AND HYDRAULICS, 3rd Edition

Fully discusses installation, operation and maintenance of both HYDRAULIC AND PNEUMATIC (air) devices. 496 pages; 5½x8¼; hardbound. **Price: $10.95**

PUMPS, 4th Edition

A detailed book on all types of pumps from the old-fashioned kitchen variety to the most modern types. Covers construction, application, installation, and troubleshooting. 480 pages; 5½x8¼; hardbound. **Price: $14.95**

HYDRAULICS FOR OFF-THE-ROAD EQUIPMENT

Everything you need to know from basic hydraulics to troubleshooting hydraulic systems on off-the-road equipment. Heavy-equipment operators, farmers, fork-lift owners and operators, mechanics—all need this practical, fully illustrated manual. 272 pages; 5½x8¼; hardbound. **Price: $8.95**

HOBBY

COMPLETE COURSE IN STAINED GLASS

Written by an outstanding artist in the field of stained glass, this book is dedicated to all who love the beauty of the art. Ten complete lessons describe the required materials, how to obtain them, and explicit directions for making several stained glass projects. 80 pages; 8½x11; softbound. **Price: $6.95**

Use the order coupon on the back of this book.

All prices are subject to change without notice.