Basic TV Course

GEORGE KRAVITZ

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Course

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To Bernice and Marvin

CONTENTS

CONTENTS

INTRODUCTION

TELEVISION is a fascinating subject and easy to learn. You need not be a mathematician or college professor; with your knowledge of electronics you have an excellent background for learning basic television theory.

As you read through this book, you'll learn how monochrome television works. In Chapter 1, you'll become familiar with the way the picture is traced on your television screen. Looking behind the screen, in Chapter 2, you'll examine the inner workings of the picture tube. Picture and sound controlled by the rf signal transmitted by the television broadcast station are covered in our study of the signal makeup in Chapter 3. Our first view of the receiver circuit, in block-diagram form, appears in Chapter 4. Chapters 5 through 8 deal principally with circuits that process the TV signal as it travels from antenna to picture tube. This is followed by a review – in Chapter 9 in which a comprehensive diagram gives you a better understanding of the circuits in a typical television set. Synchronization, sweep, sound and power supply circuits are discussed in Chapters 10 through 14 while Chapter 15 is devoted to the latest circuits in transistorized portable TV. The book concludes with a quick summary of the entire subject for review.

In this book we will consider "electron flow" and "current flow" as being one and the same thing. We will show it as flowing from minus to plus because that's what it does. We think this will make it as easy as possible to visualize the circuit theory correctly.

To the people who lent assistance and encouragement during the preparation of this volume, the author would like to express his gratitude. Our thanks to English expert Margaret Allston who reunited the split infinitives, and to secretary Lucille Kelly who

1

FORMING THE PICTURE

● ●

Turn on your television set.

All right. Have you tuned in a picture? Fine! You're now ready to learn how a picture is formed on your television screen, and you'll be amazed at how easy it is to understand.

Take a close look at your television screen. Notice that the picture consists of lines? Well, each line has light parts and dark parts. When you move back to watch the entire screen, the light and dark parts of all the lines blend together to form a picture.

Questions you'll probably ask are, "How are the lines formed?" and "How are parts of each line changed from light to dark?" Those are good questions because the answers involve an electronic wonder!

This may seem fantastic, but each line on your screen is traced by just one tiny spot of light! That's right! One spot of light, smaller than the letter "o" on this page, traces *every* line you see on your television screen. The spot starts its trip at the top of your screen. With incredible speed, the spot streaks across the screen from left to right. (Remember — we are facing the screen from the outside.) After reaching the right side, the spot darts back to the left side to trace a new line in your picture. Although just one lone spot of light traces *every* line in your television picture, the spot moves *so fast* that you see a complete picture; *you see all the lines at the same time!*

To help you understand the behavior of the spot on the television screen, a man named Charlie agreed to perform a simple experiment. You can see Charlie shining a flashlight on a wall in Fig. 101-a. He moves the flashlight beam so fast, from left to right, that we see a solid streak of light on the wall. You can compare the line of light on the wall with one line in a television picture.

Expanding the experiment, Charlie is helped by his friend Joe

in Fig. 101-b. By pulling the flashlight down, as Charlie sweeps the beam horizontally, Joe helps produce several lines of light, one under the other.

Of course, Charlie can't swing his flashlight fast enough to produce the illusion that many lines are on the wall. But the simple experiment shown in Fig. 101 helps you visualize the way a spot of light is swept on your television screen.

Just as a flashlight beam can be moved both sideways and downward at the same time, the spot on your television screen is simultaneously moved sideways and downward. Also, just as a flashlight beam produces a moving spot of light on a wall, an electron beam inside your picture tube produces the moving spot on your television screen.

White, black and shades of gray

As it moves across your television screen, the spot changes in brightness. For this reason, you see light and dark parts on each line. Let's explain.

When a line shows a black area, the spot is shut off. If dark gray appears on a line, the spot glows dimly. The lighter the shade of gray, the brighter the spot. When white appears on a line, the spot is at full brilliance. Therefore, black, all shades of gray, and white (on every line) are formed by just one little spot that changes in brightness.

Let's review the way a spot traces a picture on your television screen:

A. The spot appears in the upper left-hand corner of your screen.
B. The spot streaks across the screen from left to right. In this way, the first line of the picture is traced.
C. The spot traces all the lines in the picture.
D. The spot changes in brightness. In this way, the picture is traced.

There are 525 lines in a picture. If the lines were scanned in sequence (lines 1, 2, 3, 4, etc.), the scanning system would be called *progressive scanning*. But progressive scanning is *not* used. Instead, interlaced scanning is used. Interlaced scanning, which involves alternate tracing of all odd lines and all even lines, will be explained later in this chapter. First, however, you should learn how a strip of movie film, projected on a screen, shows a motion picture. When you understand how movies work, you'll have excellent background knowledge for learning more about the television picture.
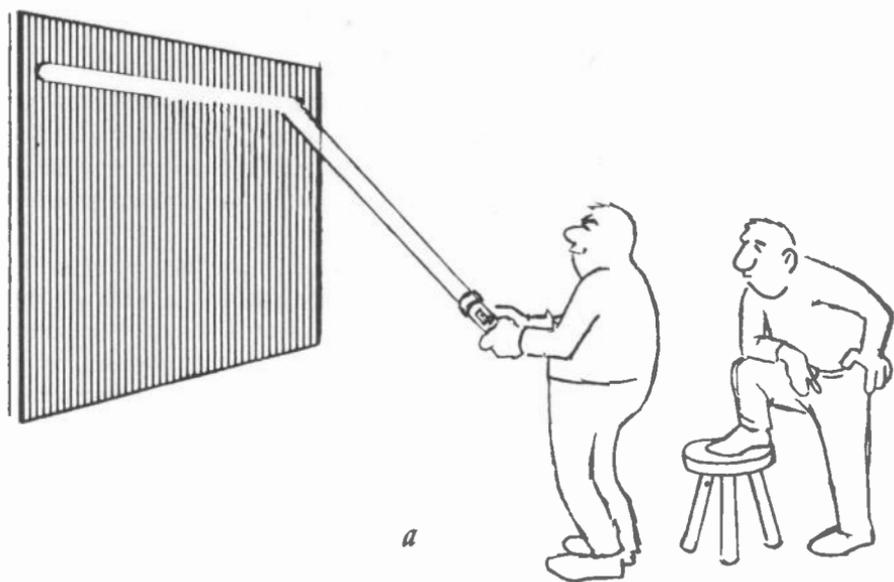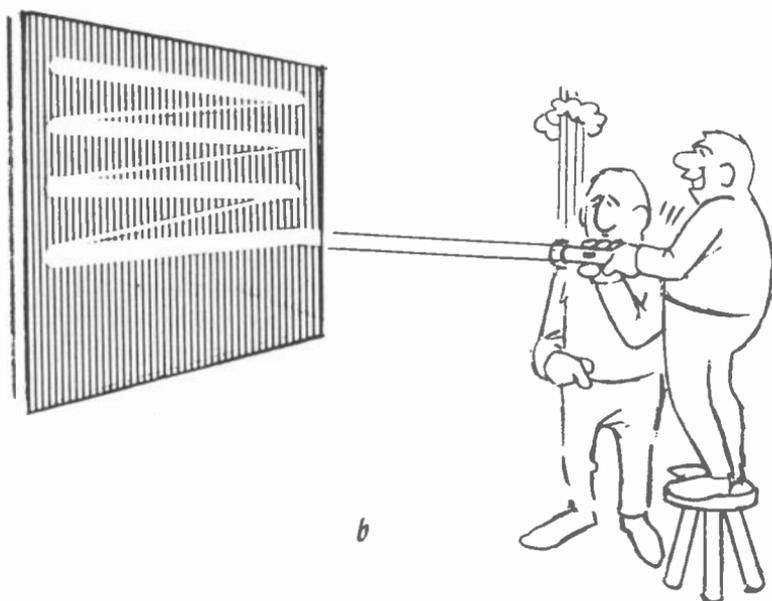
Fig. 101. *The horizontal streak of light on the wall (a) may be compared to a single line on a television picture tube screen. When the flashlight is pulled down (b), as it is swept horizontally, several streaks of light are seen.*

How movies work

In Fig. 102 you can see a strip of movie film. Notice the series of still pictures. Each picture is called a *frame*. In the illustration, each frame is numbered so that we can refer to specific frames in this discussion. Now, let's see how the series of frames produce the illusion of motion pictures.

When you watch the screen, you see one frame flashed after the other. For a fraction of a second, you see frame 1. This picture remains *motionless* on the screen for an instant. Next, the screen is blanked out for an instant. During this blanking interval, frame 2 is quickly pulled into place in the projector. Blanking the screen prevents you from seeing the film move when frame 2 follows frame 1. When frame 2 is in place in the projector, the screen is again illuminated and you see frame 2 motionless on the screen. Then, the process repeats; the screen is blanked during the instant when frame 3 is quickly pulled into place. In this manner, all frames are projected on the screen in sequence. Frames are projected at the rate of 24 per second.

Because the screen is blanked when each frame is pulled into place, the screen illumination flickers on and off. Although you would see motion, you would also see annoying flicker if a 24-times per second blanking rate were used. The flicker is eliminated by increasing the blanking rate. This is done by blanking the screen an additional time during the projection of *each* frame. Thus, the screen is blanked during each film pulldown period and again during the 1/24th second when the frame appears motionless on the screen. As a result, the picture on the screen flickers on and off 48 times per second. You don't see the flicker because your eyes retain an image for a fraction of a second after the image is removed. This characteristic of the eye is called *persistence of vision* and it enables you to see flickerless motion pictures. Similarly, we make good use of persistence of vision when watching television because the TV picture also flickers on and off. To prevent flicker in both movies and television, the blanking time must be sufficiently short and the flicker must occur at a sufficiently rapid rate.

To summarize, here is what appears on the movie screen:

A. Frame 1, motionless for 1/24 second. The picture is blanked once during the period it appears on the screen.
B. A blanking interval, during which frame 2 is pulled into place.

Fig. 102. *Individual frames in a strip of movie film. Each frame shows the action slightly advanced.*
(Allied Artists Picture Corp.)
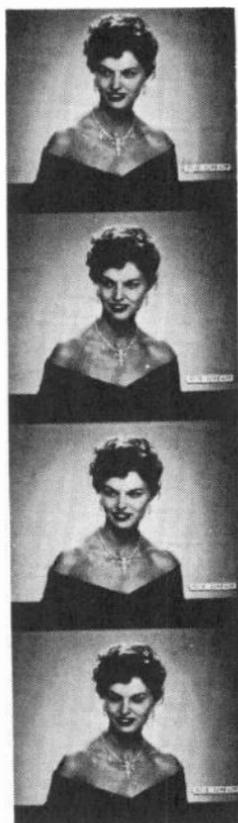
C. Frame 2, motionless for 1/24 second. The picture is blanked once.

D. A blanking interval, during which frame 3 is pulled into place.

E. Frame 3, motionless ... etc.

Note that the film is moved in a start–stop fashion. You see each frame in rapid sequence; each frame shows the action slightly advanced. You get the illusion that you see one moving picture — actually you see 24 pictures each second.

Interlaced scanning

Let's return to our study of the television picture, now that you've learned how a sequence of frames, in a motion picture, gives the illusion of motion.

At the beginning of this chapter, you learned that the television picture consists of many lines. In this way, the television picture

is different from the picture projected in a movie theatre. Another difference is the fact that a projected movie frame appears as a complete picture during each instant it is flashed on the screen. A television picture is traced by a spot of light. Now let's see how the lines are traced.

When the spot traces a television picture, it does so in this manner:

A. The spot traces line 1 of the picture.
B. The spot traces line 3.
C. The spot traces line 5.

The spot traces all the odd lines of the picture. When the spot reaches the bottom of the picture, it has traced 262.5 lines. The
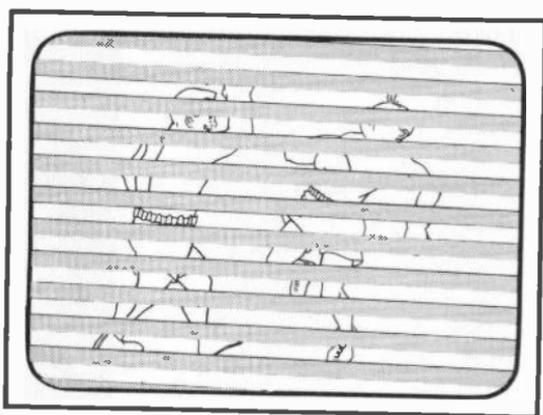
Fig. 103. *This is the picture traced by the spot during the odd-line field.*

262.5 lines are called *one field* of the picture. Thus far, we've talked about the odd-line field.

After the spot traces all the odd lines, the screen is blanked and the spot is quickly returned to the top of the screen again. The time during which the spot travels back to the top of the screen is called the *vertical retrace period*. The timing of this period is such that the spot reaches the top center of the screen when it again traces lines in the picture. But, on this second tracing, the spot traces

A. Line 2.
B. Line 4.
C. Line 6 . . .etc.

The spot traces all 262.5 *even* lines of the picture. When the spot completes the tracing of all even lines and is at the bottom of

the picture, it has traced the *even-line field*. The screen is then
blanked again, the spot is returned to the top left-hand corner of
the screen, and the tracing repeats. This method of scanning,
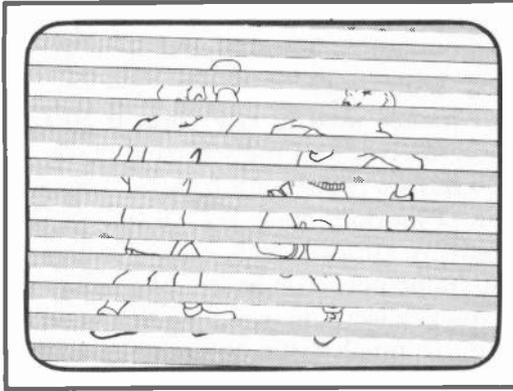
Fig. 104. *This is the picture traced by the spot during the even-line field.*

whereby the odd lines and even lines are alternately traced, is
called *interlaced scanning*.

After both the odd-and even-line fields have been scanned, the
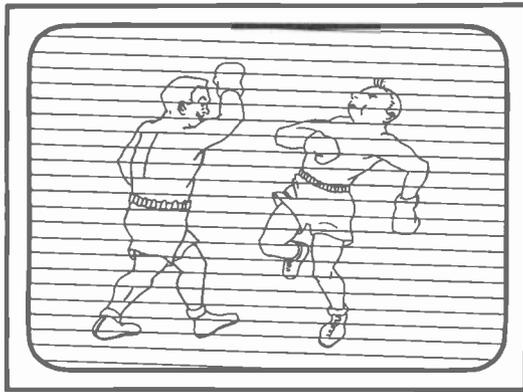
Fig. 105. *When combined, the odd and even fields are called one frame.*

spot has given us *one frame* of the television picture. Note the
use of the word "frame," borrowed from motion pictures, to indicate one complete picture that appears in a split second. In television, two fields (odd line field and even line) make one frame.

In Figs. 103, 104 and 105, you can see how two fields, one traced
after the other, show all the lines of the picture. The odd-line

field is shown in Fig. 103, and the remaining even lines in Fig. 104. When watching the television screen, you see both fields at the same time, or one frame, as in Fig. 105. Just a small number of lines are shown. Fig. 106 illustrates how the lines are interlaced and retraced.

Why interlaced scanning?

The frame frequency used in television is 30 frames a second. It was chosen because it is half the standard power-line frequency. Furthermore, 30 frames per second is more than adequate to produce the illusion of motion. Now, if each line in the picture were scanned progressively (lines 1, 2, 3, etc.), pictures could be transmitted at the 30-frame-per-second rate, but flicker would be seen. If the frame frequency were increased to eliminate flicker, the spot would have to move much faster to scan the entire picture in a shorter time period. This would result in the need for greater bandwidth. To conserve bandwidth while providing good, flicker-less pictures, the interlaced method of scanning is used. With interlaced scanning, the screen is blanked 60 times per second to eliminate flicker. The field frequency, therefore, is 60 fields per second.

Synchronization of the picture

Each particle of picture information, represented by white, gray or black, is called a *picture element.* On your TV screen, each element must correspond in position with each element of the picture produced in the broadcast station. In other words, your picture must be in step with or *synchronized* with the one produced in the station. Later in this text we will tell you how the broadcast station transmits pulses to synchronize every line in the picture, and how every picture element appears in the correct place, at the correct time, on your television screen.

Active and inactive lines

When you watch television, you don't see all 525 lines. About 488 lines carry picture information. These are called *active lines.* The 37 blanked lines are called *inactive lines.* Roughly, half the inactive lines are at the top of the screen; the other half are at the bottom. Inactive lines exist so that you won't see the line distortion inherent at the top and bottom of the picture.

The raster

When you turn on your set and have the brightness turned up, the screen will be illuminated whether a station is tuned in or

not. The illuminated area is called the *raster*. When you receive a station, the spot of light is swept horizontally and vertically in a definite pattern, and is synchronized by the broadcast station. When a station is not being received (as would be the case after signoff time), the spot is swept horizontally and vertically never-
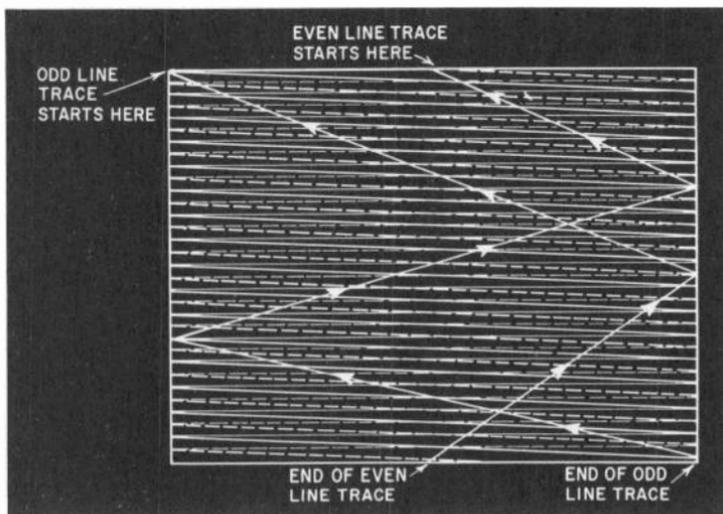
Fig. 106. *For simplicity only a small number of the 525 lines are shown in this basic interlaced scan. The vertical sweep causes the downward tilt of the horizontal lines.*

theless. Circuits within the receiver keep the spot constantly in motion to distribute energy evenly within the picture tube.

You'll see the term raster used frequently in troubleshooting charts. When you read the symptom "no raster," it means that there is no light on the screen even when the brightness control is fully turned up.

Aspect ratio

The television picture is 4 units wide by 3 units high. This ratio is called the *aspect ratio*. The picture in the studio camera measures 4 x 3 units; the picture on your television screen should have a 4 x 3 width-to-height ratio to produce a properly proportioned picture. In most receivers, the sides and corners of the picture do not appear on the screen to permit maximum use of the area on the face of the picture tube. Therefore, it is difficult to measure the aspect ratio produced by most sets. However, if height, width and linearity are adjusted when a test pattern is tuned in, you can receive the correct aspect ratio by adjusting for the best

test pattern possible. Fig. 107 shows a test pattern. Most sets won't produce a perfect test pattern; you should adjust for a pattern which resembles Fig. 107 as closely as possible. The wedges in the test pattern should be as close to equal length as possible; the circle should be as round as possible.

Fig. 107. *Ideal test pattern. Adjust sweep size and linearity for a pattern that most closely resembles the one shown. Don't expect perfection.*
(CBS Television Network)

More information on frequencies

Earlier, we gave the television frame frequency as 30 frames per second and the field frequency as 60 fields per second. Because the spot is pulled down from the top of the screen to the bottom to trace one field, a spot pulldown force in the receiver operates at the rate of 60 cps. The energy for this force is produced by a vertical oscillator which generates the 60 pulses-per-second *vertical sweep frequency*. The output signal of this oscillator is shaped so that the spot is pulled down at a linear rate and retraced rapidly after the spot reaches the bottom of the screen.

The spot is pulled across the screen, from left to right, to trace one line at the very fast speed of 57.5 microseconds. Because the spot is retraced in just 6 microseconds, it takes 63.5 microseconds for a one-line trace and retrace. To sweep the spot sideways, horizontal scanning energy is generated at the rate of 15,750 pulses-per-second by the horizontal oscillator within the receiver. This

is the *horizontal scanning frequency*. As with the vertical oscillator, the output of the horizontal oscillator is shaped so that the spot is moved across the screen in linear fashion, and the spot is retraced rapidly.

The vertical and horizontal oscillators in your receiver are *not* precision circuits. Therefore, when a station is not tuned in, the vertical oscillator operates at *approximately* 60 pulses a second and the horizontal oscillator at *approximately* 15,750, and both oscillators are subject to frequency drift. When you tune to a station, however, both vertical and horizontal oscillators are synchronized by the signal and each operates in a very precise manner.

Windup

Obviously, the tiny spot of light gets pushed around quite a bit. But it's not pushed in any old way. The spot is pushed so that it traces lines in an orderly manner. It starts at the top and traces all odd lines. After tracing each line, it must be shut off and snapped back to the starting point of the next lower line (retraced). When it's through with all the odd lines, the spot is again shut off and pulled up to the middle of the top of the screen. Now it traces even lines. Again, after tracing each even line, the spot is shut off and retraced.

The spot has another job also. It has more to do than merely trace lines. It changes in strength so that it can trace a picture. Turn the spot on full blast and you have white. Make the spot slightly dimmer and you have gray. Shut the spot off, and black is seen on the screen. This variation in scanning spot intensity is called *modulation*. And, in going from white to gray to black, the spot traces a picture. Its job: to trace each line and to vary in intensity exactly as a spot varies in the camera. The spot on your TV screen, therefore, must be perfectly synchronized with the scanning spot in the camera.

This chapter deals with the formation of a picture because most circuits in a TV receiver exist for the purpose of pushing the spot, in a controlled manner, and varying its intensity. For this reason, the device that produces the picture, the picture tube, is our next topic.

QUESTIONS

1. What type of scanning is used in television?
2. How many lines are contained in a single picture field?
3. How many fields make a frame?
4. What is meant by the vertical retrace period?
5. How many lines are contained in a single field?
6. What is the frame frequency per second?
7. What is the field frequency per second?
8. What is the total number of lines transmitted?
9. How many of these lines are active?
10. How many of these lines are inactive?
11. What is a raster?
12. What is the aspect ratio?
13. What is the frequency of the vertical sweep?
14. How long does it take to sweep a single line?
15. What is the retrace time for a single line?
16. What is the frequency of the horizontal sweep?
17. What is the word used to describe variations in scanning-spot intensity?

2

HOW THE PICTURE TUBE WORKS

● ●

H ERE's an easy way to learn how the picture tube works.
Let's imagine we're going to make a picture tube. By talk-
ing about one item at a time as the tube is assembled, its function-
ing will be made clear.

Before starting our imaginary picture-tube assembly, you should
know that there are two types of picture tubes. One type is called
electrostatic; the other type, *electromagnetic.* In this chapter, we'll
discuss the electromagnetic picture tube because it is the one used
in every popular large-screen television receiver made today. Later
in the chapter, the electrostatic picture tube will be mentioned
briefly. (Electrostatic cathode-ray tubes are used in test instruments
such as the oscilloscope.)

The first thing we need is a glass bulb or tube. Fig. 201-a shows
an empty one. Notice that the sides of the tube form an angle
of 90°. Within the picture tube, an electron beam will be deflected
at this angle. Therefore, the angle is called the *deflection angle.*
Often, you'll hear the tube called by its deflection angle. For ex-
ample, a picture tube with a 90° deflection angle (with its bell
flared at about 90°) is called a "90° picture tube." A picture tube
with a 110° deflection angle is called a "110° picture tube." Be-
cause modern picture tubes are rectangular, the deflection angle
is measured from one diagonal edge to the other, as in Fig. 201-b.

Now that we have the glass bulb, let's add a phosphor coating to
the inside surface of the front of the picture tube. This coating
forms the screen you can see from the front. The phosphor is a
fluorescent material. This means it gives off light when struck by
a stream of electrons.

NECK

90°

90°

FLUORESCENT
COATING

CATHODE

FILAMENT (HEATER)

a

b

c
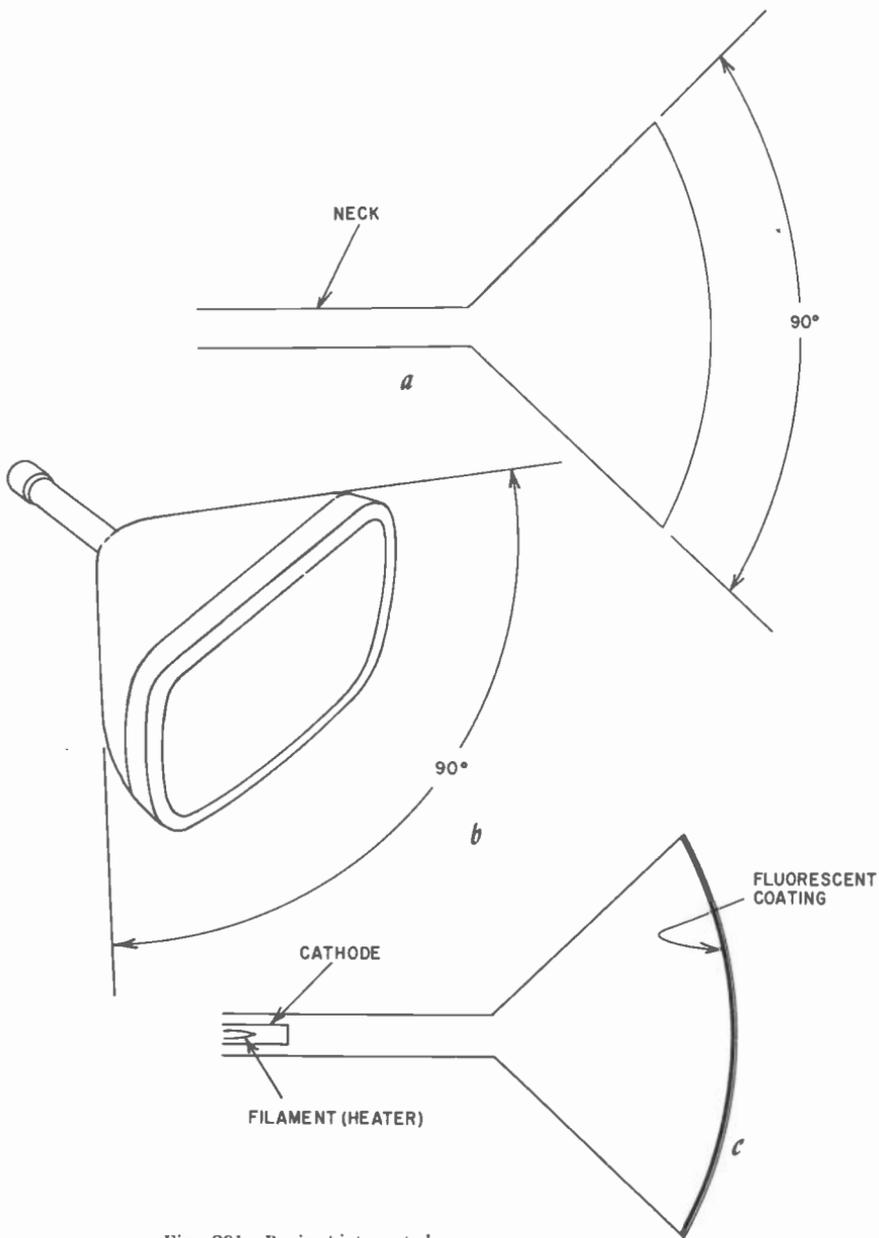
Fig. 201. *Basic picture-tube en-
velope (a), perspective view of a
typical rectangular CRT (b) and
placement of heater–cathode and
fluorescent coating (c).*

SECOND OR
HIGH VOLTAGE
ANODE AQUADAG
COATING

HIGH VOLTAGE TERMINAL

FIRST, OR
ACCELERATING
ANODE

d

FOCUS COIL

CONTROL
GRID

e
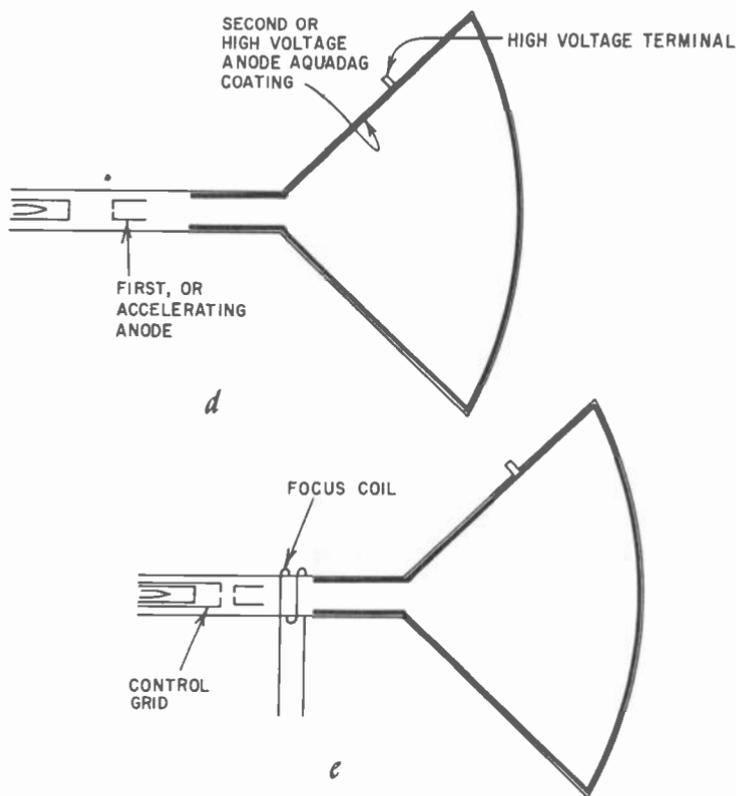
Fig. 201 (continued). *Relation of first and second*
anodes (d) and control grid (e) in the basic CRT
bulb.

In the first chapter, you learned that a spot of light on the television screen traces all the lines in the picture. The spot is produced by a narrow beam of electrons within the picture tube. The beam, a high-velocity, pin-point stream of electrons, strikes the phosphor screen. Therefore, in our imaginary construction of the tube, let's add the elements needed to produce this beam.

The first elements (those which initiate the beam) to be inserted in the tube are the heater and cathode (Fig. 201-c). When heated in a vacuum (later, when air is removed from the tube), the negatively charged cathode emits electrons.

To pull the electrons from the cathode, a positive electrode (or element) is needed near the cathode. This electrode, shown in Fig. 201-d, is called the *first anode* or *accelerating anode*. It initiates the

forming of an electron beam because the positive charge on it draws electrons from the cathode. But, because we want the electron beam to hit the phosphor screen, we need another anode located closer to the screen. Therefore, we next add the *second anode*, which is also known as the *high-voltage anode*. The high-voltage anode consists of a graphite material coated on the inside of the flared portion of the picture tube. The graphite material is called *aquadag*, and high voltage is applied to it by a high-voltage terminal. When the high-voltage anode receives voltage (which is considerably higher than that applied to the accelerating anode), the electron beam is attracted in the general direction of the fluorescent (phosphor) screen.

To summarize, here is what we have done so far in our imaginary construction of a picture tube. First, we acquired a glass bulb with a bell flared at a 90° angle. Next, we added a heater and cathode to serve as the electron source when air is removed and voltages are applied. Then, the accelerating anode (to be positively charged) was included so that it would draw electrons from the cathode. To attract the electron beam toward the fluorescent screen, high voltage was applied to the aquadag coating. When the electron beam hits the fluorescent phosphor coating, an illuminated spot formed at the point of contact.

Sharpening the spot

Do you think we'll get a sharp little spot on the screen with the electrodes included so far? The answer is no. The spot will be big, sloppy and will have an irregular outline. To form one that is small, sharp and clear-cut, the electron beam must be *focused*. And, this is why we next add the focusing coil. Fig. 201-e shows a magnetic focusing coil added to the outside of the picture tube. It is wound with fine wire to form a ring around the neck of the tube. Passing direct current through the coil forms a steady magnetic field. This magnetic field, acting upon the electron beam within the tube, focuses the beam.

If too little or too much current is passed through the coil, the beam will be out of focus. When you adjust the coil current so that the proper amount flows through the coil, the beam is focused so that the spot is tiny and sharp. Of course, you don't actually see a spot because it is kept in constant motion. But, when a focusing coil is used, you adjust the focus control until the picture is clear. There are other, and easier ways, of focusing but these will be discussed later when focusing is explained in detail.

Control of spot brightness

As you learned in Chapter 1, a moving spot traces all the lines of the television picture. The spot is formed by a beam in the picture tube. But, to form a black-and-white (monochrome) picture, the spot must vary in brightness while tracing the lines. The
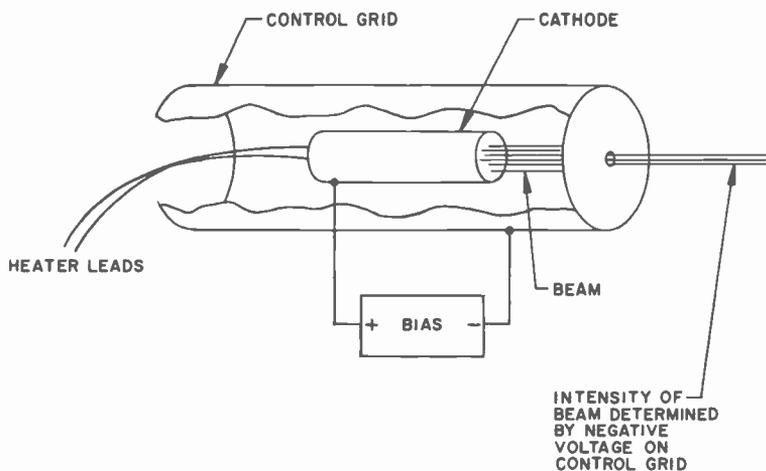
Fig. 202. *Heater, cathode and control-grid assembly.*

electron beam in the picture tube must be made *weaker* to cause a *dimmer* spot to appear on the screen, and *stronger* for a *brighter* spot. In other words, the beam must be *varied in intensity*. To do so, we need a control grid, the next electrode to be added (Fig. 201-e).

The term grid, borrowed from electron-tube theory, is somewhat a misnomer. The control grid in a picture tube doesn't look like a grid but like a tin can, open at one end, with a hole punched in the center of the other end. This grid fits right over the cathode, and electrons emitted by the cathode pass through the hole if permitted to do so. Fig. 202 shows a cutaway of the control grid.

Like the control grid in an electron tube, the one in the picture tube is normally negative with respect to the cathode. When the control grid is made *less* negative (with respect to cathode), the electron beam is made *stronger*. Therefore, the beam produces a *brighter* spot on the screen. When the control grid is made *more* negative, the electron beam is *weakened* and the spot becomes

23

dimmer. If the control grid is made sufficiently negative, the electron beam is shut off. No spot appears under this condition and the screen shows a black (or blank) area.

How the picture tube works

Actually, the negative charge on the control grid need not be varied. The same effect can be obtained by maintaining a fixed negative charge on the control grid and varying the positive charge

a   b

MAGNET
MOVED
DOWNWARD

MAGNET
MOVED
DOWNWARD,
POLES
REVERSED

MAGNET
ATTRACTS
ELECTRON
BEAM

C R T REMOVED
FROM OSCILLOSCOPE,
WIRE CONNECTED
TO OSCILLOSCOPE

MAGNET
REPELS
ELECTRON
BEAM
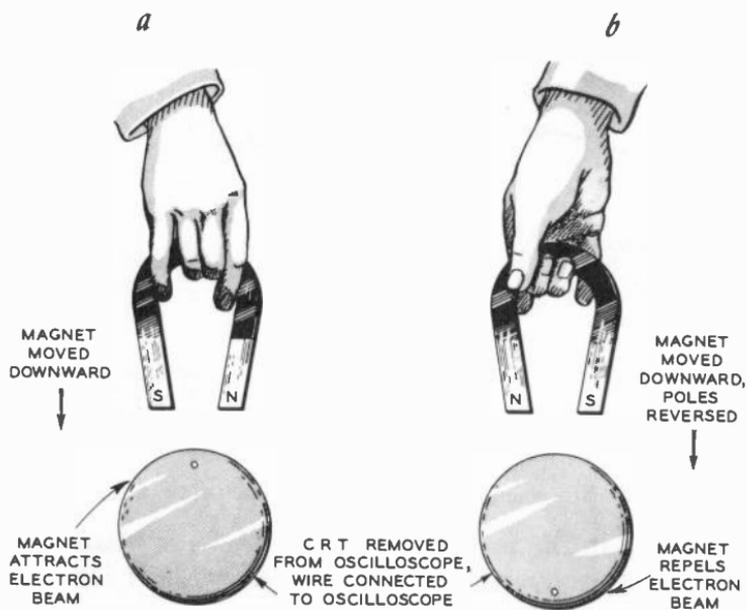
Fig. 203. *Physical setup to demonstrate the effect of a magnetic field on the position of the fluorescent spot generated by the electron beam.*

on the cathode. Making the cathode more positive is the same as making the control grid more negative. In most TV receivers today, the cathode receives the video signal. This arrangement is called *cathode drive.* When the control grid receives the video signal, it is called *control-grid drive.*

Electromagnetic deflection

So far, in our imaginary assembly of a picture tube, we've put these parts in the glass envelope: (1) a heater to heat the cathode; (2) a cathode to emit electrons; (3) a grid to control electron flow; (4) an accelerating anode to draw electrons from the cathode and speed them on their way in the form of an electron beam; (5) a fluorescent phosphor coating to form the screen; (6) a high-voltage anode (aquadag coating) to attract the electron beam so that it

strikes the fluorescent screen; (7) a magnetic focusing coil around the neck of the picture tube.

By removing the air from the tube and adding a tube base, our imaginary assembly of a simple picture tube is completed.

Our next job is to deflect the electron beam. As you learned earlier, the electron beam in the picture tube is swept sideways. This process is called *horizontal deflection*. The electron beam is also moved downward, slowly, by a process called *vertical deflection*. Electromagnetic deflection means that a magnetic field, created by passing current through electromagnetic deflection
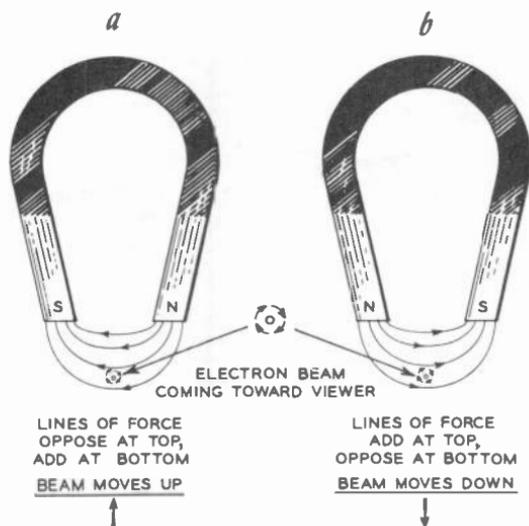
Fig. 204. *Electron beam is drawn in the direction of the opposing magnetic lines of force.*

coils, is used to deflect the electron beam in the picture tube.

Why does a magnetic field deflect a beam of electrons? Here's a simple experiment that will illustrate the principle of magnetic deflection.

In Fig. 203, a cathode-ray tube (CRT) of an oscilloscope is shown removed from its case, but connected by wires to the scope so that the CRT can be operated. The area above and below the CRT is clear so that a magnet may be brought near it, as shown. The oscilloscope is adjusted so that a stationary spot appears in the center of the screen.

Hold the magnet above the cathode-ray tube, as in Fig. 203-a. Move the magnet downward. Notice that the beam (spot on the CRT) is attracted to the magnet. Again holding the magnet above

the tube, reverse the poles, as in Fig. 203-b. Move the magnet downward, as before. This time the beam will be repelled.

The reasons for the results of the experiment are shown in Fig. 204. Magnetic lines of force exist between the North and South poles. With the beam approaching you, its magnetic lines of force appear in a clockwise direction. In Fig. 204-a, the lines of force oppose at the top of the beam and add at the bottom. Because lines of force cancel at the top of the beam, a *thick* magnetic field is created at the bottom of the beam, and a *thin* one at the
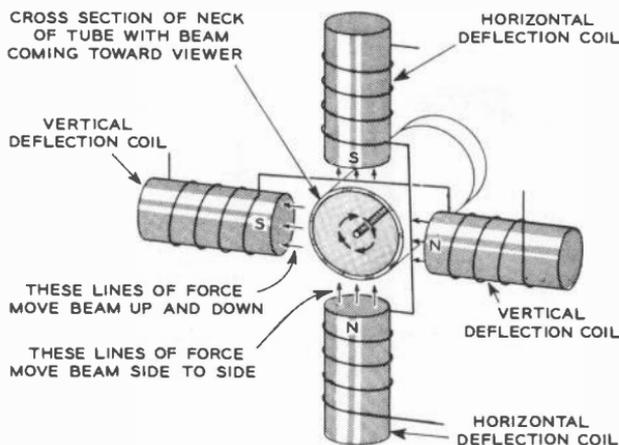
Fig. 205. *Descriptive view of the horizontal and vertical deflection coils and the forces they generate.*

top. *The beam moves from the thick toward the thin magnetic field.* Therefore, the beam is attracted in Fig. 204-a. The reverse occurs in Fig. 204-b. A thick magnetic field is developed at the top of the beam and a thin one at the bottom. Therefore, the beam is repelled.

A permanent magnet was used in our experiment to demonstrate the principle of electron-beam attraction or repulsion by a magnetic field. In electromagnetic deflection, a deflection yoke is used and the beam is deflected by a changing magnetic field, produced when the scanning current flows through the deflection coils in the deflection yoke. To deflect the beam horizontally, horizontal deflection coils are placed above and below the neck of the picture tube (Fig. 205). As shown in the diagram, the horizontal deflection coils are series-connected. Also series-connected are the vertical deflection coils — one to the left and one to the right of the picture-tube neck.

VERTICAL COIL DAMPING RESISTORS

HORIZONTAL
DEFLECTION
COILS

HORIZONTAL COIL
BALANCING R-C
NETWORKS

VERTICAL
DEFLECTION COILS
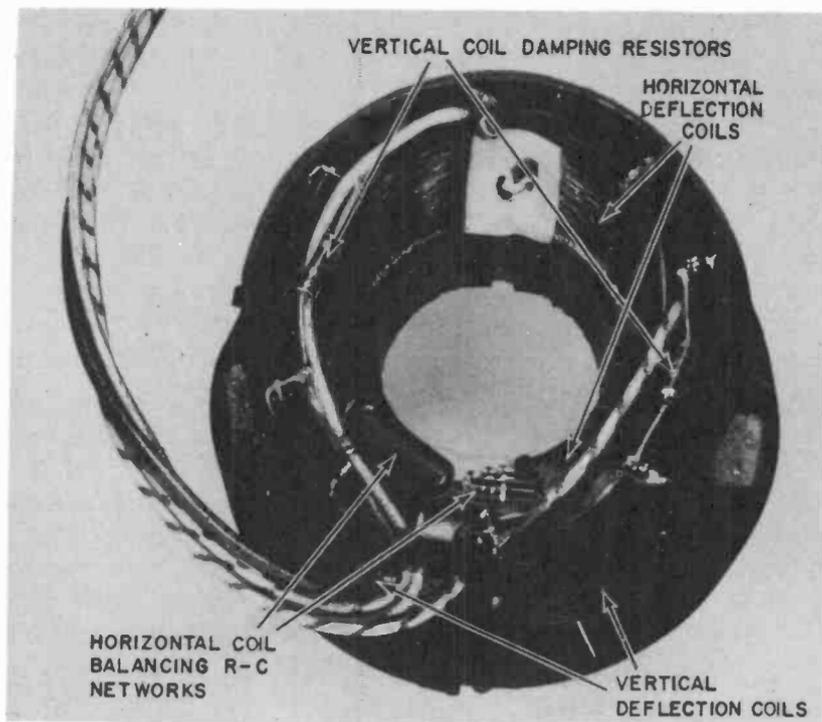
Fig. 206. *Internal construction of a typical deflection yoke.*

Compare Fig. 204 with Fig. 205. Notice that the horizontal deflection coils, although positioned vertically, will produce magnetic lines of force that move the beam horizontally. Similarly, the vertical deflection coils, although positioned horizontally, produce magnetic lines of force that move the beam vertically. Fig. 205 is drawn in this form for clarity. Physically, the deflection coils are contained in a housing called the *deflection yoke*. The construction of a deflection yoke is shown in Fig. 206. Typical yokes are shown in Fig. 207.

Sawtooth deflection current

A sawtooth current is fed through the horizontal deflection coils. The term sawtooth describes the strength of the current with respect to time. In other words, the current rises at an even rate, reaches a peak strength, then drops quickly. The rise and fall repeats in a pattern that looks like the teeth of a saw. The hori-

zontal sawtooth current repeats at a very rapid rate. As a result, a sawtooth magnetic field is produced which causes the beam to be swept rapidly across the screen, from left to right, and quickly retraced after each sweep.

At the same time, while the sawtooth magnetic field affects the beam horizontally, a slower sawtooth current is fed to the vertical deflection coils. A vertical sawtooth magnetic field is produced, which moves the beam from the top to the bottom of the screen, then quickly back to the top again. The effect of both sawtooth magnetic fields, horizontal and vertical, is the tracing of a 4 to 3 ratio rectangular raster on the screen.

Deflection yoke

Photographs of deflection yokes are shown in Figs. 206 and 207. The coils (one pair for horizontal deflection and one pair for vertical deflection) have four wires leading from the yoke.

A yoke with a *cosine* winding, also called an *anastigmatic* or *full-focus* yoke, has nonuniform windings to give better focus at the edges of the picture. The winding is thin at the front opening of the yoke and gradually increases in thickness toward the rear. This type of yoke is commonly used with all wide-angle picture tubes, where uniform focus is a problem.

Electrostatic deflection

With electrostatic deflection, the beam is deflected through the use of plates *inside* the picture tube. Plates lying in a horizontal plane (above and below the scanning area) are the vertical deflecting plates because a varying voltage on them moves the beam up and down. The negative electron beam is attracted to the positive plate and is repelled by an opposite charge on the negative plate. The horizontal deflecting plates are situated vertically; one plate is at the right of the scanning area, the other is at the left. A varying voltage on these plates moves the beam from side to side.

With electrostatic deflection, the scanning energy consists of a changing sawtooth *voltage* on both sets of plates within the picture tube. A sawtooth *voltage* that repeats rapidly is applied to the horizontal deflection plates. A sawtooth *voltage* that repeats slowly is applied to the vertical deflection plates.

Focusing, in general

The electron beam must be focused to produce a sharp spot on the screen. A poorly focused picture looks blurry; a properly focused one has raster lines that are clear and sharp.

Basically, there are two focusing methods: one, *magnetic* focus-
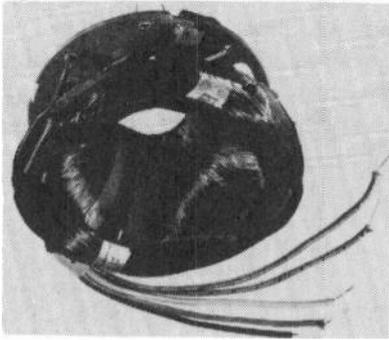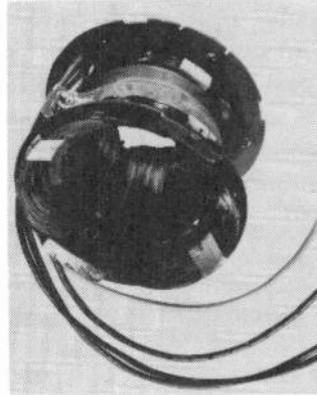
Fig. 207. *Comparison between 90° (a) and 110° (b) deflection yokes.* (Stancor Electronics)

ing; the other, *electrostatic*. Magnetic focusing includes both a permanent magnet to produce the needed fixed magnetic field or a coil through which an adjustable current is passed. The coil is called on *electromagnet*. Therefore, when the coil is used, the process is called *electromagnetic focusing*.

The focusing field (magnetic or electrostatic) forms an *electron lens*. Just as a convex lens bends rays of light so that they converge at one point, the electron lens bends streams of electrons so that they come to a sharp point at the fluorescent screen.

Electromagnetic focusing

Magnetic lines of force, which exist between the North and South poles of a magnet can be made to interact with the lines of force around a stream of electrons. This interaction is the method used to deflect an electron beam. With electromagnetic focusing, a circular coil (ring-shaped, without a core) is slipped over the neck of the picture tube and positioned behind the yoke (between the yoke and the base of the picture tube). The amount of current through the coil determines the strength of the magnetic field produced.

Fig. 208 shows a focusing coil cut in half so you can see what's going on. Notice that the electron streams fan out when they leave the cathode. If left alone, they would continue to fan out, producing a large circle of light on the screen. But, when they move into the focusing coil's magnetic field, the electron streams are

bent so that they converge at the fluorescent screen. If too much current passes through the coil, the electrons converge too soon, at a point short of the screen. Then, the electrons spread out to trace an out-of-focus picture on the screen. Or, if not enough current passes through the coil, they will not have converged when they reach the screen. This, too, results in an out-of-focus picture. For a sharp picture, the electrons must come to a point right at the fluorescent screen. To focus the raster with electromagnetic
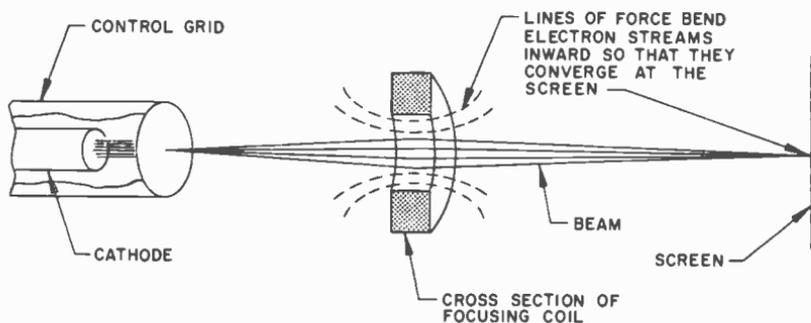
Fig. 208. *Focusing by magnetic lines of force.*

focusing, turn the control that adjusts current through the focus coil.

Some beam focusing arrangements employ both a permanent magnet and an electromagnet. The permanent magnet, ringed around the electromagnet, provides some of the magnetism needed to focus the beam, but not enough. The electromagnet is used to add the additional magnetism required. In other words, the magnetism provided by the permanent magnet is a preset rough adjustment, while the electromagnet provides a fine focusing adjustment. This method permits the use of a smaller focusing coil. Also, line voltage fluctuations don't defocus the picture to any serious degree.

If you will compare a modern tv set with an old-style receiver, you will see that the trend has been to reduce the number of controls on the front of the set. Some of the controls have been banished to the rear apron of the chassis, while others have been eliminated completely. The focus control has disappeared from many present-day tv receivers but is still found on some sets and oscilloscopes.

A permanent magnet can also be used for focusing. Such magnets come equipped with one or more slugs which can be moved in or out of the magnet, thus changing the strength of the magnetic field. The slugs are turned until the raster is in sharpest focus, and then further adjustments are not required.

But whichever method of magnetic focusing is used, the same basic principle underlies all of them. The steady field of the focusing magnet acts on the electron beam in the tube so that the cross-

EQUIPOTENTIAL LINE
A
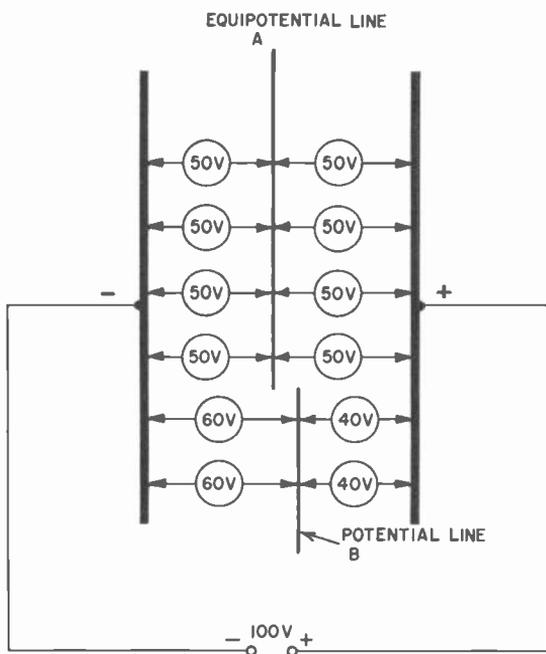
Fig. 209. *Graphic presentation of the potential lines between two charged plates. Line A is an equipotential line. Note that line B is a potential line, not equipotential.*

over point of the beam takes place right at the fluorescent screen.

Some tv sets have a pair of corrector magnets[1] placed on the deflection coil hardware. These magnets can be adjusted by moving them in or out or up and down, since they are mounted on flexible arms. They should be positioned so that the sweep lines on the screen are sharp and straight.

Electrostatic focusing

An electrostatically-focused picture tube has a focusing electrode

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[1] Also known as anti-pincushioning magnets, they are discussed further on page 39.
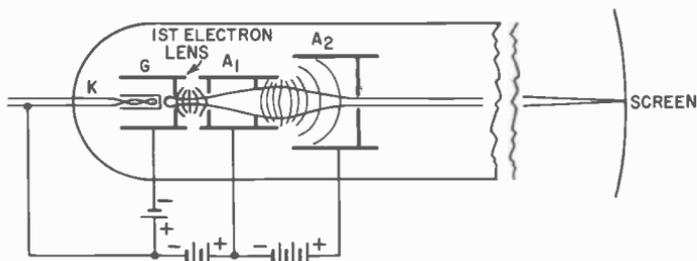
a
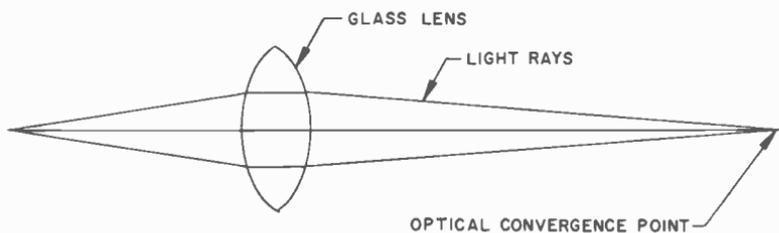
b

Fig. 210: *Electrons cross potential lines at right angles. The electrostatic lens (a) compared to the optical lens (b).*

(sometimes called a focusing grid) within the tube. Usually, a low positive voltage is applied to the focusing electrode. When you vary this low voltage, you change the focus of the picture. In some picture tubes, the focusing voltage is preset and cannot be changed. These are called fixed-focus tubes.

Electromagnetic focusing uses the same principle as electromagnetic deflection. Electrostatically-focused picture tubes, however, use a different principle which involves *another* method of changing the path of a moving electron. Let's look at Fig. 209. In this diagram, one plate has a negative charge, the other positive. Halfway between them is an imaginary line, A. If it were possible to measure the voltage between *any point* on line A and either charged plate, you would read a potential difference of 50 volts. Of course, you can't actually measure this voltage with an ordinary
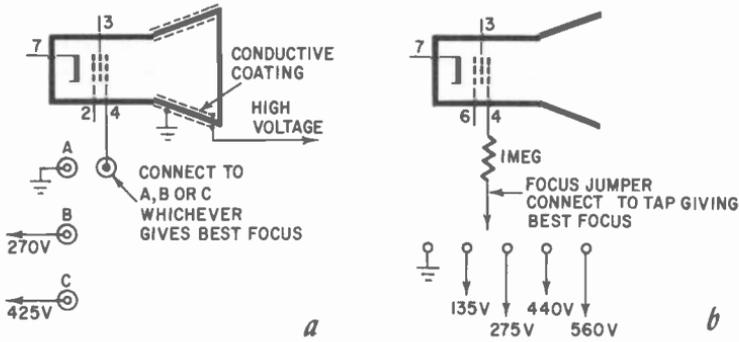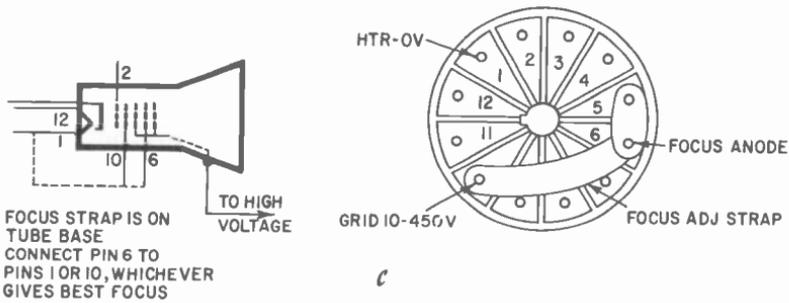
Fig. 211. *Basic circuits in the application of the electrostatic principle. Use of the strap type jumper that is held in place by the tube socket is shown at the bottom.*

meter, but in Fig. 209, a group of voltmeters are used to illustrate the idea.

Because every point on imaginary line A is at equal potential (voltage) with respect to the plates on either side, it is called an *equipotential* line. Although line A represents just one line midway between the charged plates, an infinite number of potential lines exist between the plates. As shown in Fig. 209, another line, B, may divide the voltage into a 40-60 ratio.

In Fig. 209, the potential lines are indicated as straight and parallel to the charged plates. This need not be the case, however. The size and shape of electrodes involved, the voltages surrounding the electrodes, and the openings in the electrodes can change the shape of potential lines. For example, take a look at Fig. 210-a. Notice that the potential lines are curved. They are deliberately shaped as shown by tube design engineers. Also, the curve of the potential lines can be changed by varying the voltage on the focus electrodes.

An important principle to learn is this: *when an electron cuts*

across a potential line, it always does so at a right angle. There-
fore, a bent potential line will bend (or curve) the path of a mov-
ing electron. As shown in Fig. 210-a, this principle is used to bend
the streams of electrons so that the electrons converge at the de-
sired point — the fluorescent screen. Compare this to the focusing
of light rays by a glass convex lens (Fig. 210-b). Unlike the glass
lens, however, the boundaries of the potential lines are not as
sharply defined, because an infinite number of potential lines exist
besides the ones shown in the diagram. Therefore, the bending of
the electron streams occurs very gradually.

The focus electrode under discussion is also called the *second
electron lens.* You might ask, "Where's the first electron lens?" It
occurs because of a natural state of affairs between the control
grid and the first anode. Between these electrodes, bent potential
lines exist. When streams of electrons cross these lines, they are
made to converge, then spread out. The second electron lens is the
one that is adjustable (usually) and bends the electron streams so
that a point of convergence (focal point) is reached at the screen.

In some receivers, there is a choice of voltage points to which
the focus electrode can be connected. This is done by a focus
jumper which can connect the focus electrode to any voltage be-
tween 0 and 500 volts. Another method is to use a shunting strap
on the picture tube base. All that this does is to give the viewer a
choice of focus voltages. These techniques are illustrated in Fig.
211.

In summary, the electrons emitted by the cathode converge ini-
tially between the control grid and first anode. Then, the electron
streams spread out. Under the influence of the focus anode, the
electron streams are again bent so that the electrons converge at the
fluorescent screen of the picture tube. Because electrons cross
potential lines at right angles, the shape of the potential lines in
the focus electrode determines the bending of the electron streams.
Most of the focusing action is designed into the tube by selecting
the proper shape of potential lines. However, some adjustment is
provided for varying the positive voltage on the focus electrode.

ion traps

Obviously, the purpose of an ion trap is to trap ions. This natu-
rally leads to two important questions: What is an ion? Why
trap it?

Answering the first question first, we'll define a negative ion
because this is the type that we're interested in. A negative ion is
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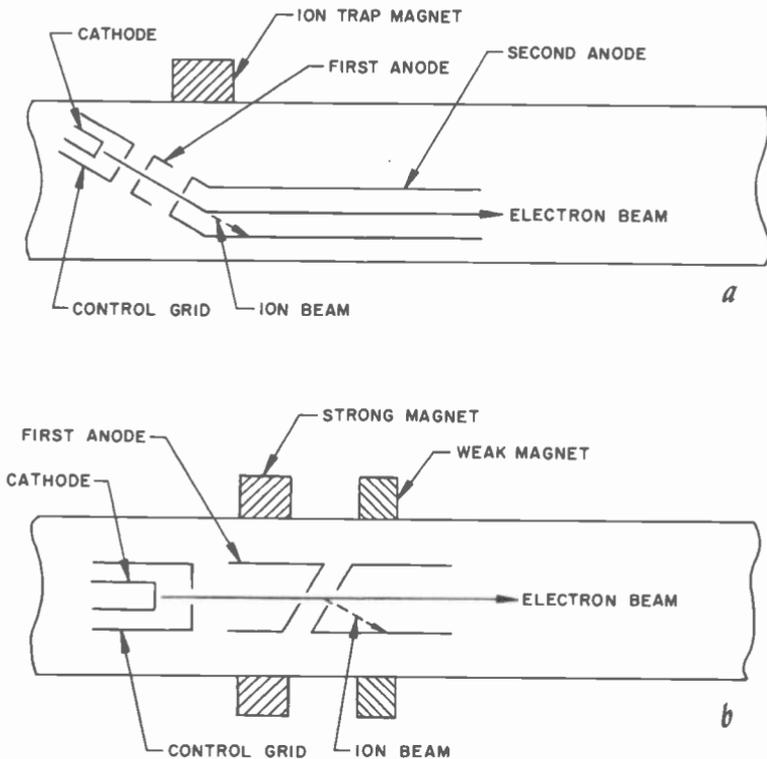
Fig. 212. *Bent-gun assembly (a) and slashed-field gun (b) with the location of the ion-trap magnets.*

an atom that, somehow, got hold of an extra electron. With the extra electron spinning around the atom nucleus, the atom takes on a negative charge.

Although the tube manufacturer does his best to remove all gases from the tube, it's a sad fact that just a tiny amount remains. Unfortunately, some of it becomes negatively ionized. Some negative ions are also emitted by the cathode.

Because of their negative charge, negative ions try to behave like electrons. The ions head toward the fluorescent screen. But, ions are big and heavy. Consequently, a magnetic field (which does a fine job deflecting electrons) does not disturb the ions. If no preventive steps are taken, the ions will bang against the center of the screen to cause an ion burn. This is seen as a brown spot in the center of the screen.

The need for an ion trap is evident. We want the electrons to reach the screen but not the ions.

35

Ion traps commonly used work on this principle: both the electron beam and negatively charged ion beam are detoured so that they are directed — not toward the fluorescent screen — but off at an angle to a positive electrode. If nothing further is done, neither the ions nor the electrons will reach the screen. For proper operation, however, a permanent magnet is placed over the neck near the base. The magnet provides a magnetic field which attracts the electron beam and directs it toward the screen. The ion beam, because ions are considerably heavier than electrons, is not attracted by the magnetic field of the permanent magnet. Therefore, the ions continue to head toward the positive electrode, not toward the screen. The electron beam, however, strikes the screen as it's supposed to do.

There are two methods for sidetracking the ion beam. One involves the use of a *bent gun* (Fig. 212-a). Because the gun is bent, electrons and ions start at an angle. A single magnet, held on the neck of the tube by a spring, straightens the electron beam (but not the ion beam).

The other method of sidetracking ions uses a slanted gap between the first and second anodes. This type of electron gun, shown in Fig. 212-b, is called the *straight-gun* or *slashed-field* type of ion trap. Because there is an appreciable difference in potential between the first and second anodes (the second anode is considerably more positive), a strong electrostatic field is present between them. The electrostatic field is also diagonal because there is a slanted gap between anodes. For this reason, ion and electron beams are diverted at an angle and both beams move toward the second anode. As with the bent-gun ion trap, a magnetic field is able to deflect *only* the electron beam. A special double magnet, consisting of a strong and a weak magnet, is used with the slashed-field electron gun. The strong magnet, set behind the gap nearer the tube base, has this effect: The magnet's field deflects the electron beam so that the slanted electrostatic field will tend to direct the electron beam toward the screen. The weaker magnet further straightens the electron beam, directing the beam toward the screen. The magnet is called an *ion-trap magnet* or *beam bender*.

Another way ion damage is prevented is through use of a picture tube with an aluminized screen. This type of tube has a thin aluminum coating on the rear side (inside the tube) of the fluorescent phosphor coating. The aluminum is thin enough to let the

electrons do their job (of tracing the picture) but ions can't penetrate the aluminum to damage the screen. We should mention, while we're on the subject, that an aluminized screen also prevents undesired reflection of light back into the tube. In fact, a 50% increase in brightness is obtained with aluminized tubes.

Centering the picture

There are several methods for centering the picture on the screen. A method commonly used in receivers having a combination electromagnet and permanent-magnet focusing coil uses a
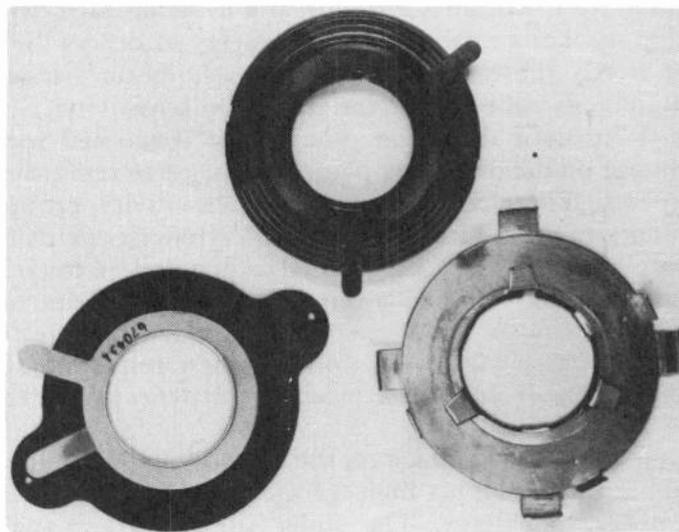
Fig. 213. *Magnetic ring-centering device may be made as part of the yoke cover (top), attached with springs to secure the yoke by pressure (left), or by a clip-on accessory (right).*

lever that sticks out above the focusing-coil assembly. The lever can be moved from side to side and locked in place by tightening a screw. Sliding the lever shifts the permanent magnet's focusing field, thereby moving the picture on the screen. In some receivers, you can move the entire focusing coil or magnet.

Another method of centering involves adjustment of a residual current through the scanning coil of the yoke. With this method, the picture can be centered both horizontally and vertically.

A more popular means of centering utilizes magnetic centering rings. This is shown in Fig. 213. Some receivers use just one ring with a tab for turning. Turn the ring and you turn the magnetic field across the ring. This shifts the scanning beam, shifting the

37

picture. Most receivers with magnetic-ring centering use two rings, each of which has a convenient tab sticking out. They are turned to center the picture horizontally and vertically.

Adjusting the picture centering tabs sometimes upsets the focus. If this happens, the focus must be readjusted, and then the picture centering tabs rotated slightly to compensate for any change in centering.

Deflection sensitivity

One characteristic of a picture tube is its *deflection sensitivity*. If a tube has low deflection sensitivity, it takes a lot of deflecting energy to move the beam a little bit. If a tube has high deflection sensitivity, it takes a small amount of energy to deflect the beam. In other words, the easier it is to deflect the beam (in terms of deflecting energy), the higher the deflection sensitivity.

With electrostatic deflection tubes, we're concerned with how much voltage on the deflecting plate is required to move the beam 1 millimeter. Therefore, the deflection sensitivity rating is in millimeters per volt. With tubes using electromagnetic deflection, ratings are in millimeters per ampere or per ampere-turn. Deflection sensitivity may also be given in inches or centimeters per volt (electrostatic) or per ampere or ampere-turn (electromagnetic) (all of which may make things slightly confusing). Simply remember that *easy to deflect* means *high deflection sensitivity*, and vice versa.

Also, the higher the voltage on the second anode, the lower the deflection sensitivity. This high-voltage condition would call for greater deflection energy. The wider the deflection angle, the lower the deflection sensitivity. Therefore, 110° picture tubes have a lower deflection sensitivity than 90° tubes. Consequently, to deflect the beam, 110° picture tubes have yokes that dissipate more power than those used with 90° tubes. (Heavier wire is used in the construction of 110° yokes to carry the required current.) The problem of low-deflection sensitivity in 110° models is overcome through use of narrow-neck tubes.

Phosphors

The inside of the picture-tube screen is coated with a phosphor. When electrons strike this material, it gives off light. Many phosphors are available for cathode-ray-tube screens. Each has a number which indicates its characteristics; the phosphor used in monochrome television is invariably a P4. This type gives off a white light of the correct persistence for a monochrome television picture.

Tube bases

Don't be frightened by the high-sounding names given to picture-tube sockets. If someone tells you a tube has a *magnal* base, it means that the base has 11 pins. A *bidecal* base simply means that it's a 20-pin type. A *diheptal* base has 14 pins and a *duodecal* base (perhaps the most popular) has 12.

Picture distortion

There are numerous types of distortion to which the picture is prone, but you should know about a few in particular.

If your picture is shaped like a keystone, the trouble is called keystoning, for obvious reasons. The picture may be wide at the top (or side) and taper toward a narrow bottom (or side) or vice versa. Corrector magnets (discussed earlier because of their effect

Fig. 214. *The 110° deflection CRT has a short, thin neck.* (RCA)

on focusing) are sometimes used to correct this condition, but the symptom is usually caused by a defective yoke. A shorted winding will do it. A shorted capacitor across the deflection coil is another common cause.

If your picture looks like a pincushion, with each side of the raster sagging toward the center, you are plagued with pincushion distortion. To pull out each side of the raster so that a rectangle is formed, the corrector magnets must be adjusted.

Other forms of distortion produced by improper positioning of the corrector magnets are barreling, in which the sides of the picture bulge, and poor linearity.

Safety

If you remove or otherwise handle a picture tube, treat it with care and respect. Don't jar or jolt it. And, for heaven's sake, don't drop it. Mishandling, of any kind, may cause an implosion. This means that air pressure will send glass flying in all directions. So, *be careful!* Goggles and gloves are good precautionary measures, too, when removing or installing a picture tube.

Windup

The electromagnetic picture tube, the type used in present-day TV sets, consists of an envelope with these electrodes: (1) heater, (2) cathode, (3) control grid, (4) first or accelerating anode, (5) second or high-voltage anode. The inside of the face of the picture

ANODE,
G3,
G5

ELECTROSTATIC FOCUS
ELECTROMAGNETIC DEFLECTION,110°
EXTERNAL CONDUCTIVE COATING (C)

MAGNETIC FOCUS
ELECTROMAGNETIC DEFLECTION,90°
EXTERNAL CONDUCTIVE COATING (C)

ELECTROSTATIC FOCUS
ELECTROMAGNETIC DEFLECTION,110°
EXTERNAL CONDUCTIVE COATING (C)

MAGNETIC FOCUS
ELECTROMAGNETIC DEFLECTION,70°
NO INTERNAL CONDUCTIVE COATING
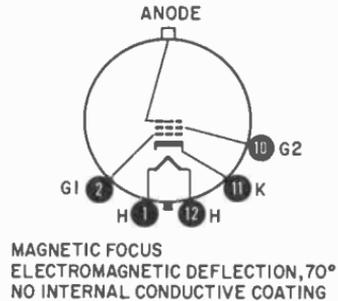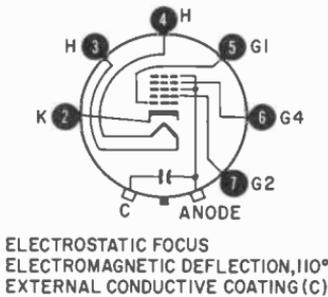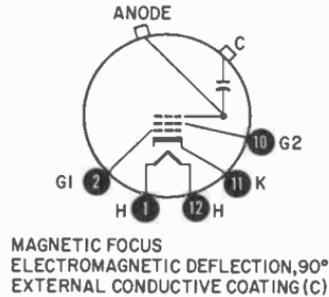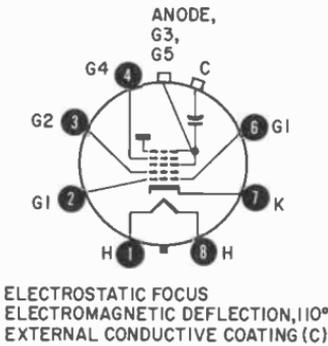
Fig. 215. *CRT base connection diagrams show a more complex internal structure when designed for electrostatic focusing.*

tube is coated with a phosphor that forms the fluorescent screen. The tube may use electrostatic or electromagnetic focusing or a combination of both, or a fixed-focus arrangement. Horizontal and vertical deflection coils, housed in the deflection yoke, receive

the scanning signals. The coils produce a sawtooth magnetic field that sweeps the beam horizontally and vertically. To prevent damage to the screen in the form of an ion burn, an ion trap is often used. Whether a bent-gun or slashed-field type of electron gun is used, the ion trap deflects ions so that only the electron beam reaches the screen. An aluminized screen doesn't require an ion trap. WARNING: Because the picture tube is highly evacuated, it must be handled with care. The 110° deflection tubes, such as the one in Fig. 214, are used in the "thin" television receivers. See Fig. 215 for the symbols of some picture tubes.

Either the control grid or cathode in the picture tube receives picture information and the deflection coils receive sweep information. You'll find picture and sweep information in the video signal that varies in amplitude. You may ask, "How does such a signal provide all the information needed by the picture tube?" The answer is in the next chapter.

QUESTIONS

1. What is meant by cathode drive? Control-grid drive?

2. Name the two types of deflection used in sweeping the cathode-ray beam.

3. What is the name of the component that produces deflection of the cathode-ray beam?

4. What type of current waveform flows through the deflection coils?

5. What is a cosine winding? What are some other names applied to this type of winding?

6. Describe two systems of focusing.

7. What is a potential line? An equipotential line?

8. What is an ion trap? How is it used?

9. What is a bent gun? A straight gun?

10. What is meant by deflection sensitivity?

11. How many pins are there in a bidecal base? In a diheptal base? In a duodecal base?

12. What is keystoning? What can cause it?

13. How could you recognize a condition of barreling?

14. What is the name given to the conductive coating on a picture tube?

3

THE TELEVISION SIGNAL

• •

HAVE you ever wondered how a television receiver can work so precisely as to produce the picture? Think about it. A great amount of precision is involved. The scanning beam within the tube must be perfectly synchronized at all times or you'll get a distorted picture. You might think that expensive construction and precision parts would be necessary in the television receiver, but we know that such is not the case. Here's the reason.

Precision is essential in television, but the precision is not in the receiver — it's in the transmitting equipment. At the television broadcast station, a precise signal is produced (by some very fine and expensive equipment). Within the television receiver, the circuits are *slaved* to this signal. For example, the 60-cycle vertical oscillator in the receiver, if left alone, will drift in frequency. But vertical sync pulses in the received signal will control the vertical oscillator of the receiver. When this vertical oscillator *locks in,* its frequency and phase are slaved to the broadcast-station video signal. Similarly, the horizontal oscillator in the receiver is slaved to the video signal. The video signal "tells" the horizontal oscillator in the receiver exactly what to do and when to do it. But, to be more specific, let's examine the control exerted by the television signal over the circuits in the receiver. Here is what the television signal does:

1. Determines when the sweeping spot on your television screen should get brighter or darker. The spot, varying in intensity, forms the picture on the screen.

2. Locks in the frequency and phase of the horizontal oscillator which controls the lateral movement of the spot. The receiver horizontal oscillator frequency and phase are synchronized with the studio horizontal oscillator (in the television broadcast station) that controls scanning within the camera. This lock-in process is called *horizontal synchronization*.

3. Shuts off the spot after it scans each line during the period when the spot jumps from the right side of the screen to the left. This is called *horizontal retrace blanking*.

4. Locks in the vertical oscillator which controls the pull-down and vertical retrace of the spot, so that the vertical oscillator's frequency and phase are exactly the same as the vertical sweep frequency and phase within the camera. This is called *vertical synchronization*.
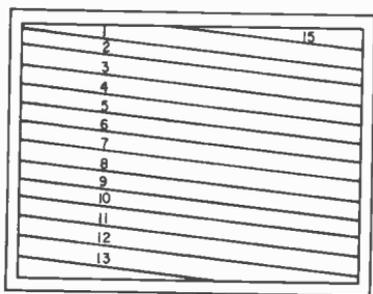
Fig. 301. *Picture of a simplified TV system showing 13 active lines on the screen. The two half-lines, 13 and 15, make up one complete active line.*

5. Shuts off the spot during the time when it jumps from the bottom of the screen to the top. This is called *vertical retrace blanking*.

6. Causes the horizontal scanning to occur in interlaced fashion. In other words, the even lines are scanned, then the odd lines, then the even, etc.

7. Carries the sound that accompanies the picture.

This is asking the television signal to do quite a few different jobs, so let's see how it accomplishes its purpose.

Understanding the video waveform diagram

Ask a television instructor anything about a waveform, and he'll immediately draw a diagram. Diagrams are great! They're even greater when we fully understand their meaning.

The two most common diagrams used where video signals are discussed are the carrier and the video waveform. To explain the meaning of the video waveform diagram, we must answer the question, "What is a television signal?" No, we don't want to

discuss frequency, etc., at this time. Instead, we want to answer the question by asking you to think of a television signal as *energy*. As you know, any form of energy can be varied in strength. For example, you make light energy stronger by making it brighter and weaker by making it dimmer. At the theatre, when house-lights dim, light energy is gradually made weaker. With an adjustable electric room heater, when you turn the control up, you increase heat energy. If the room is too hot, you turn the control down to decrease heat energy.

Outdoors, temperature (heat energy) varies throughout the day. Have you ever seen weather bureau charts showing temperature changes? The chart is simply a record drawn with a pen or pencil on graph paper. The temperature is shown with respect to time — usually a 24 hour period. Similarly, when you look at a video waveform you're seeing a written record of *how the strength of radio frequency energy changes with respect to time*. The time period, however, is a fraction of a second.

A great difference between television rf energy and, say, heat, is that the rf signal changes in strength rapidly; heat does so slowly. But remember, when you see a diagram of a video waveform, it shows how strong the television signal is at every instant. A square pulse means that the signal is strong for the width of the pulse; then instantly becomes weaker. Other parts of the video waveform diagram give the same type of information — the strength of rf energy (or voltage) at every instant.

Simplified scanning

A complex subject can often be made easier to understand by "inventing" a simplified system. First, learn the simplified system. Then, when you understand it, learn the practical (but more complex) one by studying the details and fine points.

Consider a simplified TV system using only 15 lines. We will need two lines for vertical retrace; therefore, 13 active lines are seen on the screen. This is shown in Fig. 301. The 12 complete lines plus the two half-lines make 13 active lines per frame.

In our simplified system, we want to use interlaced scanning. Therefore, the odd lines are scanned first, then the even lines. Each field has $6\frac{1}{2}$ lines.

In Fig. 302, you can see the first field, first-field vertical retrace, second field and second-field vertical retrace. In the first field (Fig. 302-a), the spot appears at the upper left-hand corner of the screen and is moved from left to right. While moving across the screen, the spot is also being pulled downward by vertical scanning
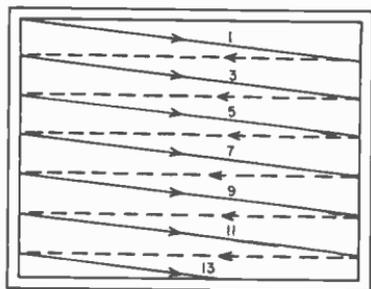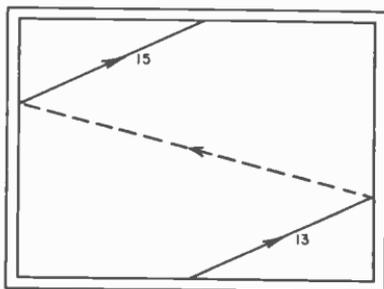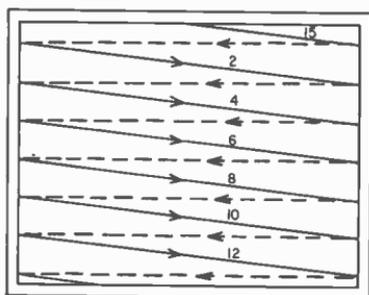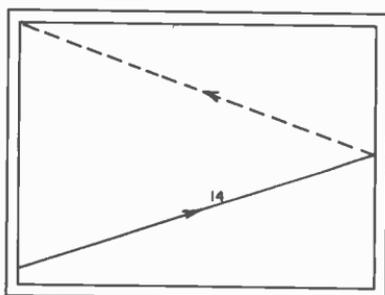
Fig. 302. *a. First field—odd lines. b. First field—vertical retrace. c. Second field—even lines. d. Second field—vertical retrace.*

circuits. This accounts for the downward slope.

The dashed lines show horizontal retrace. This is the period during which the spot is quickly moved to the left side of the screen so it can scan the next lower line. Because horizontal retrace is rapid, the dashed lines are not shown as having a downward slope. You know, of course, that each horizontal retrace line will be tilted downward, but at a very slight angle. This is so because a downward force is always present as the spot is being traced and retraced.

At the bottom of Fig. 302-a, line 13 is traced. But before line 13 can be completed, the vertical sweep period ends and vertical retrace occurs. For this reason, the second half of line 13 occurs during vertical retrace (Fig. 302-b). Notice the sharp, upward angle. The upward tilt is steep because vertical retrace is considerably faster than vertical sweep.

Before you study the rest of Fig. 302, look at Fig. 303. In this

diagram, you'll see many sawteeth at the top and two large saw-teeth at the bottom. The sawteeth at the top show the rise and fall of horizontal sweep energy that pulls the spot across the screen. This field of energy increases in strength in linear fashion, as shown by the straight upward slope of the sawteeth. The sharp downward slope tells you that the spot is quickly retraced.

The large sawtooth wave at the bottom of Fig. 303 shows how the spot is pulled down while it's being swept across. The long slope is the pulldown energy; the sharp slope is the vertical re-trace, the time when the spot is pulled back to the top of the screen.

In Fig. 303, note the start of line 1 horizontal sweep. This saw-tooth wave starts at the same instant the vertical sweep sawtooth wave begins. Now, look at the center of line 13, horizontal sweep. At this center point, vertical retrace begins. Although line 13 continues to be swept horizontally, the second half of the line occurs during vertical retrace. Observe the retrace of line 13, horizontal sweep, designated as A in Fig. 303. This retrace period also occurs during vertical retrace and is shown as the dashed line in Fig. 302-b. In Fig. 303, you can see that line 15 also starts during the vertical retrace period. This explains the presence of the start of line 15, tilting sharply upward. When line 15 is half finished, the vertical retrace period ends. The second half of line 15 is traced during the even-field vertical sweep period, and is visible in Fig. 302-c.

The ending of the line 12 retrace coincides with the start of the vertical retrace, after the even field has been scanned. You can see this in Fig. 303. Line 14 trace and retrace occur during the verti-cal retrace period that follows the even-line field.

By comparing Figs. 302 and 303, you can see how the precise timing of the scanning circuits can affect the interlaced scanning of our simplified system. Because of the half line at the top of the even field, all even lines are traced at slightly lower points than the places where odd lines were traced. For this reason, odd and even lines interlace.

Simplified tv signal

Now that you understand how a spot of light behaves on the screen in a simple 15-line system, let's see how the signal controls the spot.

Something in the television signal must "tell" the spot exactly when to start each horizontal line and, at the end of a field, when

47

to scamper back to the top of the screen and start tracing lines again.

In the television signal, a train of horizontal synchronizing (abbreviated as sync) pulses determines when the spot starts its trace
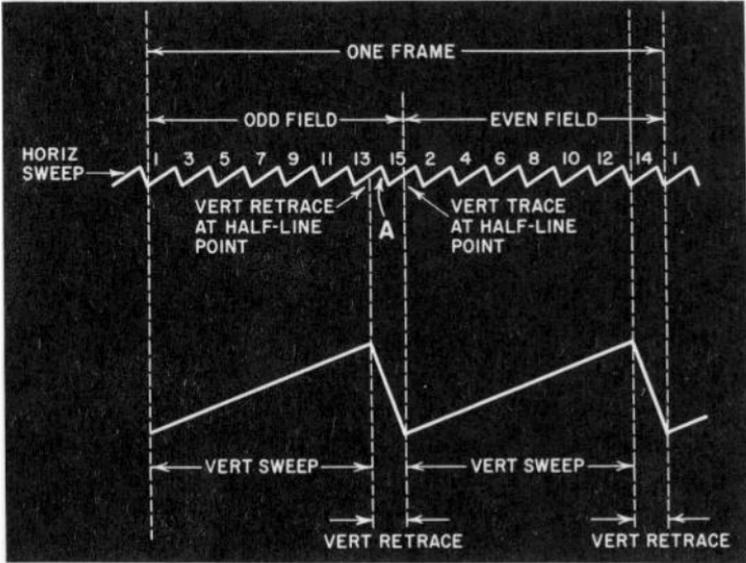
Fig. 303. *Sawtooth waves across top show rise and fall of horizontal sweep energy which pulls spot across screen. Sharp, downward slope is retrace. Large sawteeth (below) show how spot is pulled down while being swept across screen. (Waveform amplitudes are not drawn to same scale.)*

of each line. Long vertical sync pulses determine the exact instant when the spot is pulled back to the top of the screen to trace the next field.

Some students find it hard to understand the practical 525-line TV signal because the vertical pulse is mixed in with the signal. Therefore, to make our simple signal easier to understand, we are going to use a separate carrier for the vertical pulse. In Fig. 304, the signal that has horizontal sync pulses and picture information is shown across the top. The pulses, regularly spaced and jutting upward, are the horizontal sync pulses. The spaces between these pulses convey picture information.

The video wave shown in Fig. 304 is positive-going. The more positive the signal, the blacker the picture. Conversely, the less positive the signal, the whiter the picture. When the signal is at the amplitude point marked "black reference level," the moving spot is shut off. This corresponds to our friend, way back in Fig. 101 (Chapter 1) who used a flashlight to trace a line of light on the wall. If someone sneaked up behind him and turned off the

flashlight switch, our not-so-bright friend would still be moving the flashlight back and forth. But the flashlight (compared to our beam of electrons) would not stop its tracing action.

The signal shown at the top of Fig. 304 is a voltage waveform. Suppose we were to send this signal voltage into the cathode of a picture tube. Making the cathode positive is the same as making the control grid negative. The black reference level in Fig. 304 is that amount of voltage which will make the control grid just negative enough to cut off the electron beam. We say that the screen becomes black. All that this means is that there is no light on the screen. It isn't the same black that you get at the bottom of a coal mine with all the lights turned off.

When the signal becomes even more positive than the black reference level (as it does when horizontal sync pulses are transmitted), this signal is said to be *blacker than black*. By making the sync pulses blacker than black (more positive than any other part of the signal), we can make circuits in the receiver *separate* the sync pulses. We use the horizontal sync pulses to slave the horizontal scanning circuits, controlling both frequency and phase of the horizontal sweep.

The vertical sync pulse, shown as a separate signal in Fig. 304, triggers the vertical retrace. After retrace, the vertical sawtooth wave is created anew. Vertical retrace isn't triggered exactly at the start of the vertical pulse, but at some time during the pulse. During vertical trace, the vertical sweep signal gradually gets stronger in linear fashion. The stronger the vertical sawtooth signal, the farther down it pulls the beam. At a point before line 13, the vertical sync pulse appears. The precise timing of this transmitted pulse is such that vertical retrace is triggered exactly at the center of line 13. For simplicity, the picture information is not interrupted in the signal shown at the top of Fig. 304. During retrace, the picture area transmitted would be lost as the spot rushes to the top of the screen.

Notice that the horizontal sync pulses are comparatively narrow, and vertical sync pulses are broad. This is true of the 525-line system. The horizontal sync circuits in the receiver respond only to the narrow sync pulses while the vertical sync circuits respond only to broad vertical sync pulses.

525-line video signal ⁷

By studying a simplified television signal, you learned how an amplitude-modulated signal can control scanning. You know that a spot of light on the screen (produced by a beam within the

picture tube) can be slaved so that the spot scans in an interlaced fashion. Now let's see how the same principles are used in the 525-line video signal — the standard signal used in the United States.

First, an overall view. Because three frames of a video signal are shown in Fig. 305, details can't be seen. The diagram merely shows that the vertical synchronizing pulse is transmitted for a short time. The picture information, horizontal blanking and
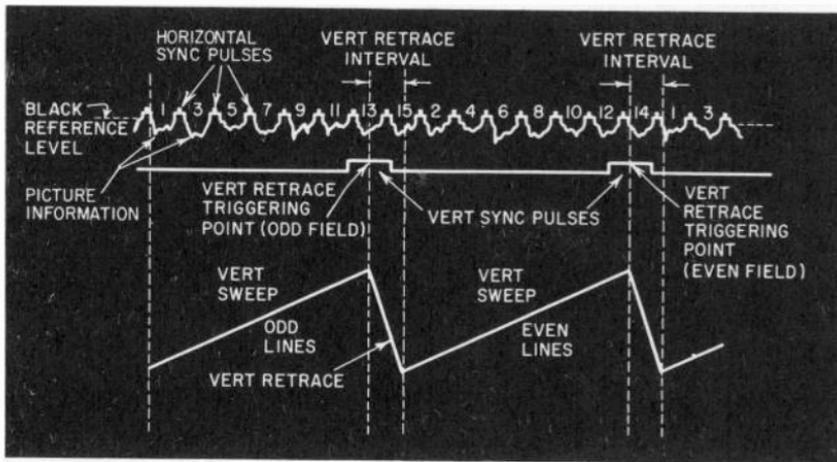
Fig. 304. *Positive-going video signal (top) contains both picture information and horizontal sync pulses. Vertical sync pulses (center) trigger vertical retrace. Vertical sweep sawtooth waves (bottom) trace both fields. (Waveform amplitudes are not drawn to the same scale.)*

sync information are transmitted for a much longer time, followed by another vertical sync pulse, etc. Because Fig 305 is an overall view of the signal, you can't see individual horizontal sync pulses.

Let's take a closer look at the end of the odd-line field, the vertical blanking and sync period that follows, and the start of the even-line field (Fig. 306-a). Fig. 306-b shows the end of the even-line field, vertical blanking and sync, and the start of a new odd-line field.

Remember, a waveform diagram shows the *strength* of energy. Therefore, Fig. 306 shows when the carrier is weak and when it is strong. The weakest possible carrier is, of course, zero carrier. We don't want the signal reduced to zero, even momentarily, because this would cause distortion and an instantaneous off-the-air condition. Consequently, the whitest signal has been set at 15% of full carrier strength. This means that the signal is 15%

50

Fig. 305. *The composite TV signal (not drawn to scale).*

of maximum when you see the whitest part of a picture on the screen. When the signal is at 75% of full strength, the spot is shut off and the screen is blank (black). Thus, 75% carrier represents the *blanking* or *black reference level*.

In studying the video waveform, let us first consider the timing information and, second, picture information. To begin, let's examine the timing pulses: (1) horizontal sync, (2) vertical sync and (3) equalizing pulses.

Timing information in the video waveform

The timing information in the video carrier consists of horizontal sync, vertical sync and a means of producing interlace.

So that your picture will always be synchronized, the receiver must be *constantly* supplied with a precise 15,750-pulse-per-second (pps) frequency. When the picture is transmitted, horizontal sync pulses occur regularly in the blacker-than-black region of the carrier. The last four picture-information lines of the odd-line field are shown in Fig. 306-a. Note the evenly spaced horizontal sync pulses. Following the horizontal sync pulses are six equalizing pulses. The purpose of these pulses will be explained later, but their frequency is worth mentioning now. Equalizing pulses occur at twice the horizontal scanning frequency (31,500 pps). The fact that the horizontal scanning frequency is momentarily doubled does not affect horizontal synchronization. The 15,750-pps effect continues, and horizontal synchronization is maintained.

Following the equalizing pulses is the vertical sync pulse. You should think of this pulse as one long pulse, *but notched at twice the 15,750-pps rate*. The notches (more commonly called serrations) serve to maintain the ever-present 15,750-pps frequency needed by the horizontal sync circuits. Accordingly, the vertical pulse is called a *serrated vertical sync pulse*.

51

Following the serrated vertical sync pulse, you'll find six more equalizing pulses. As with the pulses that come before the serrated vertical sync pulse, the equalizing pulses that follow continue to provide horizontal synchronization. Following the equalizing pulses are a train of horizontal sync pulses for the inactive lines of the picture. Blanked-out inactive lines at the top of the picture enable the beam to reach the correct speed before picture information is presented, so you see a distortion-free picture.

The time taken by one complete horizontal sweep cycle (from leading edge of one horizontal pulse to the leading edge of the next) is 63.5 microseconds. But nobody wants to keep saying "63.5 microseconds", so the letter H is generally used to indicate the
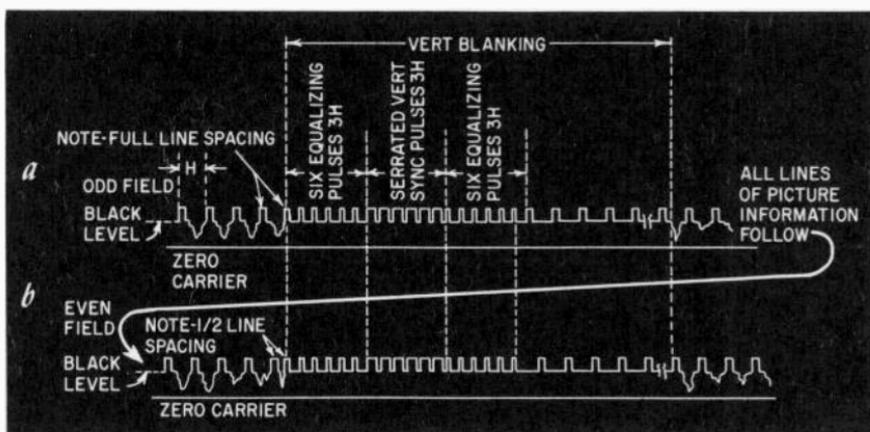
Fig. 306. *Actual signal with vertical and horizontal sync. pulses mixed together.*

same (63.5-μsec) interval. Thus, in Fig. 306, 3H means an interval three times as long as H. Obviously, when you see 0.5H written on a diagram, you know that it means an interval half as long as H.

The vertical pulses are precisely timed by precision electronic equipment at the broadcast station. *The timing of vertical sync pulses with respect to the number of lines (525) that comprise a picture results in interlaced scanning.* This statement requires explanation, so let's discuss the process.

First, a short review is in order. Fig. 304 shows the vertical sync pulses as being independent of the horizontal sync pulses. (We'll ignore the picture information for the time being). Horizontal sync pulses repeat at a rapid rate while vertical sync pulses repeat at a much slower one. You might think of the relationship between horizontal and vertical sync pulses by imagining that you

have a fast-ticking wrist watch and a slow-ticking old-fashioned grandfather's clock. While the pendulum of the grandfather's clock swings back and forth slowly, the wrist watch ticks rapidly. Compare the rapid ticking of the wrist watch to the rapid horizontal pulses and the slow ticking of the grandfather's clock to the slower vertical pulses. With this analogy in mind, remember that the *exact instant* when the grandfather's clock ticks, with respect to each tick of the wrist watch, is *very* important.

In Fig. 304, note how important the exact timing of the vertical sync pulse is with respect to the exact timing of the horizontal sync pulse. The vertical retrace of the odd field must be triggered *exactly* in the center of line 13. The frequencies of horizontal and vertical sync pulses result in the triggering of the vertical retrace at the end of the even field *exactly* at the end of line 12 retrace. Now, let's return to Fig. 306 which shows the actual signal with vertical sync pulses mixed in with the horizontal sync pulses. *The effect is the same as shown in the simplified signal explanation and illustration.*

The exact timing of the vertical pulse at the end of the odd-line field causes the following: the beam is retraced vertically so that it starts the even-line trace at the top center of the raster. Because of this starting point, each even line will be slightly lower than were the odd lines. Even lines will *fit between* the odd lines. Through correct timing of the vertical sync pulse that follows the even-line field, the beam is retraced vertically so that it starts the next odd-line field at the top left-hand corner of the raster. The timing of vertical pulses, with respect to horizontal sync information, results in interlace. However, additional pulses must be added to the video signal for correct interlace. These are the equalizing pulses.

Equalizing pulses

You might think that the serrated vertical sync pulse could appear just as soon as the last line of the picture finished. Not so. If this were done, the vertical sync circuits would not trigger properly for this reason: the voltage provided by the serrated vertical sync pulse is used to charge a capacitor. Because of a half-line difference between each succeeding field, the charging of the capacitor would not be the same for each field. For example, where there is a half line between the last horizontal sync pulse and vertical sync pulse, the capacitor would have more of a charge than when full-line spacing separated the horizontal sync and serrated vertical sync pulses. For this reason, a *buffer* time interval,

during which six equalizing pulses are transmitted, is used. Both conditions, for *charge* of the capacitor *before* the serrated vertical sync pulse and *discharge after* the serrated vertical sync pulse are used, to equalize the capacitor charge. This nullifies the effect of the half-line discrepancy between fields. In this way, the serrated vertical sync pulse triggers at the correct instant, and proper interlace results.

Horizontal sync pulses

During a moment of jocularity and good cheer, someone gave the name *front porch* to the interval before the horizontal sync pulse which sits on the blanking pedestal. Carrying the merriment a bit farther, someone dubbed the interval after the horizontal sync pulse the *back porch*. You can see both porches in Fig. 307.

The front porch enables the sync pulse to be independent of the blanking pulse. This is desirable because the timing of blanking pulses is affected, very slightly, by the brightness of the picture when a blanking pulse appears. If the picture is white when a blanking pulse appears, the blanking pulse reaches the blanking (black reference) level slightly later than would be the case if a black signal came before the blanking pulse. This is caused by the rise time of the blanking pulse. If this pulse starts from a low (white) level, it takes a little time for the blanking level to be reached. Therefore, the blanking pulse will exhibit a slight tilt. If the horizontal sync pulse were to start at the same time as the blanking pulse, it too would be subject to a slight lag. If the blanking pulse started when black information appeared on the video signal, there would be no rise-time problem. For this reason, a 1.27 μsec (0.2H) front porch is used. Thus, the precision timing of horizontal sync pulses is maintained.

The back porch is a good deal more spacious. After the horizontal sync pulse has done its work, the back porch keeps the screen blanked for 3.8 μsec (0.06H) during horizontal retrace.

Picture information in the video waveform

Fig. 307-a is the video waveform as it appears on the air. Notice that the lower half of the wave is a mirror image of the upper half. The video signal fed to the picture tube, however, varies in one direction only. This type of signal, a negative-going wave, is shown in Fig. 307-b.

In Fig. 307-b, the separation between the blanking pulses is shown as an uneven line. This is the picture information which will invariably be uneven in appearance because white, black and

54

many shades of gray can appear on one line of picture information. If you'll take a close look at one line of a picture on your television screen, you'll notice that, while some lines may be mostly black and some lines almost all white during a given instant, the majority of lines vary in intensity throughout their length. In Fig. 307-b, the line starts with dark gray, becomes white, gradually increases in gray tone, then becomes black, dark gray and white at the end of the line. The blanking pedestal is, of course, black, and the horizontal sync pulse appears in the blacker-than-black region.

Understanding the carrier diagram

Do you find television carrier diagrams confusing? If so, you're not alone. Many students don't understand the meaning of diagrams such as Fig. 308. For this reason, we'll try a different method of explanation to help you understand what the diagram says.

First of all, let's discuss the radio broadcast carrier because we're all familiar with the small radio. We can take advantage of this familiarity to learn the nature of the television carrier.

When you tune your radio set, you receive a radio frequency (rf) carrier. The carrier takes a certain amount of room on the dial. For example, suppose you tune in a station at 1,000 on the dial. The station doesn't lock in when the dial pointer hits one tiny pinpoint on the dial. Rather, the station can be heard, weakly, as the dial pointer approaches the 1,000 mark. You tune until the station is loud and clear. In other words, the station has some *broadness*; it occupies a little space above and below 1,000.

Carrier, amplitude modulation and sideband formation

Now, let's relate the broadcast band to the television band. Although an AM station has some broadness, it is a very sharp signal compared to a TV signal. Remember, many stations fit on your AM broadcast dial. Now, Fig. 308 shows only *one* channel in the TV frequency spectrum. Notice how much room the TV station occupies on the "dial." We use quotation marks because you don't actually have a dial to tune on your TV set, *with reference to any single channel*. When you switch to a channel, you tune in the *entire* frequency band covered by the channel at the same time. (You switch to a different broad band when you switch channels.) However, if you think of the base line in Fig. 308 as being like a dial (similar to your AM broadcast dial), you can better understand the way the base line indicates a segment of the TV frequency spectrum. The curve shows the signal strength over the frequency range (band) covered by the channel.

When the broadcast station is listed as having a frequency of 1,000 kc, it means that the voltage induced in your antenna flows back and forth 1,000,000 times a second. (The abbreviation kc means 1,000 cycles[1]. Therefore, 1,000 kc is equal to 1,000,000 cycles. Before a radio station begins its day of broadcasting, you'll hear a rushing sound when your radio is tuned to the station. This sound is caused by the carrier which is *unmodulated*. Modulation

WHITEST
SIGNAL   BLACK
DARK   GREY   WHITE
GREY

ZERO SIGNAL

THE SIGNAL ON THE AIR
a

ZERO VOLTS
DARK GREY   GREY   WHITE   BLACK
                                    REFERENCE
            WHITEST   OR BLANKING
            SIGNAL   LEVEL
                                    BLACKER-
                           BLACK   THAN-BLACK
                                    REGION
SYNC PULSE   BACK PORCH
5.08 μ SEC   3.8 μ SEC
DURATION   DURATION
      FRONT PORCH
      1.27 μ SEC DURATION
      DETECTED VIDEO SIGNAL
            b
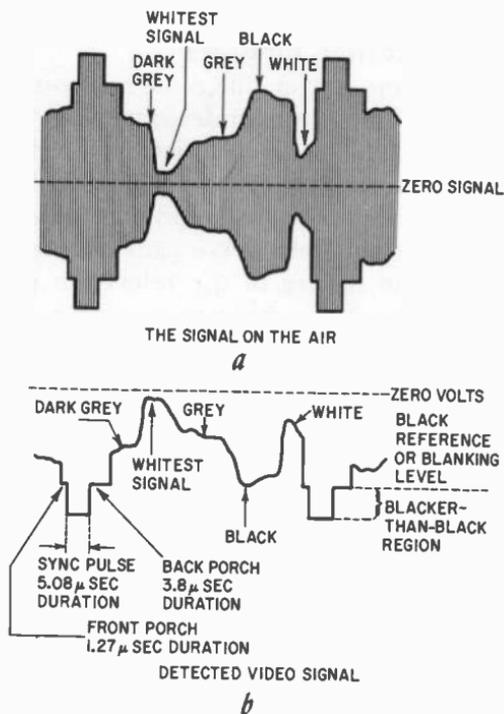
Fig. 307. (a) *Video signal as it appears on the air. Bottom half of wave mirrors top half. (b) Detected video signal. Uneven line between blanking and sync pulses is picture information. Line of picture information shows changes in intensity from beginning to end.*

refers to the superimposing of sound on the broadcast carrier. When the carrier is amplitude-modulated, it changes in strength according to the modulating sound. What does this mean? Simply

[1] Whenever the word cycle or the abbreviations kc or mc are used, a time period of one second is understood. Thus, kc means kilocycles per second. Mc refers to megacycles per second. An audio frequency of 1,000 cycles means that this many cycles are produced every second.

this: if the carrier is modulated by a 1,000-cycle tone, it gets weaker and stronger 1,000 times a second. (Instead of "times" a second, "cycles" are used).

Don't confuse the *modulating frequency* of 1,000 cycles with the *carrier frequency* of 1,000,000 cycles. The 1,000 cycles is an audio frequency while the 1,000,000 cycles (or 1,000 kc) is a radio frequency. Remember this when you read information dealing with this subject because both frequencies are mentioned often. In television, too, we have the carrier frequency (in millions of cycles)
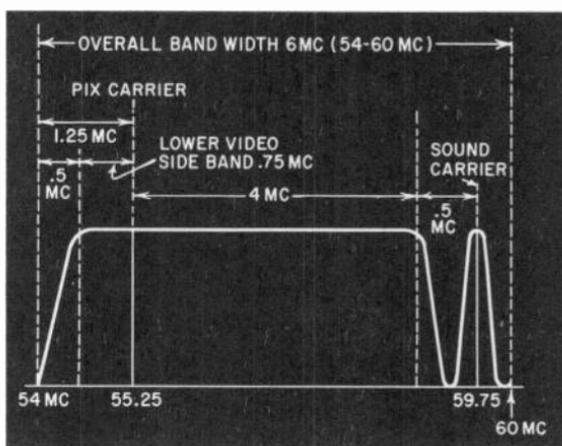
Fig. 308. *Diagram of television carrier. Total band space for picture and sound is 6 mc.*

(*megacycles*) modulated by video information with frequencies up to 4 megacycles.

Let's return to the subject of the radio broadcast carrier. The broadness of the modulated carrier is also called its bandwidth. If the station occupies a little room on the dial, it transmits a signal that has a *narrow bandwidth*. Most AM broadcast stations are restricted by law to a bandwidth of 10 kc, because many stations must occupy the standard AM broadcast band.

To understand how the carrier develops width, assume that a 1,000-cycle tone is broadcast on the 1,000,000-cycle carrier.

When the 1,000-cycle tone amplitude-modulates the carrier, causing the carrier height to vary 1,000 times a second, the tone also does something else. It produces *two new frequencies*. These are the sum and the difference of the modulating frequency (1,000 cps) and the carrier frequency (1,000,000 cps). Consequently, in addition to the 1,000,000-cycle carrier, both 1,001,000 cps and 999,000 cps will be present. For this reason, the broadcast

57

station will occupy more room on the dial. The signal, in other words, will be *broader*. Fig. 309 shows the points where sidebands appear. Suppose we modulate the carrier with a 2,000-cycle tone. The new frequencies produced will be 1,002,000 cps and 998,000 cps, because these are the sum and difference frequencies. The signal, therefore, will be *still* broader. As you can see, *the higher the modulating frequency, the broader the bandwidth.*

The new *higher* frequency produced by the modulating frequency (2,000 cps in the example just given) is called the *upper sideband* (1,002,000 cps). The new *lower* frequency produced by the modulating frequency is called the *lower sideband* (998,000 cps).
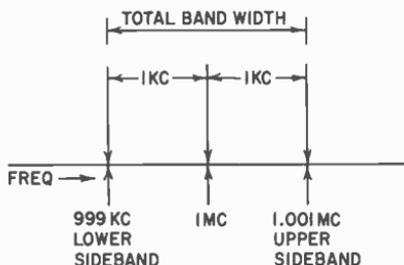
Fig. 309. *1-mc carrier amplitude-modulated by a 1,000-cycle tone. Illustration shows points where upper and lower sidebands appear.*

A standard AM broadcast station transmits both upper and lower sidebands. The sidebands convey intelligence. We don't need *both* sidebands; either sideband, plus the carrier, can be used to carry all picture and sound information. Because we want to conserve television band space, we want to get rid of the lower sideband. We would like to suppress all of it, but this is difficult, so *almost* all of the lower sideband is suppressed while *all* of the upper sideband is transmitted. Because we transmit just a little bit or a vestige of the lower sideband, the system is called *vestigial* sideband transmission. The vestigial sideband is about 0.75 megacycles wide.

The finer the picture detail, the higher the frequencies that modulate the video carrier. For you to see a sufficiently detailed picture, the bandwidth required is 4 megacycles. But, because you also want to hear the sound, the total band space for picture and sound is 6 megacycles.

Now let's get back to Fig. 308. Think of the horizontal base line as a dial on some sort of high-frequency radio. The 55.25-mc point is the spot on the dial where you'll find the picture carrier. The 4-megacycle area covers a wide area on the dial. At the 59.75 point on the dial, you receive another signal. This is the frequency-modulated sound.

Frequency modulation

In Chapter 13, the subject of sound and frequency modulation will be discussed in detail. At this time, however, a quick run-through is in order because the television signal includes a sound signal too.

To convey audio, the sound portion of the television carrier is varied in frequency above and below a center frequency. The carrier frequency is varied so that it follows the sound pattern with respect to audio frequency and audio waveshape. Loudness of sound is conveyed by the amount of carrier-frequency swing. The louder the sound, the greater the carrier-frequency deviation either side of the center frequency.

You know how a picture is formed, how the picture tube works, and how the video carrier conveys the information to be sent to the picture tube. Now, let's look at the marvelous electronic instrument that changes the rf signal into a picture with sound — the television receiver.

QUESTIONS

1. What is meant by horizontal retrace blanking? Vertical retrace blanking?

2. Explain black reference level. What is meant by blacker than black?

3. What is a front porch? A back porch?

4. What is the equalizing pulse frequency?

5. Why are vertical pulses referred to as serrated?

6. What is the time interval represented by the letter H?

7. Describe the process of amplitude modulation.

8. What is the difference between a modulating frequency and a carrier frequency?

9. What is meant by bandwidth?

10. How are sidebands produced?

11. What type of modulation is used for the picture? For sound?

12. Why is horizontal synchronization needed?

13. Why is vertical synchronization needed?

14. How do we obtain interlaced scanning?

15. What is a positive-going signal? A negative-going signal?

4

THE TELEVISION RECEIVER

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THE best way to study the television receiver is to start with a block diagram. In this chapter, we'll begin with a very simplified one. Then, when you and the receiver have a nodding acquaintance, we'll go into a detailed block diagram of a commercial receiver chassis.

Remember, the block diagram discussions (simplified and detailed) serve only as a general introduction to television receiver theory. Later, when you study circuits and detailed theory, you'll gain a more complete understanding of television receiver operation.

Split-sound and intercarrier receivers

The television signal is picked up by the antenna and fed into the receiver. Among the circuits that handle the signal are a series of amplifiers. Originally, it was thought that the sound signal had to be separated from the picture signal rather early in the signal-amplification process; therefore, each was processed through a separate section of the receiver. The sound portion of the signal was removed in the tuner or a stage later. This *split-sound* receiver has been replaced by the more efficient and economical *intercarrier*-type receiver.

In the intercarrier receiver, the type being made by all major manufacturers today, both the sound and picture signals are amplified in the video if section. In the detector, the sound signal is separated from the video signal. The sound signal is removed (tapped off) either in the detector or in the video output stage.

The intercarrier receiver, in addition to being more economical to make than the split-sound type (it uses less tubes), provides an advantage in much simpler tuning of picture and sound.

Simplified block diagram

First, let's look at the simplified block diagram in Fig. 401. We can consider the television signal as carrying three types of information: picture, sync and sound.
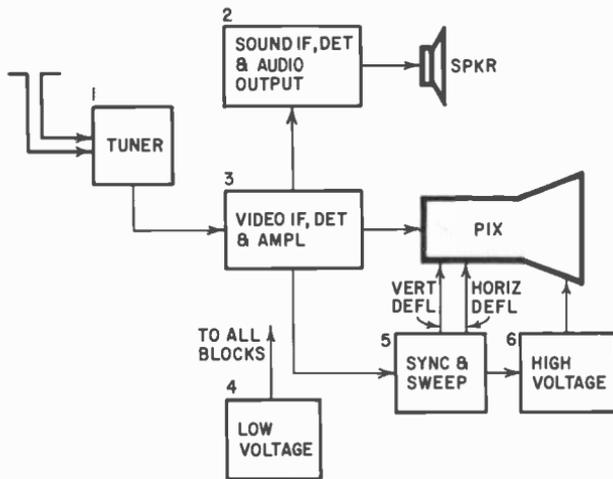
Fig. 401. *Simplified block diagram of an intercarrier television receiver.*

All three signals must be amplified, separated from each other and sent to their destinations. For example, the picture information in the video signal, after being sufficiently amplified, is fed to the picture tube to control the intensity of the scanning beam, the sync signal to circuits that control beam deflection, and the sound signal to the speaker.

For convenience, we've numbered the blocks in the diagram. The antenna picks up all the television broadcasts in the area, and the tuner (block 1) selects the desired signal. The television signal, which still contains all three types of information, is passed along to block 3. Within block 3, after the signal has been considerably amplified, a sampling of it is fed to block 5. Block 5 removes the sync pulses and processes them so that they control the horizontal and vertical sweep of the beam in the picture tube. A byproduct of the sync (sweep) signal is the high voltage (block 6) fed to the picture tube.

In block 3, the frequency-modulated sound signal is removed

and sent to block 2. This FM signal is processed so that the sound, which accompanies the picture, is detected and made strong enough to operate the speaker.

Low voltage, from block 4, is connected to almost every tube in the receiver.

Detailed block diagram of an intercarrier receiver

Now we can examine the detailed block diagram of a television receiver (see Fig. 402). Let's follow the signal through the TV set and discuss the circuit functions.

A vhf (very-high-frequency) antenna is constructed to pick up channels 2 through 13. All the channels are simultaneously picked up by the antenna and fed through a transmission line into the rf tuner. You can select the desired channel by turning a channel selector located in the tuner. Your chosen signal is amplified by the rf amplifier and fed to a mixer tube.

When you rotate your channel-selector knob, you do two things: you select coils that tune to the desired channel, and you select an oscillator frequency that beats with the incoming channel frequency. As a result, the tuner produces an intermediate frequency (if). The if is always the same, no matter which channel is chosen. A manufacturer can pick any one of a number of intermediate frequencies when he designs a set, but in recent years the following have become standardized:

<div align="center">

Picture if: 45.75 mc

Sound if: 41.25 mc

</div>

Throughout this book, these frequencies will be used whenever the subject of video if is discussed.

Both picture and sound are amplified by the first, second and third video if stages. Both are sent to the video detector, which has a double function:

First, it changes the symmetrical rf signal to dc that varies in one direction. If you'll check back to Fig. 307, you'll see this illustrated. Fig. 307-a shows the signal as it exists either on the air or in if form; Fig. 307-b shows a negative-going detected signal.

Second, in the video detector, the picture carrier if (45.75 mc) beats with the sound carrier if (41.25 mc) to produce a 4.5-mc difference frequency. This is the intercarrier sound if.

From the video detector the picture signal travels to the picture tube via a video amplifier. At the plate of the video amplifier, the 4.5-mc sound signal is trapped and fed to the sound section. The 4.5-mc sound if is amplified, demodulated by a ratio detector, amplified, and is finally sent through the audio output stage to the

speaker. The other signals, shown as flowing here and there in the block diagram, function in a slightly more complex manner.

Sync, sweep, agc and power supply

Continuing our study of the detailed block diagram (Fig 402), we see that the sync clipper receives a signal from the video amplifier. The sync clipper separates both the horizontal and vertical pulses from the video signal.

Horizontal pulses control the sweep of the beam across the picture tube. The circuit that produces the horizontal frequency of 15,750 pulses per second is the horizontal oscillator. The horizontal output tube amplifies the pulses. The frequency and phase of the horizontal oscillator is controlled by the phase detector. Therefore, these three circuits — the phase detector, horizontal oscillator and horizontal output — are involved in producing a synchronized horizontal sweep signal. The automatic frequency control (afc) feedback loop, from the horizontal output, supplies a comparison horizontal pulse signal back to the phase detector. The phase detector compares the sync clipper horizontal pulse signal with the feedback signal from the horizontal output stage. If the horizontal oscillator is at the correct frequency and phase, the phase detector doesn't bother the horizontal oscillator; it has no voltage for it. But if the horizontal oscillator drifts off frequency and phase, the phase detector senses this immediately and produces a voltage which corrects the drift. Thus, by comparing the horizontal pulse signal from the sync clipper with the pulses fed back from the horizontal output stage, horizontal scanning is synchronized.

Vertical pulses control the vertical movement of the beam in the picture tube. The vertical multivibrator produces the 60-cycle vertical sweep frequency, which is amplified by a vertical output tube. The sync clipper feeds a sync signal, derived from the vertical pulses in the video signal, to the sync input of the vertical multivibrator. This vertical sync signal triggers the vertical multivibrator and locks in its frequency and phase.

The automatic gain control (agc) system in any receiver automatically reduces the receiver gain when strong signals are received. In many receivers, such as the chassis being discussed, delayed agc is used. The gain control voltage is *not* sent to the rf amplifier stage when very weak signals are received. We want maximum gain in the rf amplifier with weak signals. Even a small amount of agc control voltage would reduce amplification in this low-level amplifier stage. In this particular chassis, a negative volt-

Fig. 402. Detailed block diagram of a representative television receiver. The rf amplifier, the mixer and local oscillator, is shown enclosed in broken lines since the tuner is a separate unit with its own chassis. Only one video amplifier stage is shown. Some sets have two video amplifiers but these are a minority. The audio section is designed to handle an FM signal. The picture signal is AM.

age developed by the sync clipper is used as agc to set a bias level for the rf and first video amplifiers. This voltage is combined with a reference voltage established in the video detector. All video information is filtered from the agc signal. The agc clamp stage produces the agc delay.

High voltage for the picture tube is produced, indirectly, by pulses from the horizontal output stage. Actually, it is the horizontal retrace (or flyback) that produces high-voltage pulses. A transformer increases the voltage level considerably and the high-voltage rectifier changes the sharp pulses to dc. The rectified high-voltage dc is connected to a high-voltage terminal on the picture tube which, in turn, is attached to the aquadag coating within the tube. The damper stage is involved with the horizontal sweep of the beam and the production of an additional B-plus voltage called boost B-plus. The low-voltage power supply distributes about $+250$ volts throughout the set. Some tubes make use of the full voltage; others require less.

Windup

In thinking about the TV receiver in block diagram form, you might compare the electronic system with the mechanical system in a machine. For example, your automobile has a carburetor that has its purpose. It sprays gasoline vapor into a chamber. The ignition system then comes into play; a spark appears at the correct instant (for each piston) to explode the gasoline vapor. In this way, power is developed to turn a crankshaft in the engine. There are other systems throughout the car; each performs a function but the car cannot be operated if a system fails.

In the television set, many systems are at work. For example, while picture information is fed to the picture tube, the sweep section performs its function. And, within the sweep section, the horizontal deflection system, perfectly timed by horizontal pulses in the signal, causes the beam to be swept across the screen. At the same time, the vertical deflection system, perfectly timed by vertical pulses in the signal, pulls the beam down slowly, then retraces the beam. The sound system enables you to hear the sound that accompanies the picture. Power supplies can be considered as another system. All of these operate at the same time and cooperate with each other to produce the picture on your screen and accompanying sound in the speaker.

5

ANTENNAS AND TUNERS

● ●

You are an antenna. Even as you read this book, hundreds of little voltages are running through your body. Why? Any radio or television station that can be received in your area exists in the form of energy in the air. The energy carries the information transmitted by the broadcast station. Your body picks up the energy; each radio station induces a very tiny voltage in *you*. As a matter of fact, not only do the broadcast stations induce a voltage in you, the hundreds of shortwave stations also do the same. Of course, the voltages are so weak you don't feel a thing. Your only shock may be the knowledge that you, and everyone, are actually an antenna. If you doubt it, hold your hand near the built-in antenna of your midget radio. Chances are the sound will get louder because you, serving as an additional antenna, are added to the radio's built-in antenna.

Every piece of metal is an antenna. This is because every piece of metal picks up radio and television signals. This leads to a problem you might think about. Suppose you had two metal rods, one 70 and the other 52 inches long. You know that voltages from many stations are induced into both rods. Which rod will develop the greatest voltage induced by TV channel 2? The answer: the 52-inch rod. Why? A length of 52 inches is closer to the *resonant frequency* of channel 2.

Resonant frequency

Can you solve this puzzle?

A trumpet player was practicing in his living room. Whenever

he played middle C, the glass lampshade rattled. Other tones did not noticeably affect the lampshade. Why?

The answer is simple. The lampshade has an *audio resonant frequency*. The audio frequency of the tone middle C happened to be the resonant frequency of the lampshade. Size determines the resonant frequency of an object. If the lampshade had been smaller, it would have had a higher audio resonant frequency; if it had been larger, a lower one.

Actually, the lampshade vibrates in response to any sound in the room. But it vibrates *strongly* when the frequency of the sound is the same as the lampshade's natural audio resonant frequency.

In the preceding example, we discussed audio frequency so that we could talk about familiar objects you can visualize. Now, let's apply the idea to radio frequency. Note that a similar principle applies.

Earlier we said a 52-inch rod is close to the rf resonant frequency of channel 2. This means that the strongest voltage is built up in the rod by the channel 2 television signal. All other television signals (radio, too) induce their signals into the 52-inch rod, but the rod is broadly resonant at the channel 2 frequency — 54 to 60 mc. A 70-inch rod, because it is *not* resonant at channel 2, will develop a weaker voltage in response to that channel.

Any rod — one piece of metal — will be resonant at some radio frequency. The basic television antenna (dipole), however, is made of not one rod, but two.

Dipoles and folded dipoles

Look at the rooftops in your neighborhood, and you'll see that antennas come in many varieties. We won't get involved with more than two. Also, we won't go into very much detail because this subject can get extremely complicated.

A dipole looks like the antenna in Fig. 501-a; a folded dipole looks like the one in Fig. 501-b.

An antenna has impedance. As you know from basic electrical theory, to get the greatest output from a generator, the load impedance must be just the same as the generator impedance. A similar condition exists with an antenna. For example, the impedance of a folded dipole (Fig. 501-b) is 300 ohms. The TV signal energy is carried along a transmission line which is made so that it has an impedance of 300 ohms throughout its length. At the receiver, the 300-ohm transmission line (usually 300-ohm ribbon) connects to the receiver input.

A dipole has an impedance of 72 ohms, and tends to have a

sharp response. This means that a strong signal voltage develops in the dipole for the station that transmits the resonant frequency for which the antenna is cut. For example, if the antenna is resonant at channel 7, this channel will induce a strong signal in the antenna. The antenna will receive other channels, but not too well. A folded dipole (Fig. 501-b), however, has a broader response and does better on all channels.

Dipoles are directional

A dipole, or folded dipole, is directional. Imagine a straight line leading from the broadcast station's transmitting antenna to
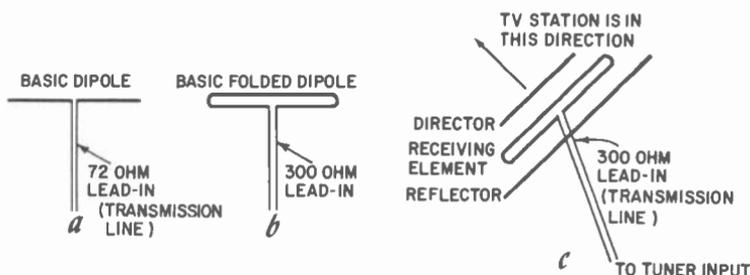

Fig. 501. *(a) Dipole with 72-ohm coaxial lead-in. (b) Folded dipole with 300-ohm transmission line. (c) Director-reflector type of antenna with 300-ohm lead-in.*

a dipole receiving antenna. The receiving antenna develops the strongest signal when it is at right angles to the imaginary line. If the receiving antenna is turned off at an angle, the signal it develops gets weaker. If the receiving antenna is turned parallel to the imaginary line from the transmitter, the signal developed by the antenna will be weakest. In this position, the receiving antenna is said to be at a null point.

Someone once made an important invention. He took a dipole receiving antenna and turned it broadside to a station so that he received the strongest signal. Then, he put a longer rod behind the antenna and the signal got *still* stronger! The longer rod reflected much of the signal back to the dipole; therefore, the long rod served as a *reflector*. Next, this bright fellow placed a shorter rod in front of the dipole. "Egad", he exclaimed, "The signal is still stronger!" Yes, the shorter rod, called a *director*, helped pull more signal to the dipole. Therefore, the antenna in Fig. 501-c picks up a stronger signal than those in Figs. 501-a or -b. Furthermore, the antenna with director and reflector discriminates against signals arriving from the reflector side. This characteristic is useful in eliminating undesired signals.

69

The director – reflector type of antenna usually must be turned toward the broadcast station for best results. In weak signal areas, more directors (each progressively shorter) and more reflectors (each progressively longer) are added to the antenna.

You may also have noticed antennas on towers. This is done because increasing the height of an antenna usually increases signal pickup in fringe areas.

A basic dipole or folded dipole is bidirectional. This means that it picks up equally well in two directions. For example, a bidirectional antenna that picks up well from stations located to the north will pick up equally well from stations located to the south.

A unidirectional antenna picks up in one direction only. For example, a unidirectional antenna may pick up stations located to its north, but no signals from east, west or south. The pickup pattern of an antenna, when drawn on a graph, looks like a lobe. The antenna design determines the lobe pattern; many variations are possible.
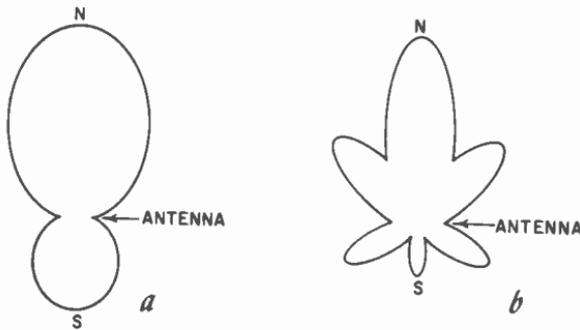

Fig. 502. *Lobe pattern (a) is typical for a wide-band antenna operating at a low-channel frequency. Used for reception on one of the high-band vhf channels, the pickup pattern often develops many minor lobes (b) that make orientation difficult.*

Fig. 502 shows two possible lobe patterns. That shown in Fig. 502-a is typical for a unidirectional antenna. There is usually a small lobe in the undesired direction, but most of the pickup is in a single direction as in the illustration. The lobes may be wide or narrow. If you want to pick up stations located to the north and are troubled with considerable interference from east and west, you might use an antenna with a narrow lobe. The lobes will vary from channel to channel; therefore, the lobe pattern is chosen to suit the channels to be received. If you live in a strong signal area, a good general-purpose three-element antenna usually works well, and the antenna location is usually determined by trial and

error. In the fringe areas, a multi-element antenna on a tower may be needed. Practical antenna installation experience, in the particular fringe area, is rather important.

Antenna placement

The receiving antenna is *usually* turned toward the broadcast station. This would be the case under ideal conditions, but under practical conditions you may find many problems. For example, the TV signal may bounce off a nearby building, and sometimes (not often), the best signal is obtained when the antenna is pointed toward the building. However, such reflections are more often a nuisance than a help, because they cause ghosts. On your screen, a ghost looks like a duplication of each object in the picture, a little to the right of each object.

Ghosts are caused in this way: the signal travels from the transmitter to your receiver in a straight line. The same signal hits a building and is reflected toward your receiving antenna. Therefore, your antenna gets the signal directly from the station and, a microsecond or two later, picks up an identical signal reflected from the building. Both signals appear on your screen. Highly directional antennas help eliminate ghosts. Another way to eliminate them is by careful antenna placement — finding the right spot on the roof (or up on a chimney, perhaps) for the antenna and turning the antenna properly (usually by trial and error).

When all the television stations are not located in one direction, you may have to turn the antenna to a compromise position. Again, you will probably use a trial-and-error testing method. If the stations are widely separated, you may have to use multiple antennas or an antenna rotator.

Vhf and uhf antennas

The information given on dipoles, folded dipoles and directional antennas applies to both vhf and uhf antennas. Vhf, which stands for *v*ery *h*igh *f*requency, takes in channels 2 through 13. The vhf range is from 54 to 88 mc and from 174 to 216 mc. Uhf, which means *u*ltra *h*igh *f*requency, consists of channels 14 through 83. The uhf range is 470 to 890 mc.

As we go up in frequency, antenna size comes down. Hence a uhf antenna is smaller than one for vhf. Its placement though, is usually more critical. In other words, it is more difficult to find the correct spot for a uhf antenna. Sometimes, a uhf antenna won't work even though it appears up and in the clear. But when moved

a foot higher, it may pull in a fine picture. Again, trial and error is used to find the right spot.

So much for antennas. Remember — we have just covered two basic types, but books can be (and have been) written on this subject alone. But now let's follow the television signal down the transmission line to the tuner.

Vhf tuner

The vhf television signal picked up by antenna travels down the transmission line to the vhf tuner. The tuner is a separate chassis physically connected to the television chassis (usually bolted). Wires electrically connect the tuner to the rest of the set.

This is what the tuner does:

1. It selects the channel. When you turn your channel selector, you turn a switch in the tuner.

2. It amplifies the incoming signal.

3. It changes any selected channel-frequency band to the *same* intermediate-frequency band.

We use the term "channel-frequency band" because each TV station transmits a band of frequencies. For example, channel 2 covers a band from 54 to 60 mc. The tuner input accepts and passes this broad signal. The channel 2 picture carrier is at 55.25 mc; its sound carrier is at 59.75 mc.

In a typical modern receiver, the picture if consists of a *band* of frequencies from slightly above 41 mc to slightly below 46 mc. When this if band is used, the exact picture if is 45.75 mc and the exact if that initially carries the sound is 41.25 mc. The function of the tuner is to change the selected channel (between 2 and 13) to the 41 – 46-mc if band.

To summarize, when channel 2 is selected, a 55.25-mc picture signal and a 59.75-mc sound signal go into the tuner. After amplification, the tuner changes the input signals to a 41.25-mc sound if signal and a 45.75-mc picture if signal. And remember this: when the channel selector is turned so that a higher channel is received, the tuner if output will still be 41.25-mc sound and 45.75-mc picture. In other words, the same if is always fed out of the tuner no matter what channel is received.

Coil-switching methods

To change channels on your TV set, you have to switch several coils in the tuner. A different set of coils is needed for each channel. With respect to the coil-switching systems, there are two types of tuners. One is called the *incremental,* the other the *strip* tuner.

In the incremental tuner, ganged wafer switches are used. When you turn the channel selector, you short a part of each wafer switch. The part you don't short, combined with the distributed capacitances around the coils, forms the tuned circuits. In other words, the part of each coil shorted is effectively taken out of the circuit. The part of each coil left in the circuit (combined with distributed capacitance) tunes to the desired channel.

You switch coils in the strip tuner by inserting the desired set of coils in the circuit and completely removing all sets of coils for undesired channels. On some strip tuners, each set of coils (one set for each channel) is mounted on a turret. As the turret is turned, only the desired set of coils is engaged. The unused sets of coils are left out of the circuit. In the strip tuner to be studied in this chapter, the sets of coils are mounted on a disc. Nevertheless, the principle remains the same — only the desired set of coils are switched into the circuit when a channel is selected.
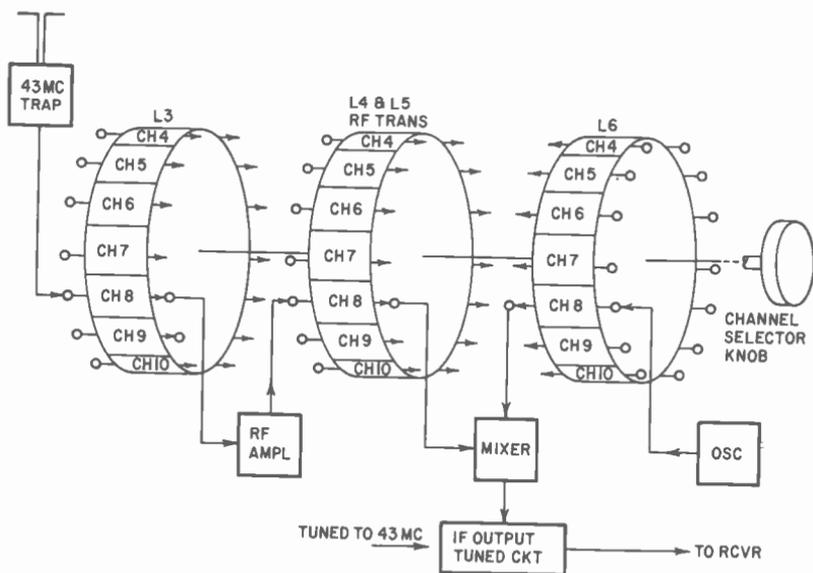

Fig. 503. *Block diagram of a strip vhf tuner. Note how only one set of coils at a time is in the circuit.*

The strip vhf tuner

To simplify the explanation to follow, let's talk about the television signal as though it were one frequency instead of a broadband signal. Also, let's imagine that the intermediate frequency also

73

consists of one frequency – exactly 43 mc, instead of a band from about 41 to 46 mc.

Fig. 503 is a somewhat unusual block diagram of a strip vhf tuner. To help you understand how coils or rf transformers are switched by the channel selector, they are drawn as blocks on a wheel. Notice that only one set of coils is in the circuit at a time; the others are out of the circuit. The tuner in Fig. 503 is a block diagram of the one shown schematically in Fig. 504. The wheels are ganged; when you turn the knob, you switch three blocks (coils or rf transformer) at the same time. Input and output contacts of each block are shown; the arrows show direction of signal flow.

Now let's follow the television signal in its trip toward the input of the receiver. At the end of our antenna discussion, the signal was still in the antenna. More accurately we should say *signals,* because each vhf station sends its own signal into the antenna; the antenna accepts them all. All signals (channels) slide down the transmission line. But before we pick the channel we want, our first task is to get rid of any signals around 43 mc. Why? Well, the if section of our receiver is designed to welcome 43-mc signals. We want the 43-mc if *developed in our tuner,* but we don't want any *interfering* 43-mc signals. If 43 mc is in the air (possibly transmitted by a shortwave station or as a harmonic of a lower-frequency station), our tuner will pick up this interference. The undesired 43-mc signal will go right through the tuner into our if system because the receiver doesn't know the difference between a desirable or an unwanted intermediate frequency. We must, therefore, tell the 43-mc interfering signal, "Keep out." A 43-mc trap does this.

The channel selector in Fig. 503 is set at channel 8, 177 mc. All the channel 8 coils (L3, L4, L5 and L6 in Fig. 504) are in the circuit but all the other unwanted strips are disconnected. The L3 block is resonant at the channel 8 frequency. This means that this block (which represents a coil or tuned circuit) builds up a strong voltage in response to 177 mc. This signal voltage is amplified by the rf amplifier and fed to L4 and L5. In this tuner, L4 and L5 comprise an rf transformer resonant at the channel 8 frequency (177 mc) and is the rf transformer which couples the signal to the mixer.

No matter what channel we receive, the if must be 43 mc. As you know, the oscillator frequency, when mixed with the signal frequency, produces new frequencies. The new frequencies are the difference and the sum of the oscillator and signal frequencies. (We get other frequencies as well. These would include the
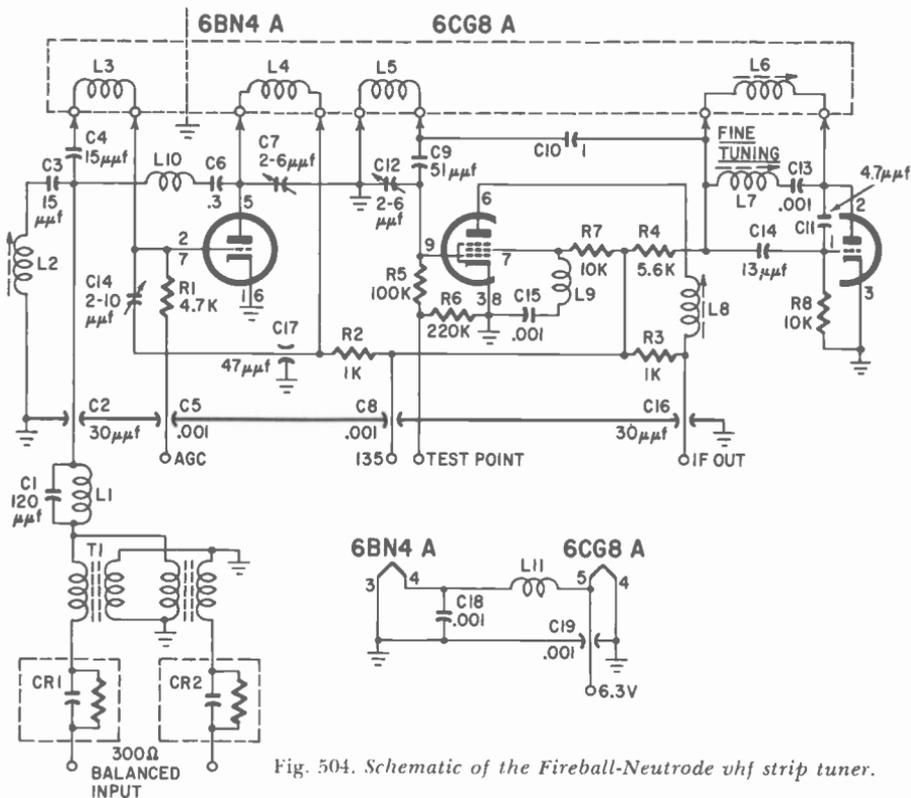
74

Fig. 504. *Schematic of the Fireball-Neutrode vhf strip tuner.*

original rf and local oscillator frequencies, plus a number of harmonic frequencies.) However, the new frequencies we might be able to use are the oscillator frequency *plus* the signal frequency or the oscillator frequency *minus* the signal frequency. (The oscillator frequency is higher in most tuners.) As you can check with pencil and paper, an oscillator frequency of 220 mc, when mixed with the signal frequency of 177 mc (channel 8), will produce these new frequencies: 397 mc (the sum) and 43 mc (the difference). The oscillator is designed to generate 220 mc when the channel 8 oscillator coil is switched in (as shown in the block diagram). We're not interested in the sum — it is the difference frequency we want. For this reason, the if output tuned circuit is tuned to 43 mc, and this frequency is fed to the receiver if input.

Standard Coil Neutrode (Fireball) vhf tuner

Because Standard-Kollsman is one of the major producers of tuners, we've chosen one of its popular units for study — the Fireball Neutrode. The tuner circuit is shown in Fig. 504.

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The very first parts encountered by the incoming television signal are CR1 and CR2. These are isolation networks included in the circuit because many receivers have their chassis directly connected to one side of the ac line. In every home, one side of the ac line is connected to ground. Because all water and radiator pipes are also connected to ground, one side of the ac line is connected to all pipes in the house. The other side of the ac line is "hot" with respect to ground. If you were accidentally to touch a pipe and the hot side of the ac line at the same time, you would get a shock. If the receiver has one side of its ac input connected to the chassis, the chassis may also be hot. With the tuner mechanically connected to the receiver chassis, the tuner and antenna terminals would be electrically hot with respect to ground. Isolation network CR1 and CR2 prevents shocks that might result from touching a bare antenna wire, or a short circuit that may be caused by accidental grounding of the antenna or lead-in.

Transformer T1 matches the balanced 300-ohm input to the 75-ohm tuner input. If the input were of the unbalanced type (and this design is rarely used), one side of the lead-in would be grounded at the tuner input. With balanced input design, the electrical center of T1 is grounded and all parts of the antenna and lead-in are symmetrical with respect to chassis ground. The balanced input design is better because noise is cancelled in T1.

The traps in the 43 mc range, mentioned in the block diagram discussion, are L1 and C1 (parallel trap) and L2 and C3 (series trap). Coil L3 is one of the rotatable coils. This means that a different L3 is switched in for each channel. This coil, resonant at the desired channel frequency, is actually a tuned circuit. "Where is the capacitor?" you might ask, because a tuned circuit consists of a coil and capacitor. Distributed capacitance of the coil, the rf amplifier tube and wiring is the capacitor. The space between the windings of the coil and around the coil effectively form a capacitor. This distributed capacitance joins with the coil inductance to act as a tuned circuit.

The rf signal, fed to the grid of the 6BN4A, is amplified by the tube. A look at Fig. 504 will show an agc input connected to the grid of the 6BN4A rf amplifier. Agc works by varying the bias on the amplifier tubes (rf amplifier in the tuner and if amplifiers in the receiver). Increase the bias on an amplifier and you lower the gain. Agc is discussed in Chapter 7 but, for now, you should know that the agc voltage, fed back from a later stage in the receiver, controls the gain of the rf amplifier in the tuner.

This particular tuner (Fig. 505) uses neutralization to give high gain with low noise level. A small portion of the signal in the plate circuit of the 6BN4A is fed back, out of phase, through, the small variable capacitor C14 to the control grid. This negative feedback cancels the effect of capacitance between the tube
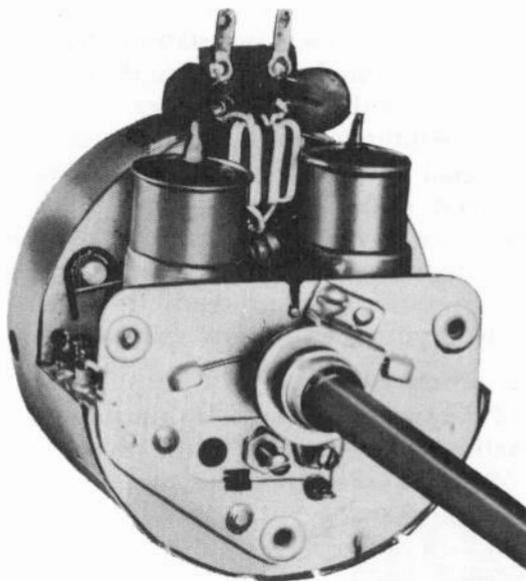

Fig. 505. *Vhf tuner of Fig. 504. Tuner provides high gain with low noise level.* (Standard-Kollsman)

elements, thus nullifying the undesirable effects of in-phase or positive plate-to-grid feedback within the tube. Plate-to-grid positive feedback is undesirable because too much of it causes oscillation. Positive feedback also narrows the bandpass, something we cannot afford here. By cancelling the feedback through the tube through neutralization, the tube can be made to give considerable gain without oscillation. The neutralized triode circuit shown is a special TV tuner circuit that has been dubbed Neutrode.

Mixer and oscillator

If you'll glance again at Fig. 503, you'll see that L3, L4, L5 and L6 are all switched when you turn the channel-selector knob to change channels. The amplified signal (Fig. 504) developed across L4, is magnetically coupled to L5 and fed to the grid of the mixer, the pentode half of the 6CG8A. The oscillator coil, L5, is switched so that the oscillator will produce the desired frequency.

If it were possible to produce a perfect tuner (at a reasonable price) we would need only the oscillator coil to determine the oscillator frequency. Such a precision tuner is not practical. Therefore, a variable inductance, L7, is used to make slight corrections in oscillator frequency. This variable inductance is the *fine-tuning control.* Earlier models of the Neutrode tuner used a variable capacitor for this. However, oscillator stability has been improved by substituting the variable-inductance fine tuning in later production runs of the Fireball Neutrode tuner.

You tune the fine-tuning control for best picture detail if you live in a strong signal area. The best detail, however, doesn't represent the strongest signal. Therefore, in fringe areas where signals are weak, you may have to adjust the fine-tuning control for the strongest signal. In fringe areas, a weak signal tends to slip out of sync; a stronger signal tends to remain in sync because stronger sync pulses accompany the picture.

Broad-band characteristics

At the start of the tuner discussion in this chapter, we gave some specific information about channel 2: the picture is at 55.25 mc and sound at 59.75 mc. (Picture and sound are separated by 4.5
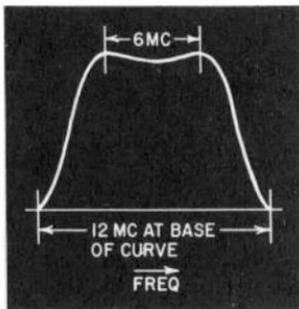

Fig. 506. *Response curve shows how tuner accepts a band signal about 12 mc wide. A 6-mc wide TV signal is easily accepted.*

mc). Later, in discussing the tuner block diagram, we asked you to think in terms of one frequency being amplified and converted rather than a band of frequencies. Now, let's return to practical frequencies.

It is important to realize that a tuner must handle a broad-band signal — you have to adjust the tuner to pass a band of proper width. Although a tuner amplifies and converts (to the intermediate frequency) the 6-mc-wide television signal, a tuner accepts a band about 12 mc in width. The flat part of the received signal is 6 mc wide. (Fig. 506). The curve tells you that a signal 6 mc wide is welcomed by the tuner input. Because it's not practical to design a tuner that accepts *only* the desired 6-mc signal and no

other frequency, most tuners actually respond to a band 12 mc wide. However, as you can see in Fig. 506, the frequencies are progressively weaker on either side of the desired signal.

To summarize, the rf stage in the tuner is designed to amplify the broad rf signal; the oscillator and mixer produce a broad if signal. The tuner output tuning coil is resonated at the broad if signal. In the examples given in this chapter, the if band covers approximately 41 to 46 mc.

Direct-coupled amplifiers

Because the cascode circuit, which we will investigate next, is a variation of the basic dc amplifier, it's a good idea to know something about such amplifiers in general. The basic dc amplifier circuit is shown in Fig. 507.
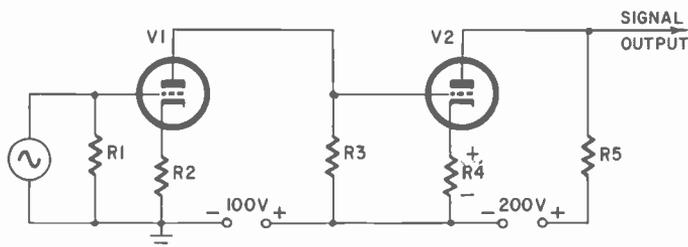

Fig. 507. *Schematic diagram of basic direct-coupled amplifier circuit.*

Most amplifier circuits are of the resistance-capacitance (R-C) type: the coupling capacitor isolates the plate circuit of an amplifier stage from the control grid circuit of the next amplifier stage. In the dc amplifier, the plate of one stage is connected directly to the control grid of the stage that follows (Fig. 507).

In mentioning voltages in the discussion, we'll use round numbers for simplicity; also, we'll ignore the voltage drops across the plate load resistors. (Obviously, the voltage on the plates will be lower than the battery voltage when a tube draws current; however, we're interested in the main idea behind dc amplifier theory).

In Fig. 507, 100 volts (positive) exists between the plate of V1 and ground. This is fine for operating V1, but you might wonder how we can operate V2 with 100 volts (positive) on its grid. Easy. We simply put more than 100 volts (positive) on the cathode of V2. Therefore, the grid voltage of V2 is *negative with respect to the cathode voltage of V2*. Resistor R4 also makes the grid of V2 negative with respect to V2's cathode. Remember, when we say a voltage is positive, the idea is not complete until we answer the question, "positive with respect to what point?" Usually, positive

voltages are given with respect to ground; this is often assumed and not stated. However, in the dc amplifier, the grid of V2, although positive with respect to ground, is negative with respect to its own cathode and plate.

Incremental cascode tuner

The block diagram in Fig. 508 is of a typical incremental type cascode tuner. A simplified schematic is given in Fig. 509.

The cascode circuit used in this tuner is different from the basic dc amplifier circuit (Fig. 507) in that the tuner circuit has the plate of V1a (Fig. 509) tied to the cathode of V1b. This is a cathode-drive arrangement similar to that used between the video amplifier and picture tube of most new sets. However, the basic
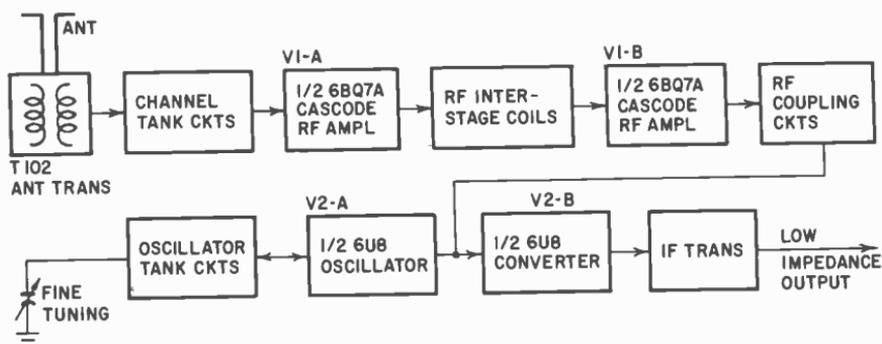

Fig. 508. *Block diagram of incremental type cascode turner.*

dc amplifier principle still applies because the cathode of V1b is positive with respect to V1b's grid.

The television signal picked up by the antenna is fed through a 300-ohm transmission line to the antenna transformer, which has a balanced center-tapped primary. Therefore, the signal voltages across each half of the transformer are equal and 180° out of phase. This serves to eliminate noise and low-frequency interference, because noise signals are usually of the same phase in each leg of the transmission line. As a result, the interfering signals cancel in the transformer.

The secondary of T101 is tapped so that on low-frequency channels (2 through 6), the full secondary winding is used. On high-frequency channels (7 through 13), the tapped portion in series with C100 is used.

The cascode rf amplifier offers the advantage of the low-noise feature of a triode amplifier with the gain characteristics of a pentode. The dc amplifier principle gives us this benefit.

To give even greater gain, the interstage coupling within the cascode circuit is tuned for each channel. This provides greater individual channel gain than could be achieved with a single coil tuned to pass the entire bandwidth of all channel frequencies.

The automatic gain control (agc) voltage, fed back from a point later in the receiver, controls the bias on the grid of V1a. This tube gets additional cathode bias from its cathode resistor R102, which sets the tube's minimum operating bias.
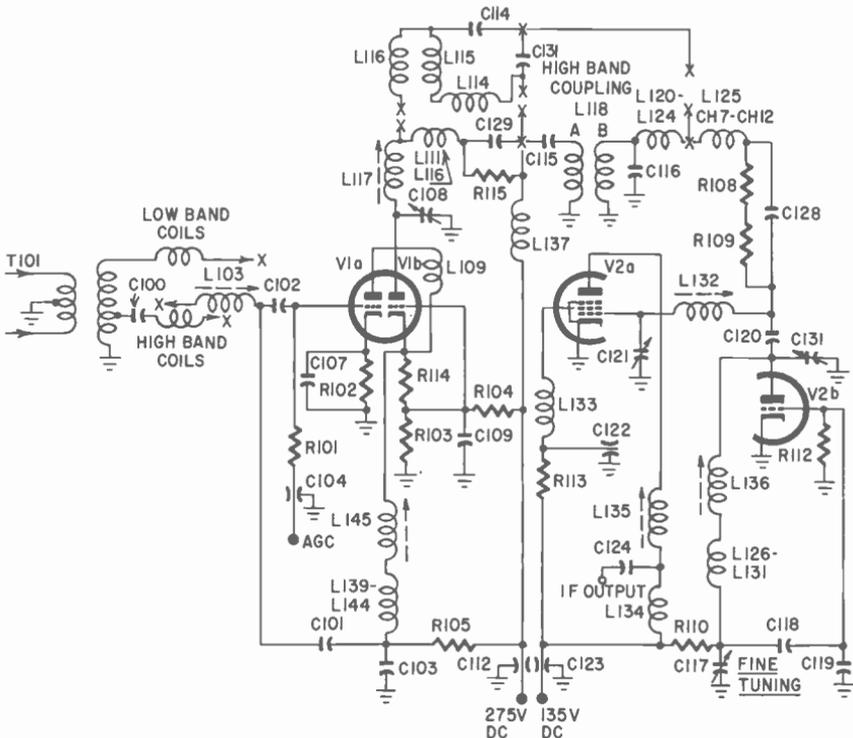

Fig. 509. *Cascode-tuner circuit. Direct coupling is used by the rf amplifier.*

The plate of V1b is tuned by series tapped coils, the distributed capacitance in the circuit, plus trimmer capacitor C108.

The output of cascode rf amplifier V1 is coupled to the converter in three ways. On channels 2 through 4, coupling is achieved by capacitors C114 and C115, and the inductive high-band coupling L118-a and L118-b. On channels 5 and 6, it is obtained by capacitors C114 and C115 and inductive coupling L118-a and L118-b. On channels 7 through 13, coupling is through capacitor C115 and the inductive coupling of L118-a and L118-b.

In Fig. 509, the mixer is V2a and the oscillator V2b. The mixer grid is tuned by series tapped coils and by trimmer capacitor C121. The oscillator couples into the grid of the mixer through C120. For covering the 12 vhf channels, the oscillator has a tapped tuned tank circuit providing the range required for the frequencies involved. At the end of this tank circuit is fine-tuning capacitor C117, adjusted to provide for exact alignment of the oscillator on each channel.

The mixer plate output circuit is low-impedance-coupled to the if section. Plate coil L135 is normally tuned to the center frequency of the if passband. Inductor L133 is included in the screen circuit of the mixer to permit adjustment of the bandwidth to increase the high-channel output. The tuner output is coupled to the receiver if input through a capacitor.
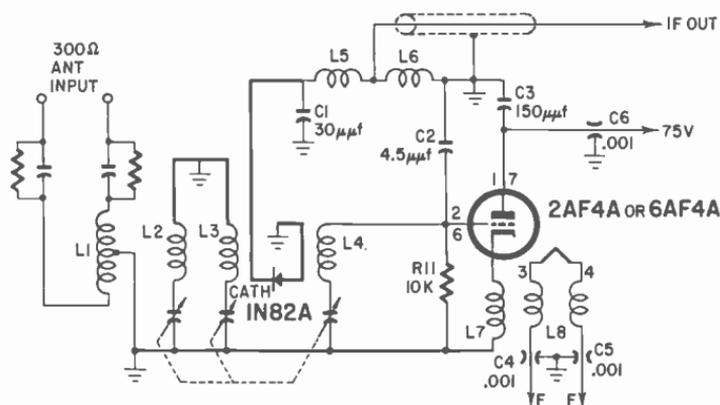

Fig. 510. *Schematic of "Piggyback" uhf tuner. The entire unit is a high-frequency oscillator and a crystal mixer.*

Uhf tuner

If you live in an area serviced by an ultra-high-frequency (uhf) station, knowing how uhf tuners work is important. Although the term uhf tuner is commonly used, the device is actually a converter. It converts the high frequency (uhf) to a lower frequency (vhf).

Although several types of uhf tuners are in use, let's discuss one of the simplest and most popular types — the single-conversion uhf. A typical example is the Hoffman "Piggyback" uhf tuner shown schematically in Fig. 510. Hoffman likes the name Piggyback because the uhf tuner operates in conjunction with a vhf tuner (as do all single-conversion uhf tuners). The entire unit is simply a high-frequency oscillator and a crystal mixer. Here's how it works:

To use it, first set the vhf tuner to a position marked uhf on the

plate that indicates channel numbers. (On some receivers, the uhf position is shown as a dot or line). When you switch to the uhf position, you change the vhf tuner into an if amplifier by disabling the vhf oscillator. You also switch in coils resonant in the 41 – 46-mc range. When you select a uhf station, you adjust the frequency of the uhf oscillator (located in the uhf tuner). The uhf oscillator frequency mixes with the uhf station frequency in a crystal mixer, a 1N82A in Fig. 510. One of the frequencies produced by the mixing process is the desired if (41 to 46 mc). The vhf tuner, now acting as an if amplifier, amplifies this frequency. Of course, the if section in the receiver supplies still more gain.

Windup

A hospitable antenna graciously welcomes all vhf rf television signals broadcast in the area, as well as other rf signals, short and long waves, harmonics, ignition noise, static and anything else that may be in the air. All signals blithely slither down the transmission line, naively hoping to get into the tuner. But the tuner, being fussy about which signals it invites into its circuitry, accepts only the desired vhf television-channel frequency.

If the tuner is a strip type, individual coils are switched in which select the channel and oscillator frequencies. If an incremental tuner is used, a portion of a tapped coil is switched into the circuit when the channel selector is turned.

The tuner selects and changes the vhf channel frequency to an intermediate-frequency band in the 41 –46 mc range and feeds it to the video if section.

QUESTIONS

1. What is direct coupling? How does it differ from resistance-capacitance coupling?

2. What is a director? A reflector?

3. What is the characteristic impedance of a basic dipole? Of a folded dipole?

4. For maximum signal pickup, how must a TV antenna be positioned with respect to the broadcast station?

5. What is an antenna lobe pattern? What information can we obtain by looking at such a pattern?

6. What is the vhf range? The uhf range?

7. What is one cause of ghosts? How do the ghosts appear on the picture-tube screen?

8. What is the function of a TV tuner?

9. How do incremental and strip tuners differ?

10. What is the advantage of balanced imput in a tuner?

11. What circuits are used in the tuner to minimize power-line shock hazards?

12. What types of traps are used in the tuner? What purpose do they serve?

13. Name one advantage of the cascode tuner.

14. What type of component is used as the mixer in a uhf tuner?

15. What is the separation in frequency in megacycles between the picture carrier and the sound carrier?

6

HOW THE VIDEO IF WORKS

• •

Having studied the tuner, you know what happens to the television signal when it is first processed by the receiver. You know, for example, when you select channel 8, your tuner changes the 181.25-mc picture frequency and 185.75-mc sound frequency to *intermediate frequencies* (if). Typically, in your set, the picture if may be 45.75 mc and the sound if 41.25 mc. Any other channel frequency, when tuned in, will also be changed to 45.75-mc picture and 41.25-mc sound if.

When an intermediate frequency leaves the tuner, it is so weak that the signal voltage can't be measured with an ordinary voltmeter, nor can the signal be seen on a service-shop oscilloscope. The if signals must be strengthened in the video if amplifier section of the receiver before being detected and fed to the picture tube.

Split-sound and intercarrier receivers

As explained in Chapter 4, early television sets used a split-sound if technique. In this system, the sound and picture if's are separated from each other early in the if amplification process. For example, in some split-sound receivers, the sound if is removed immediately after the tuner. Then the picture signal is amplified in the video if section and the sound if is amplified in the sound if section. Other split-sound receivers are designed to amplify both picture and sound through one or two tubes—then the sound is separated.

With the intercarrier if system (also called intercarrier sound), both the picture and sound if's are amplified in the video if section of the receiver. (Somehow, the name video if amplifier is used, but you know that the 41.25-mc sound if is amplified

85

through the video if section). Commercially, intercarrier receivers have proven superior.

The intercarrier receiver actually has two sound if's. The tuner produces a 45.75-mc picture if and the *first* sound if of 41.25 mc. In the video detector stage, the picture if is heterodyned with the first sound if to produce a *difference* and a *sum* frequency. We're interested only in the *difference* frequency, which is exactly 4.5 mc. This is the *second* if, which is removed in the detector or video output stage and amplified in a 4.5-mc FM if section.

What the video if section does

First, the video if section amplifies both the picture and sound intermediate frequencies. Therefore, *amplification* is one if section function. In fact, the video if signal must be amplified by a factor of several thousand.

Second, the video if section must be designed to amplify a *broad band* of frequencies. The video if section is different from the if of an AM superhet radio: the radio is designed with sharply-tuned if circuits. To show what is meant by broadly and sharply-tuned if designs, we've drawn typical AM radio and TV if curves.
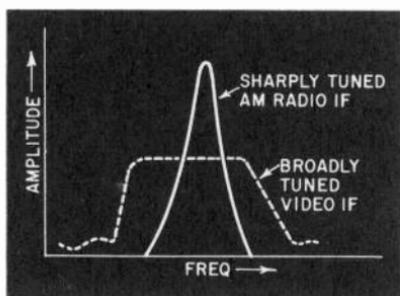

Fig. 601. *Comparison curves between sharply tuned AM radio if and broadly tuned TV intermediate-frequency amplifier.*

Fig. 601 shows a comparison between a sharp if curve such as might be used in a selective radio receiver (solid line) and a broad TV if curve (broken line).

The third function of the video if section is to reject undesired frequencies. For this reason, it includes trap circuits that get rid of the higher adjacent-channel picture if and the lower adjacent-channel sound if. You'll find more detailed information on traps later in this chapter.

The fourth function of the video if section is to shape the if curve correctly. You can see an ideally-shaped curve, with frequencies at their ideal points on the curve, in Fig. 602.

To summarize, the video if section is designed to amplify; pass

a broad band; reject undesired frequencies; provide a correctly shaped if curve.

Locating picture and sound if's on the curve

When you first look at an ideal if curve (Fig. 602), you will probably wonder why the picture if is not right at the top somewhere so we'd get a maximum signal. To understand why the picture if is at the 50% point on the curve, remember that vestigial-sideband transmission is used in television. This means that the upper sideband is transmitted in full and the lower sideband is almost (but not entirely) suppressed.

The broadness of a sideband is determined by the frequencies that modulate the carrier; therefore, you'll get wider sidebands if you modulate the carrier with higher frequencies. So here is what is done: the upper sideband is modulated by frequencies up
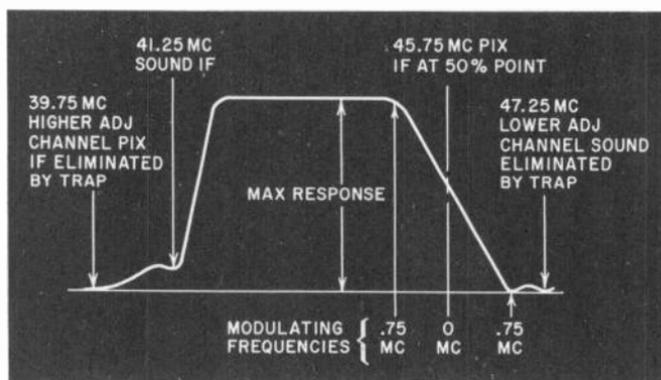
Fig. 602. *Ideal intermediate frequency response curve. Note how intermediate frequency is at 50% point on curve to compensate for vestigial-sideband transmission.*

to 4.5 mc. This gives adequate picture detail and an upper sideband that is 4.5 mc wide. The lower sideband, however, has its high modulating frequencies severely suppressed. Frequencies above 0.75 mc are cut out; only low frequencies (below 0.75 mc) modulate the lower sideband. This is fine for eliminating the lower sideband but, if you'll think about it, you'll realize that we'll have an overabundance of low frequencies unless something is done to prevent this unequal distribution of sideband power. To fix the if section so that it responds correctly to the modulating frequencies, the frequencies between 0 and 0.75 mc are balanced out by placing the picture if at the 50% point. Fig. 602 shows that the frequencies between 0 and 0.75 mc drop off gradually to

the right of the picture carrier. This even dropoff compensates for the additional frequencies to the left of the picture if, thus balancing the response.

How to get a broad if response

One fact mentioned earlier is certainly worth repeating: A television rf signal carrier, (whether at the high frequency transmitted by the broadcast station or at the lower intermediate frequency produced in the receiver) is modulated by signal frequencies up to 4.5 mc. This modulating frequency tells us how *wide* the carrier must be because the modulating frequencies (which are picture and sync information) add to the carrier to form sidebands. Although we cut out most of the lower sideband of the transmitted signal, we have to pass a wide upper sideband through the if section of the receiver. What happens if a TV if section dos not pass a wide band but, instead, passes only the lower frequencies? The fine picture detail is lost because the small details in a picture represent high modulating frequencies. The finer the detail, the higher the modulating frequencies.

Methods used to get a broad if response in the receiver if section include: 1). Stagger tuning; 2). Resistive loading of if transformer or if impedance; and 3). Overcoupling of if transformer primary to secondary.

Let's take a detailed look at these broad-band if designs.

Stagger tuning

To align an AM radio receiver such as a midget set, each if transformer is tuned to the same frequency—probably 455 kc. You want a sharp overall if curve because an AM radio should be fairly selective to separate the stations and prevent interference from stations adjacent to the desired frequency. When you tune the first if stage of your radio, the response curve isn't very sharp. When you tune the second if stage (to the same 455-kc if), the response curve becomes considerably sharper. In a radio with a third if stage, you get an even sharper response curve with all three if transformers tuned to the same intermediate frequency.

In television, to get a broad if curve, each video if transformer is tuned to a *slightly different* frequency. This method of broadbanding is called *stagger tuning* and is the most widely used today.

A typical stagger-tuned if strip is shown in Fig. 603. The if stages are tuned as follows: first video if input (tuner output): 43.75 mc; first video if: 43.25 mc; second video if: 45.25 mc; third video if: 43.75 mc.

Notice that the first if transformer, T201, has R207 shunted across its secondary. The resistor loads the secondary and further broadens the response.

Overcoupling and resistive loading

Using an if transformer that permits adjusting the coupling, here's an experiment you could try: with the transformer in a suitable circuit and with an oscilloscope and sweep generator hooked up, you would see how a sharp curve could be made broad. With loose coupling (Fig. 604-a), you see a sharp curve. But, move the coils of the transformer closer together (Fig. 604-b) and notice how the curve becomes broader (but lower in amplitude). Move the coils of the transformer still closer together (Fig. 604-c) and your curve gets even broader and develops two humps.
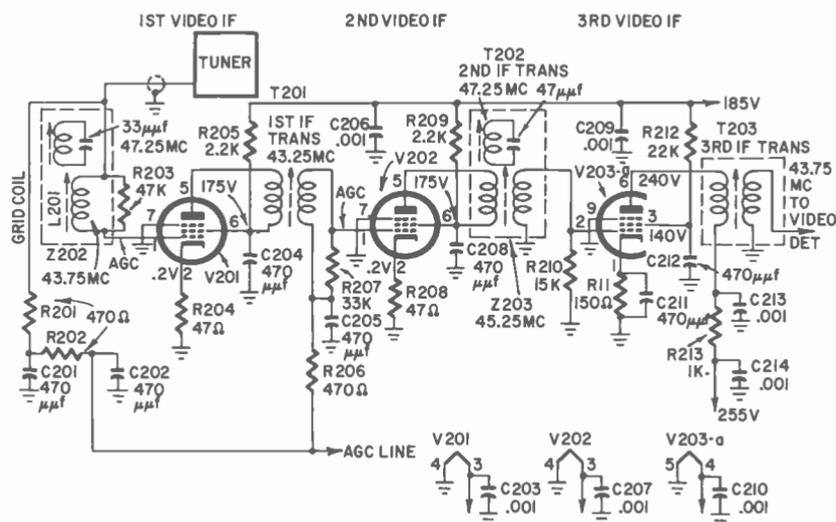
Fig. 603. *Stagger tuned if circuit.*

If you're still experimentally inclined, try adding a loading resistor. Notice how this too broadens the curve and can be used to shape it.

When you broaden the response curve, you lower the Q of the circuit; a resistor that shunts a coil is a common way of lowering the Q. And, if you're a little hazy on the meaning of Q, here's a simple nonmathematical way of refreshing your memory: high Q tuned-circuit gives a narrow, sharp curve steep in amplitude. Low Q tuned-circuit gives a broad curve lower in amplitude. It's as simple as that.

Interference traps

Examine the schematic diagram of any television set and you'll find traps in various parts of the if circuitry. The traps get rid of signals that may interfere with and spoil reception. If you wonder why traps are necessary, remember that tuner and if circuits are designed to pass a broad band of frequencies. Because most channels are separated from each other by only 1.5 mc, unless traps are used, an interference problem will arise. The if circuits, in addition to accepting the desired channel, will also accept part of the next lower and next higher channel.

The adjacent-channel signals that often prove troublesome are
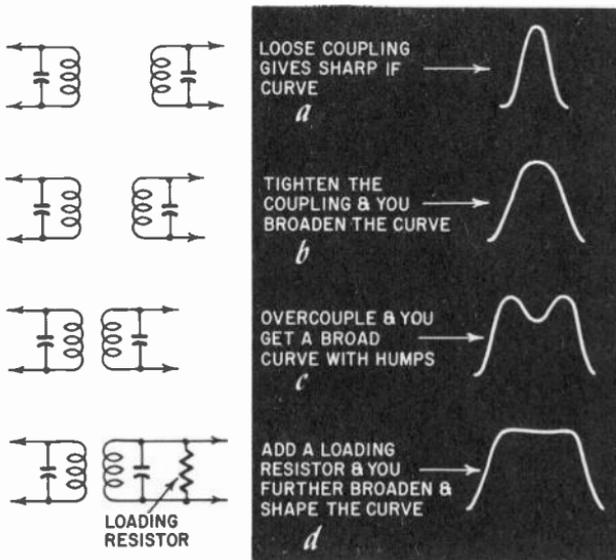
Fig. 604. *Broadening a sharp response curve using an intermediate frequency transformer with adjustable coupling.*

the picture signal from the next higher channel and the sound signal from the next lower channel. When if's of 41.25 mc for sound and 45.75 for picture are used, the potentially annoying signals are the adjacent-channel picture at 39.75 mc and the adjacent-channel sound at 47.25 mc. These frequencies are produced in the tuner when the oscillator, in addition to beating with the picture and sound carriers of the desired channel, also beats with the picture and sound carriers of channels above and below the desired one.

If you find it confusing that the *lower* adjacent-channel sound is at 47.25 mc (a higher if) and the *upper* adjacent-channel pic-

ture is at 39.75 mc (a lower if), remember that the frequency sequence is reversed in the if section. This sequence reversal
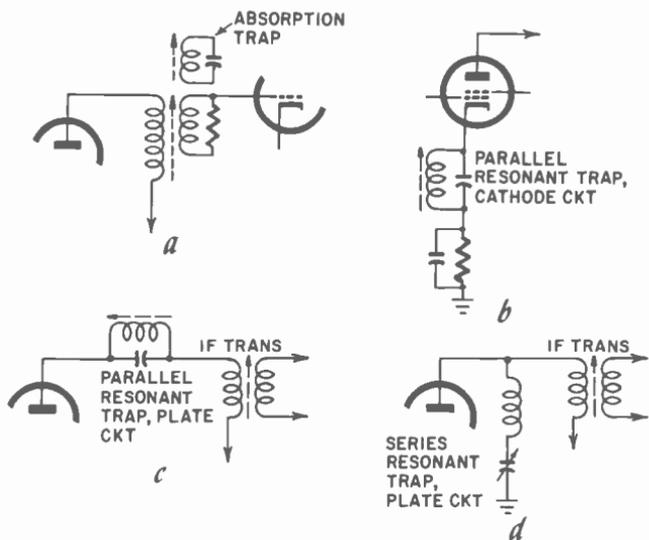

Fig. 605. (a) *Commonly used absorption type interference trap.* (b) *Parallel-resonant trap in cathode circuit of intermediate frequency amplifier.* (c) *Parallel-resonant trap in amplifier plate circuit.* (d) *Series-resonant trap.*

takes place because we subtract the signal frequencies from an oscillator frequency. You can understand this if you think in terms of round numbers. For example, if you subtract the ascending numbers 6, 7, 8 and 9 from 10, you'll get descending numbers 4, 3, 2 and 1. Now let's compare this example with the condition in a TV set. When transmitted, the sound carrier is higher than the picture carrier. But when both carriers are subtracted from the oscillator frequency, the sound if carrier is lower than the picture carrier. The lower adjacent sound, in the if, appears as a still higher if.

A commonly used interference trap is the absorption type. The circuit is shown in Fig. 605-a. It consists of a tuned circuit— a coil shunted by a capacitor. This circuit is built into the if transformer can. When the trap is tuned to the undesired frequency, it absorbs this interfering energy. The trap is sharply tuned (has a high Q); the idea is to absorb only the interfering frequency and not bother the desired if. But, unavoidably, the trap will exert some effect on the if curve. Therefore, when a video if stage is aligned, the final curve is the result of all adjustments.

There are other types of traps, such as the parallel-resonant and series-resonant. A parallel-resonant circuit offers a high impedance at the resonant frequency; and the series-resonant circuit offers a low impedance at the resonant frequency. (Of course, the res-
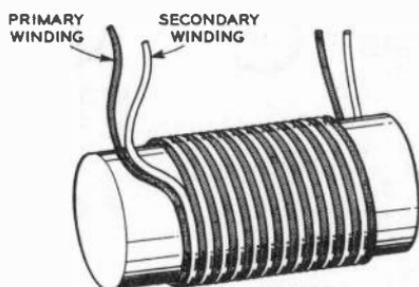

Fig. 606. *Bifilar-wound if transformer.*

onant frequency is the one to which you tune the trap). There-fore, a parallel-resonant trap has high impedance that blocks the undesired signal. The series-resonant trap bypasses the undesired signal by offering a low-impedance path to ground.

Fig. 605-b is a typical parallel-resonant trap in the cathode circuit of an if amplifier. Fig. 605-c shows a parallel resonant trap in a plate circuit, and Fig. 605-d a typical series-resonant trap hookup.

Bifilar-winding if transformer

For maximum efficiency, the bifilar-winding type of if (Fig. 606) transformer is widely used. With this type of winding, the primary and secondary are interlaced. The secondary turns fit between the primary turns, and coupling is as tight as it can possibly be.

Video if transformer construction

Like other parts, video if transformers sometimes come in cans. The can shields the coils. A hole or protruding slotted screw at the top of the can lets you insert a nonmetallic screw driver or alignment tool to adjust the powdered-iron-core slug. In a tele-vision set of recent vintage, it is likely that an absorption trap will be included in the if can. A resistor or capacitor may be inside the can, too, because the circuit design may call for the shortest connections possible. The loading resistor is often also included. If you have to adjust an iron core in a video if trans-former, it's advisable to consult the service data to find the loca-tion of the slug adjustments. In some if transformers, the adjust-ment at the top of the can changes if tuning while in others, trap

adjustments are on top and inductance adjustment at the bottom. In Fig. 607, video if transformers, as seen from the side and below, are shown.
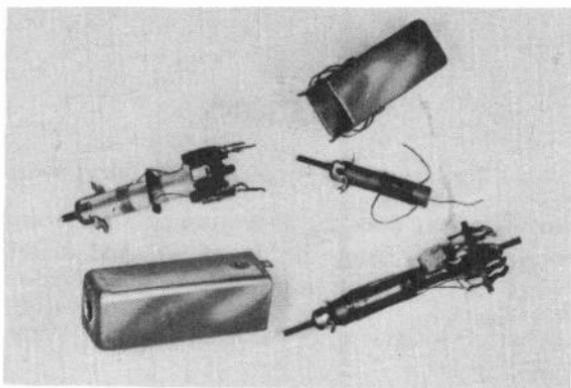

Fig. 607. *Three types of video intermediate frequency transformer construction.*

Windup

Let's quickly review the video if stage before journeying farther into television circuitry.

In a typical modern intercarrier receiver, the video if section amplifies these frequencies: 45.75-mc picture and 41.25-mc sound. Stagger tuning is commonly used to achieve a broad-band if response; resistive loading is often included in the design. Over-coupling is another method of achieving a broad-response if section. Resistive loading is also used with overcoupled if transformers to widen the band and shape the if response curve.

On the if response curve, the picture carrier is located at the 50% point, and the sound is held at about 2% to 10% of maximum response.

When you examine a television schematic, you'll see a lower adjacent-channel sound trap (47.25 mc) and an upper adjacent-channel picture trap (39.75 mc). You tune for minimum response at trap frequencies when you adjust the traps. And, when you adjust the trap, you also adjust the shape of the if response curve.

The video if section receives its if signal from the tuner (mixer output) and feeds it to the detector.

QUESTIONS

1. What are typical values of picture if and sound if?

2. In what way does the if section of a television receiver differ from the if of an AM broadcast receiver?

3. What is vestigial sideband transmission? Why is it used?

4. What determines the broadness of a sideband?

5. How is fine picture detail obtained?

6. Name three methods for obtaining a broad if response.

7. What is stagger tuning? Why is it used?

8. What is the difference between a high Q circuit and one that has low Q?

9. What is the function of traps in the if section?

10. Describe an absorption trap. A parallel-resonant trap. A series-resonant trap.

11. Describe a bifilar-wound if transformer.

12. What is overcoupling? Why is it used?

13. Where on the if response curve is the picture carrier located? The sound carrier?

14. What is the difference between split-sound and intercarrier receivers?

7

THE VIDEO DETECTOR AND AGC

● ●

SOME circuits in radio and television are so similar that they
are more closely related than kissing cousins! A half-wave
power-supply rectifier (or a signal detector) in a lowly, inexpensive
AM set can claim kinship to the video detector (demodulator or
signal rectifier) since their jobs—basically—are the same. But there
are some very important differences.

In Fig. 701 we have the video detector and its input signals.
Notice the sound if varies in frequency and the picture if in
amplitude.

The lines within the picture signal tell you that the current
flows back and forth (alternates) very rapidly. These alternations
represent the 45.75-mc if, which we can also call the rf component
of the signal. The original rf, of much higher frequency, was used
to carry the signal from the broadcast-station transmitting antenna
to the receiving antenna. The rf signal traveled down the 300-
ohm ribbon (transmission line) into the tuner of the TV set. The
tuner reduced the station's frequency so that we could process
it through the video if section of the receiver. Now that we've
amplified the video if signal, the time has come to make some
important changes in it. We feed the signal into our video de-
tector circuit, which does the following: 1. Slices off the top or
positive portion of the video signal (Fig. 701); 2. Gets rid of the
rf component. 3. Reduces the 41.25-mc FM sound signal to a
4.5-mc FM sound signal. Now let's see how the video detector does
its job.

How picture and sound signals are processed

The 45.75-mc picture signal varies above and below the zero
axis. This means that the signal will alternate between positive

and negative across the video detector crystal diode (Fig. 701). When the anode of the crystal diode is positive with respect to its cathode, current flows through the diode with ease. When the signal polarity reverses (the cathode is made positive and anode negative), practically no current will flow through the diode. Consequently, the video signal is rectified and only half of the
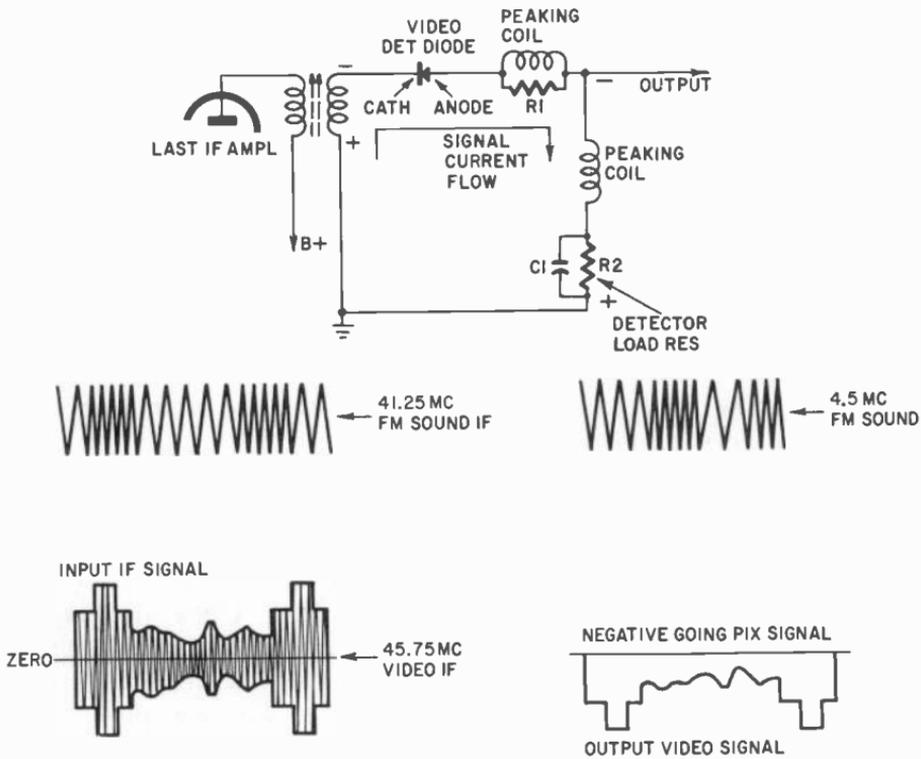

Fig. 701. *Typical video detector circuit and the appearance of the input and output waveforms. Waveforms are not to scale with regard to time.*

signal develops across R2, the detector load resistor. Because current flows through R2 from the top of the resistor to ground, a negative-going signal will be taken from R2.

Subtract 41.25 mc from 45.75 mc, and you get 4.5 mc. This is what happens in the video detector. The picture carrier signal beats with the sound carrier signal to produce the difference frequency (4.5 mc) and also a sum frequency. The difference frequency is the one that is taken off, usually in the video output stage. This 4.5-mc signal, which varies in frequency to convey sound information, is fed through the FM audio if section of the receiver.

The capacitor shunted across R2 bypasses the rf component of the picture signal. It does this quite easily because of the wide difference in frequency between the video modulating signal (30 cps to about 4 mc) and the if of 45.75 mc. The reactance of any capacitor, including C1, varies inversely with frequency. This simply means that its opposition to 45.75 mc is quite low, but very high to the video modulation. As a result the video signal takes the easier path through the diode load resistor. The other—and much higher frequencies—prefer the very low reactance of C1 as a detour around the detector load resistor.

Frequency compensation

One important difference between a video detector and the AM detector in a broadcast receiver is the need to preserve high
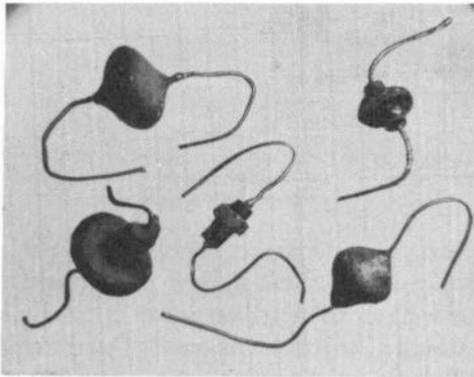
Fig. 702. *Peaking coils have many forms. Some are encapsulated or dipped in moisture-excluding compounds.*

frequencies in the video signal. An AM radio may not have frequencies much higher than 4,000 cycles, while the video detector has to handle video signal frequencies from 30 cycles to about 4 mc. The high frequencies are the fine picture details. So the video detector is designed to pass this wide band. First of all, the video detector has a relatively low-resistance diode load resistor (R2); a resistance value of 3,300 ohms is typical. To boost the high-frequency response, the video detector requires peaking coils. Both series and shunt peaking coils are used and a resistor is generally connected across the series peaking coil. In the schematic of Fig. 701, two peaking coils are shown. A photo of various peaking coils is pictured in Fig. 702.

The combination of a low-resistance diode load and peaking

coils in the circuit produces the needed 30-cycle-to-4-mc response. Fig. 703 shows a representative video detector circuit. L304 and L305 are the peaking coils. Note the low value of detector diode load resistance (R314).

Agc

When you switch from a weak to a strong channel, the automatic gain control (agc) circuit lowers the amplification. This is
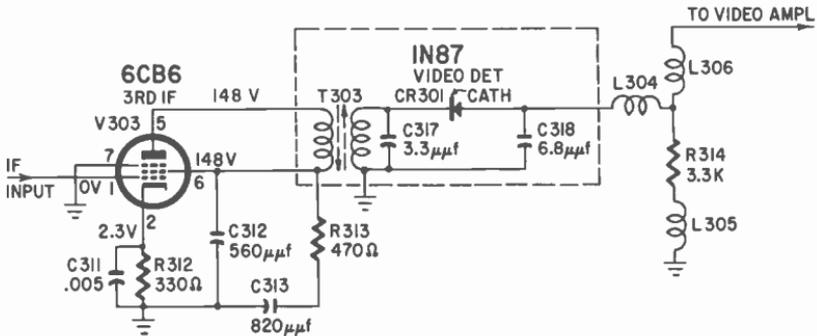

Fig. 703. *Schematic of typical video detector showing coupling circuitry between third video if and video amplifier. Parts inside the box are contained in a shield can.*

done by increasing the negative grid bias in the rf and if stages. As a result, the gain of these stages is reduced. Because of agc action, you don't have to readjust your contrast control; the agc circuit automatically adjusts contrast. Furthermore, if the TV signal should change in strength, the agc circuit keeps the picture steady in contrast.

Each television signal has synchronizing pulses that are of constant amplitude. The amplitude of the picture signal voltage changes with light and dark picture information, but the sync pulses (horizontal and vertical) always reach the same level. Therefore, most agc circuits are designed to respond to the sync-pulse level—not to the picture-signal level.

There are many types of agc circuits. The simplest has several resistors and capacitors and involves a connection to the video detector. This circuit works, but the more complex agc circuits work better. But, rather than talk in generalities, let's discuss typical agc circuits.

Agc tapoff from video detector

Fig. 704 is a simple agc circuit. The signal current flows through diode load resistor R2 to ground. Therefore, the top of R2 is

negative and the bottom end is positive. The stronger the video signal, the greater the current flow through R2, and the larger the negative voltage at the top of R2. This negative varying dc voltage is filtered by R1 and C1 and fed back to the if amplifer grids. Therefore, a more-negative voltage (produced by a stronger signal) causes a higher-negative bias voltage. Thus, the if amplifier gain is lowered and the desired stabilizing action results.

Unfortunately, the simple agc circuit of Fig. 704 doesn't know the difference between sync pulses which give true signal strength
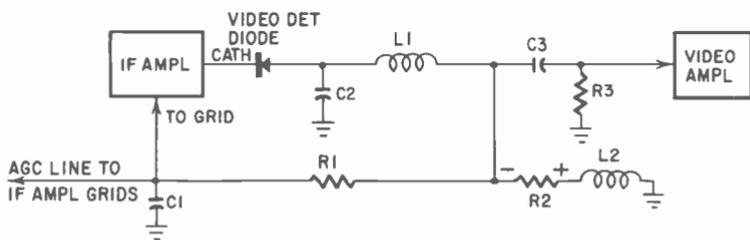
Fig. 704. *Basic agc circuit.*

and the video signal (which varies with brightness). Although the sync pulses have greater amplitude, they do not last as long as the video signal. Thus, if we were to take an average of sync and signal amplitudes, we would find that video signal strength dominates this agc arrangement.

Agc with diode rectifier

A quick glance at Fig. 705 reveals that two diodes are used in a video-detector—agc-rectifier combination. One diode detects the video signal; the other provides video rectification for the agc line.

The video if signal that appears at the agc diode rectifier plate swings above and below zero (positive and negative). When the video signal is positive, current flows through the agc rectifier, through R2 and back to the cathode. The direction of current flow makes the top side of R2 negative with respect to ground. The negative voltage at this point is filtered by R1 and C1 and fed to the if amplifier grids. The stronger the incoming video signal, the greater the negative bias voltage developed at the top of R2 and the lower the if amplifier gain.

In the simple agc tapoff arrangement (Fig. 704), R2 was rather low in resistance because the detector is designed for wide-band response. This broad response design is of first importance: the agc circuit does its best with the rectified signal it taps off. In the improved duo-diode circuit (Fig. 705), R2 has a high resist-

ance. (The detector has its own load resistor.) The agc filter time constant is such that the agc voltage produced is proportional to average signal. (In the circuit just described, diodes in two separate multipurpose tubes are sometimes used).
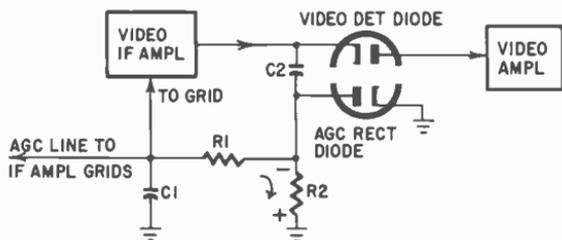

Fig. 705. *Basic duo-diode agc circuit. Signal is coupled to agc diode plate by C2, reducing loading on video circuitry.*

An agc circuit using two crystal diodes is shown in Fig. 706. The principle of operation is the same as when a duo-diode electron tube is used. The agc rectifier diode and its associated circuit develop a negative voltage proportional to the sync peaks. This voltage represents the average signal level.
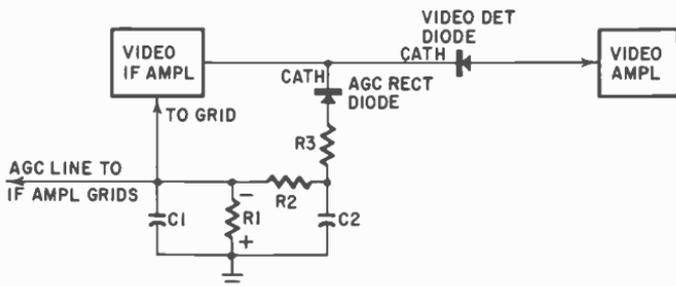
Fig. 706. *Semiconductor diodes can also be used to reduce video loading.*

Coincidence or "and"-gate

Before studying the keyed agc circuit, you should learn the fundamental idea upon which this circuit is based. The principle is that of the coincidence gate, which is also called an "and" gate. (A gigantic branch of electronics—computer and logic circuits—makes extensive use of gating circuits).

The "and" gate is drawn in pictorial-diagram form in Fig. 707 which shows four "and" gates with four possible input signal conditions. Each "and" gate has two inputs and one output. For an output pulse to appear, an input pulse must appear

on *both input lines at the same time*. In Figs. 707-a, -b and -c, the required conditions are not met. But, in Fig. 707-d, the necessary condition exists. Pulses must coincide with respect to time; hence, the name "coincidence" gate. The term "and" gate is used to indicate that a pulse must appear on the first *and* second input lines simultaneously for an output pulse to appear.
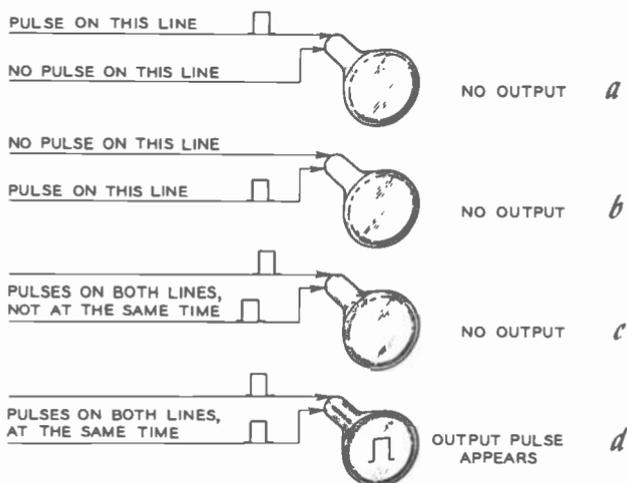
Keyed agc makes good use of the "and" gate principle.

Fig. 707. *Keyed-agc circuit is actually a* coincidence–and gate *circuit. Similar circuit principles are used in some computers.*

Keyed agc

One of the best agc circuits is the keyed type. During each instant when a horizontal sync pulse appears in the video signal, the keyed agc circuit develops its agc voltage. Between horizontal sync pulses, when picture or vertical sync pulse information is sent, the keyed agc system is cut off. Therefore, picture information and noise pulses appearing between horizontal sync pulses do not affect the agc system. Fig. 708 illustrates the principle with mechanical switches but, of course, the keyed agc circuit operates electronically. The switch closes only during sync pulse transmission.

The keyed agc circuit of Fig. 709 makes use of a pentode keyer tube which receives two inputs: (1) A video signal is fed to the control grid from the video amplifier. This is the signal we sample to get our signal information; (2) Sharp positive flyback pulses are fed to the plate from the horizontal output transformer.

A closer look at Fig. 709 shows there is no B-plus on the plate of the keyer tube. The only source of positive voltage is the horizontal

output transformer, which supplies positive pulses 15,750 times per second. Here is where the "and"-gate principal comes into use. The circuit and tube voltages are such that the keyer tube conducts only when a positive horizontal flyback pulse appears on the plate *and* a horizontal sync pulse appears on the grid of the keyer tube *at the same time*.

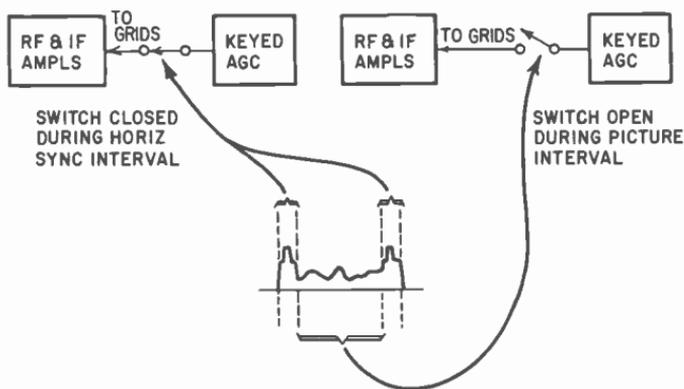Normally, horizontal flyback and sync pulses in the signal appear simultaneously. Therefore, the "and"-gate conditions are met

Fig. 708. *Mechanical switches can also be used to illustrate the keyed-agc principle.*

only during the horizontal sync interval, at which time the keyer tube is keyed (gated) on, current flows through the tube and agc voltage develops in the plate circuit of the keyer tube. Because the plate current flow is toward the horizontal output transformer (the source of positive voltage), the developed agc voltage is negative with respect to ground. Capacitor C2 holds this negative agc voltage—the average agc proportional to signal strength.

The circuit of Fig. 709 has an agc feed to the rf amplifier stage, with R1 and C1 serving as decoupler and filter. The agc line that feeds the if stages is filtered and decoupled by C3, R2 and C4. A positive voltage, usually in the 100 to 300-volt range, is fed to the keyer cathode. This voltage establishes the grid bias voltage when the tube conducts. Although the video signal to the grid is positive, the cathode is *more positive*. Therefore, the grid is biased negatively with respect to the cathode.

Now, let's make a quick review of the keyed agc action. The keyer tube is gated only during the horizontal sync interval because positive voltage is supplied by flyback pulses from the horizontal output transformer. The horizontal sync pulses in a strong video

signal are more positive. Hence, a strong video signal causes more current to flow through the keyer tube. As a result, a greater negative agc voltage is developed and fed to the rf and if amplifier grids to reduce gain. The reverse occurs when a weak video signal appears in the video amplifier. Horizontal sync pulses are less positive; less current flows through the keyer tube, and agc voltage becomes less negative. When this happens, the rf and if amplifier
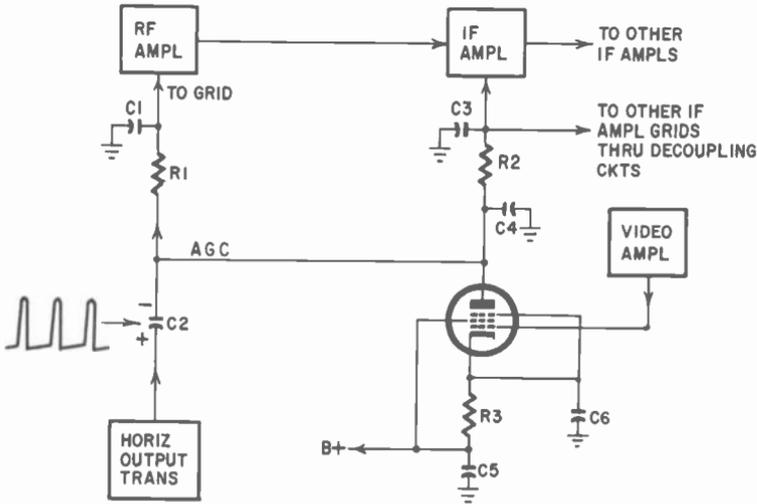

Fig. 709. *Keyed-agc circuit. Blocks are used to indicate associated stages.*

stages receive less agc bias voltage; thus, rf and if amplification is increased.

Delayed agc

With no signal present, just the tube noise will be amplified and detected (or rectified) into an agc voltage. If a weak signal is received additional voltage will be had—at a time when it would be better for the rf amplifier to have no bias at all. The circuit in Fig. 710 will do just that.

When the agc detector diode conducts, a negative voltage will appear across R1 and is applied to the video if amplifier grids through filtering and decoupling networks. The agc to the rf amplifier is delayed by the positive voltage injected into the decoupling network, through R4, to oppose the negative agc voltage from the agc diode. When you add +3 volts to —3 volts you have zero volts.

Resistors R2 and R3 have such values that the positive voltage applied to point B keeps it at zero bias until the received signal

103

reaches, and exceeds, a certain level. To do this, point B must have a positive voltage to oppose the varying negative voltage from R2. Since a fixed positive voltage would allow point B to become positive when the signal level was low, a clamp diode is often used to prevent a positive voltage from reaching the rf amplifier grid.

With a positive voltage on the plate the clamp diode will conduct, effectively grounding point B and keeping the bias at zero volts.

The diode will stop conducting when point B returns to zero or becomes increasingly negative as the signal level increases.
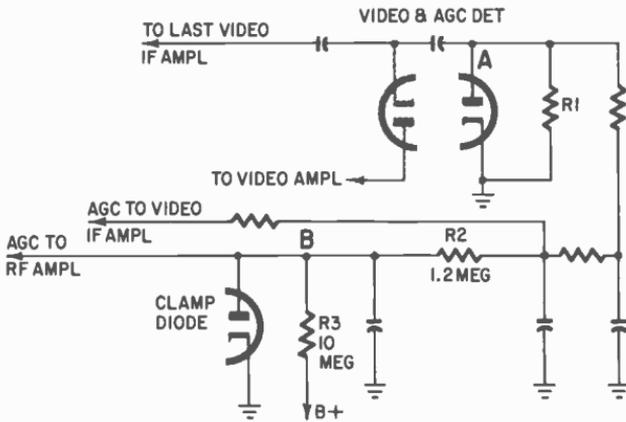
Fig. 710. *This simplified schematic of a delayed agc system has delay for the rf amplifier only.*

Windup

The video detector does quite a bit of work. One that produces negative-going signals (and most do these days) removes the top (positive) portion of the symmetrical video waveform. The video detector (plus its associated parts) also gets rid of the rf component in the signal, produces a varying dc video waveform and a 4.5-mc FM sound if.

Delayed agc is a circuit that does not increase the negative bias on the rf amplifier control grid when weak signals are received. All agc systems try to get their signal-strength information from the level of the sync pulses. Simple agc systems do their best, but the keyed agc system does a superior job because it receives no video information between horizontal sync pulses.

The output of the video detector, developed across the diode load resistor, is the picture signal voltage we want. As yet, however, it is still too weak to feed into a picture tube. Some signal build-up is needed and this will be supplied by a video amplifier.

During this buildup we cannot change the TV signal. This would be distortion. There are many ways the signal can be distorted. There is *white compression* which means that the light shades of grey will be very close together in color. *Black compression* means that it will be difficult to separate the dark shades of grey on the screen.

Frequency amplitude-distortion is another problem to be avoided. This is the result of an improperly compensated detector load or video amplifier. The signal is amplified more (or less) for a particular section of the video frequency band. A small percentage of TV picture distortion is more obvious to the eye than a much larger percentage of sound distortion would be to the average ear.

QUESTIONS

1. What is a typical value of diode-load resistance?

2. Why is a low value of diode-load resistance used?

3. What is the reason for using delayed agc?

4. What circuits are controlled by agc?

5. What is a coincidence circuit?

6. What is the advantage of keyed agc over simpler forms of agc?

7. Name two functions of a video detector.

8. What is the purpose of a peaking coil?

9. What is the method used for removing the rf component of the picture signal after detection?

10. Describe the functioning of an "and" gate.

8

THE VIDEO AMPLIFIER AT WORK

● ●

B EFORE plunging into a study of the video amplifier, let's quickly review the trip taken by our television signal.

The rf signal was weak and puny when it entered the vhf tuner. The tuner amplified the signal somewhat and lowered it to an intermediate frequency in the 41—46-mc range. Next, the if section amplified the intermediate frequency and fed it to the video detector. Here we got rid of the intermediate frequency (45.75-mc picture signal) and chopped off the upper half of the video waveform. This left us with a negative-going video wave that carries picture and sync information. The video detector also changed the 41.25-mc sound if to 4.5-mc.

Video amplification

We still have to amplify the video signal so that it will have the strength to drive the picture tube. This calls for a video amplifier stage. When you examine tv receiver schematics, you'll find most with one video amplifier and a few with two. When two video amplifier tubes are used, one is likely to be a triode and the other a pentode. Many sets use one video amplifier tube, invariably a pentode or beam power tube.

Video amplifiers are broad-band

In every video amplifier, you'll find parts included to give the circuit a broad response. Here's the reason: the video signal consists of low and rather high frequencies. The low frequencies form

the large objects in the picture as well as the vertical sync frequency. The high frequencies are your fine picture detail—the small objects. Look at a television picture formed by a signal with its high frequencies intact and you'll see clear and beautiful detail; if the picture shows a closeup of a 10-year-old boy, you can count each freckle on his nose. Also, the sharp, abruptly changing waves in the video signal have a high-frequency component. For example, a square wave has a fast rise and decay time. If your set does not have good high-frequency response, objects will look indefinite; generally speaking, the picture will not be bright and sharp.
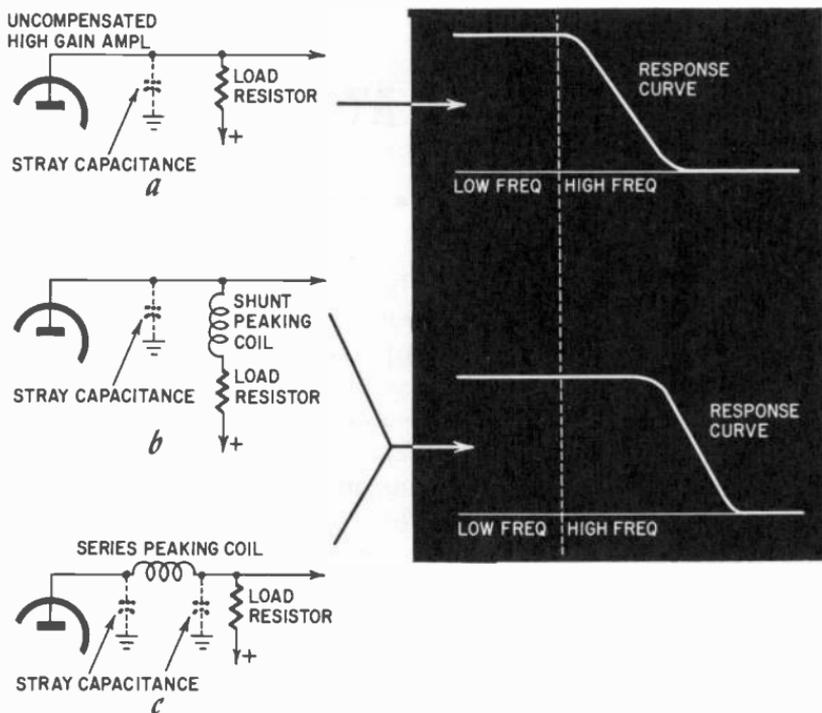
Fig. 801. *Some methods used to broaden the response of a video amplifier. (a) Stray capacitance (dashed lines) of an uncompensated high-gain amplifier destroys high-frequency response. (b) Shunt peaking-coil hookup. (c) Series peaking-coil hookup.*

Ideally, the video amplifier should amplify frequencies ranging from 30 cycles to about 4 megacycles. That's quite an order, so special techniques are used to design the video amplifier for broad response.

First of all, the size of the plate load resistor has an effect on frequency response. The lower the value of the resistor, the flatter the response curve; manufacturers use a plate load resistor rela-

tively low in resistance. But, as you reduce the resistance of the plate load, down goes the gain. And we need quite a bit of gain. Therefore, other design principles are also used to broaden the response of the video amplifier. Let's discuss the methods used to give us low-frequency and high-frequency compensation.

High-frequency compensation

One of the methods for getting broad response is to use peaking coils. These boost the high frequencies in the video signal, are connected in two ways: in shunt and in series. A shunt peaking-coil hookup is shown in Fig. 801-b; Fig. 801-c is a series arrangement.

Before going on, lets review something you learned in basic electronics. No, we won't need a mathematical formula; the idea can be stated in words and the principle, a simple one, has to do with ac at different frequencies: 1). A capacitor has a high capacitive reactance at low frequencies and a low capacitive reactance at high frequencies. As you increase the frequency across a capacitor,
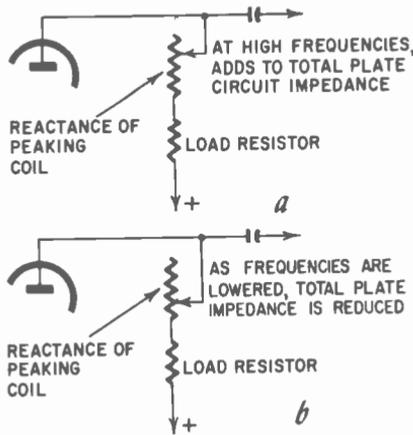
Fig. 802. *Equivalent circuits of Fig. 801. (a) As frequency is increased, shunt peaking coil adds to total plate impedance, increasing reactance. (b) Total plate impedance is reduced when frequency is lowered.*

you lower its opposition or capacitive reactance; 2). A coil has a low inductive reactance at low frequencies and a high inductive reactance at high frequencies. As you increase the frequency across a coil, you increase its inductive reactance.

You might keep this in mind: Capacitor—at high frequencies, a capacitor acts as a short circuit; Coil—at high frequencies, a coil has high reactance; at low frequencies, a coil almost acts as a short circuit.

If no compensation were used in an amplifier, the stray capacitance (dotted lines in Fig. 801-a) would demolish the high-frequency response by shorting the highs to ground. As the frequency gets higher, the stray capacitance has more of a shorting effect. Figs. 801-b and -c show how highs are preserved through use of peaking coils.

In shunt peaking (Fig. 801-b), the peaking coil is in series with the load resistor. The term shunt peaking is used because the coil is shunted *across* the signal path of the video signal. This signal path is from the video amplifier plate to either the next video amplifier (in a two-stage amplifier) or to the picture tube. Because the peaking coil has a greater reactance at high frequencies, the high-frequency voltages are developed across the coil; the total load impedance is greater for high frequencies. The peaking coil offers progressively higher reactance as frequency is increased. The equivalant circuits in Fig. 802 show this. Here the reactance offered by the shunt peaking coil is compared to a variable resistor. Gradually lowering the frequency moves the arm of the variable resistor downward. In practice, of course, many frequencies are present in the video signal, and the shunt peaking coil simultaneously offers a high reactance to the highs and a low reactance to the lows.

When series peaking is used (Fig. 801-c), the peaking coil serves to break up stray capacitance. The series peaking coil effectively forms a pi-network filter; stray capacitance to ground exists on either side of the coil. With series peaking, a large plate load resistor is used to get greater amplifier gain.

Many designs use both series and shunt peaking to give high-frequency boost. A resistor is often shunted across peaking coils to reduce the Q of the peaking coil and broaden the high-frequency peak. (In practice the peaking coil is wound directly on the resistor body.) The aim is to increase broadly the video amplifier's response at the high end of the frequency spectrum.

Low-frequency compensation

In the video amplifier shown in Fig. 803, the low frequencies are kept intact by the use of large coupling capacitors (C165 and C170) and a large cathode bypass capacitor (C401-d).

Bass-boost circuits are found in some video amplifier designs. One such circuit can be examined in Fig. 804-a. The bass boost consists of R2 and a large electrolytic capacitor, C2. The capacitor in equivalent circuits, Figs. 804-b, -c, is represented by a variable resistor. Referring to basic electronics theory once again, we find that the capacitive reactance rises as frequency drops. Conse-
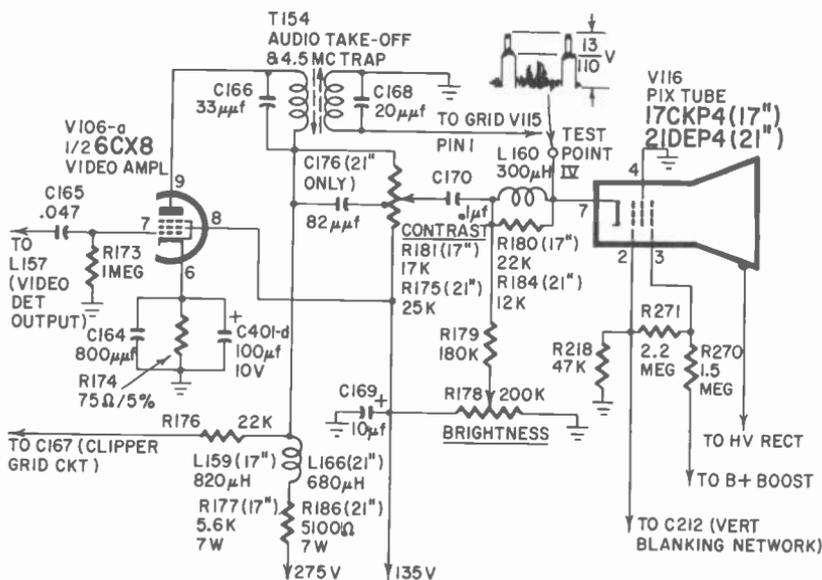
Fig. 803. *Large coupling capacitors and a large cathode bypass capacitor help pre-serve the low-frequency response of the video amplifier.*

quently, at the higher end of the low-frequency portion of the spectrum, C2 acts as a short circuit. The signal frequencies develop across R1 but not across R2 because R2 is bypassed to ground. We show this as a short (Fig. 804-b) but realize that the "short" is seen only by the higher frequencies (in the lower frequency range). The very low frequencies see a different picture because, at the extreme low end of the spectrum, C2 looks like a high resistance. Therefore, the lows develop across R1 and R2, which add to give higher gain for the lows.

Phase distortion

If the frequency response of the video amplifier is not right, we're not only bothered by poor contrast and loss of picture detail, but further troubled by phase distortion. Phase distortion shows up as a smeared picture.

When the term phase is used, we're talking about a time relationship. In other words, the phasing of two or more waves means the timing of the waves with respect to each other. Phase distortion is a condition that causes distortion of square waves.

A square wave is formed by the odd harmonics of a sine wave. The third, fifth, seventh, ninth and all odd harmonics add to and subtract from the sine wave. At places where they add, the sine

wave increases in amplitude; where they subtract, the sine wave decreases in amplitude. Fig. 805-a shows a sine wave and its third harmonic. The other odd harmonics are not shown but, if they were all considered, their adding and subtracting effect would change a sine wave into a square wave. The broken-line wave shows this in Fig. 805-a.
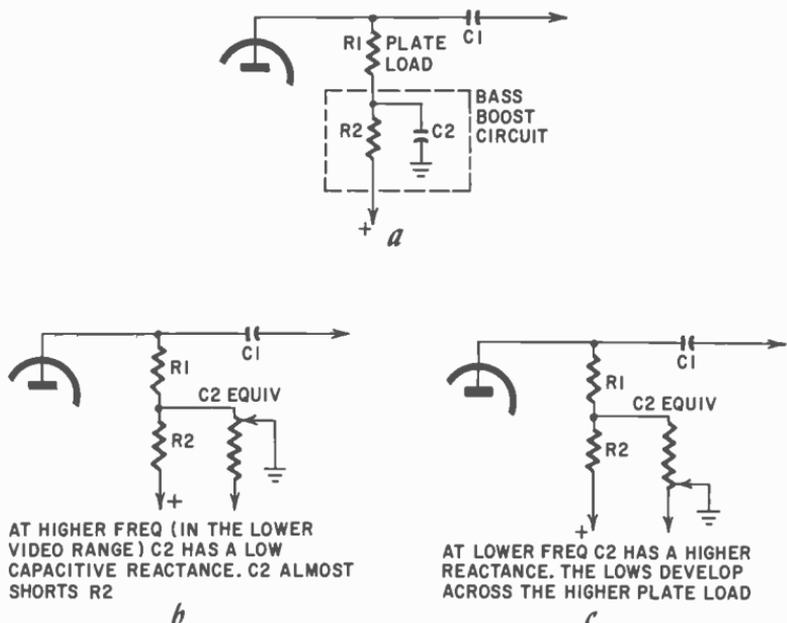

AT HIGHER FREQ (IN THE LOWER VIDEO RANGE) C2 HAS A LOW CAPACITIVE REACTANCE. C2 ALMOST SHORTS R2

AT LOWER FREQ C2 HAS A HIGHER REACTANCE. THE LOWS DEVELOP ACROSS THE HIGHER PLATE LOAD

Fig. 804. *(a) Bass-boost circuit (R2 and C2) for low-frequency compensation. (b) Equivalent circuit using variable resistor in place of C2. C2 acts like a short circuit at higher end of low-frequency portion of spectrum. (c) At lower frequencies, C2 has a higher reactance.*

If the harmonics were shifted in phase, the resultant wave formed by the sine wave and odd harmonics would not be square but distorted. The distortion is shown in Figs. 805-b and -c as the superimposed wave drawn with a broken line.

Contrast control

Any monochrome picture (television, movie or still) is formed by black, white and varying shades of gray. The picture looks natural and pleasing when the tonal gradations (black through gray to white) are correct. Fig. 806 illustrates the difference between a correctly proportioned video signal which produces a pleasing picture, a signal that produces a picture with too little contrast, and a signal that produces a picture with too much contrast. The picture with too little contrast will look flat and washed

out. Note that the video signal producing this flat picture is too low in amplitude. The picture with too much contrast will look harsh. Elements in a contrasty picture will be either too black or too white. This type of picture is produced by a video signal with too much amplitude.

Because the amplitude of the video signal determines the contrast, you select the amount of contrast by adjusting the gain of an amplifier. In many receivers, the adjustable gain is in the video amplifier. Often, you'll find the contrast control to be a series-variable cathode resistor in the video amplifier stage. If you increase the value of this cathode resistor, you increase the grid bias.
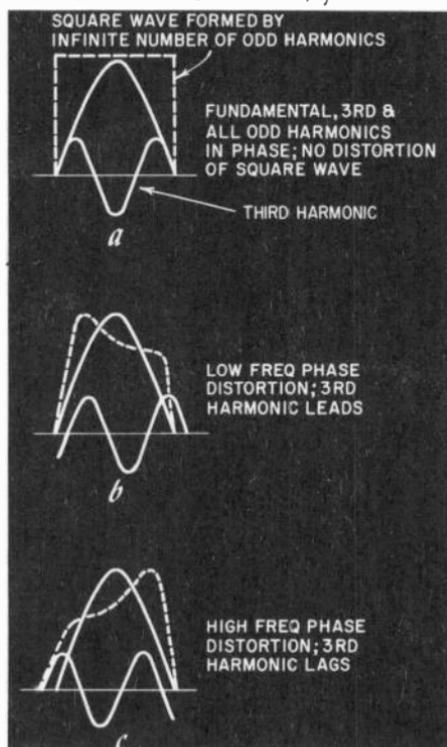
Fig. 805. (a) Square wave formed by odd harmonics of sine wave. (b) Resultant distorted wave when harmonics are phase-shifted. (c) Broken line shows high-frequency phase distortion.

When you increase the grid bias, you reduce the gain of the amplier. This gives you less contrast because the video signal has less amplitude. The reverse occurs when you reduce the value of the cathode resistor. Your picture develops greater contrast.
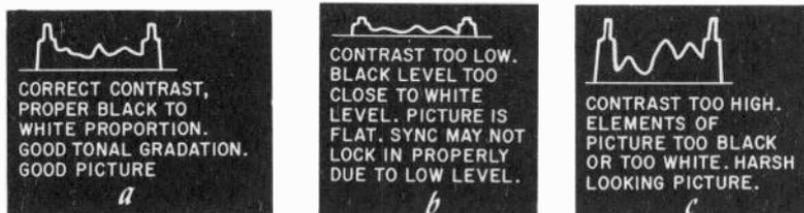
Fig. 806. (a) *Correctly proportioned video signal—pleasing picture.* (b) *Incorrectly proportioned signal—picture has too little contrast.* (c) *Incorrectly proportioned signal—contrast too strong.*

Connecting the contrast control

There are two other ways in which you're likely to see the contrast control hooked up: 1). The contrast control may be in the grid circuit of the video amplifier (output of the detector). The potentiometer resistor is the grid resistor; the arm of the potentiometer connects to the video amplifier control grid. When you adjust contrast, you pick off part of the detector output voltage. 2). The contrast control may be in the plate circuit of the video amplifier as in the circuit shown in Fig. 803. In this case, the potentiometer resistor serves as the plate load resistor; the arm picks off a portion of the voltage developed across the plate load and feeds this voltage to another video amplifier stage or to the picture tube.

Brightness control

The video signal fed to the picture tube rides on top of a bias voltage. This bias voltage exists between the control grid and cathode of the picture tube; the grid is negative with respect to the cathode. When you turn the brightness control in a counterclockwise direction, you increase the negative grid bias. Therefore, the screen is darkened. When you turn the brightness control in a clockwise direction, you decrease the negative grid bias. As a result, the screen is brightened. By adjusting the grid bias, you control the number of electrons in the scanning beam within the picture tube. (When the brightness control is set to the point where picture-tube grid cutoff is reached, the screen is black; there is no scanning beam.) When the video signal is added to the bias, the scanning beam becomes lighter and darker (as it sweeps the screen) to form the picture. Therefore, when you set your brightness control, you set the black level in your picture.

There is an interrelationship between the brightness and contrast controls. The contrast control is involved with brightness because it makes the light parts of the picture brighter and the dark

parts darker. The brightness control, because it can make black parts of the picture gray and gray parts whiter, affects contrast. So for a pleasing picture, you have to adjust both brightness and contrast controls.

When the video amplifier is coupled to the picture tube by either cathode drive or grid drive, the brightness-control arrangement is the same (Fig. 807). In both hookups, you adjust the grid bias voltage by varying the positive voltage applied to the picture-
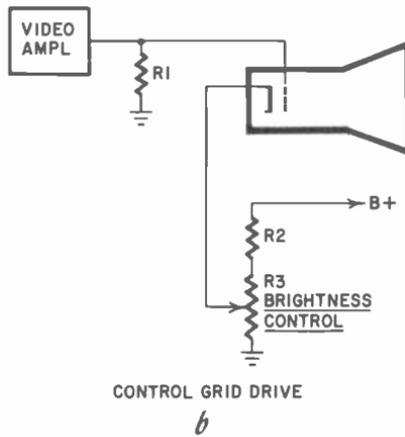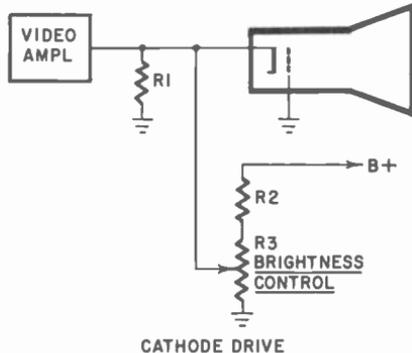

Fig. 807. *Two methods of coupling video amplifier to picture tube. In both cases, brightness control arrangement remains the same.*

tube cathode. When you make the picture-tube cathode more positive, you make the grid more negative with respect to the cathode. This method of adjusting brightness is widely used.

115

4.5-mc traps

In many receivers, you'll find a 4.5-mc trap in the video amplifier. The purpose of this trap is to get rid of any 4.5-mc signal that might have leaked through from the video detector. If a small amount of the 4.5-mc signal passes through the video amplifier to the picture tube, the 4.5-mc signal degrades the picture by adding grain. So you're likely to encounter a parallel resonant trap such as the one shown in Fig. 808-a. Or you might come across a circuit using a series-resonant trap such as the one in Fig. 808-b. Either type of trap is adjusted to eliminate the undesired 4.5-mc signal.

Dc restorer

Where capacitive coupling is used from the video amplifier to the picture tube, you may find a dc restorer circuit used in some sets. Here is the theory behind the need for a dc restorer: A detected video signal has an ac and a dc component. The dc component gives average brightness information; the ac component gives picture sync and blanking information. When the signal is passed through a capacitor, the dc component is lost because the capacitor does not pass dc. And, because a capacitor operates by charging and discharging, the signal that gets through the capacitor will consist of a back-and-forth flow of current. Therefore, the signal that gets through the capacitor will vary in a positive and negative direction as the average voltage changes with brightness.
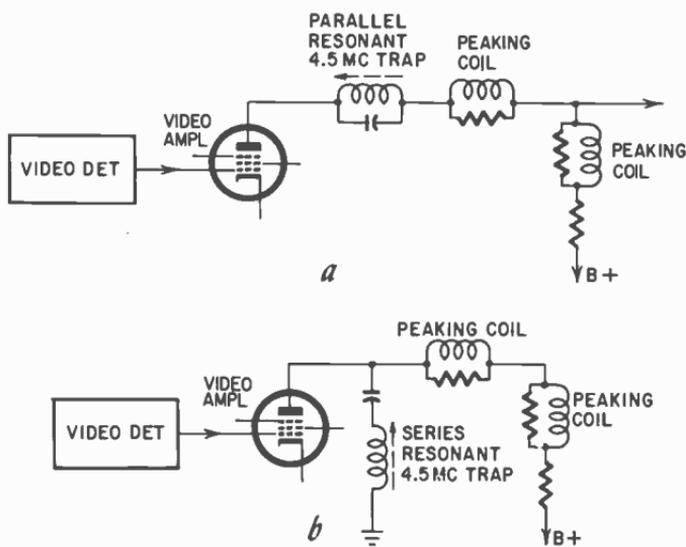

Fig. 808. (a) Parallel resonant 4.5-mc trap. (b) Series resonant 4.5-mc trap. Any 4.5-mc signal that may have leaked through from the video detector stage is trapped out with either type.

As a result, the blanking pedestal will vary with average brightness. If the average brightness is low, the blanking pedestal will be lower in amplitude. If the average brightness is high, the blanking pedestal will be higher in amplitude. If the same gray object is shown in two scenes, one with high average brightness and the other with low average brightness, the object will not have the same gray tone in both scenes.

The bias supplied by the brightness-control circuit does a rather good job of restoring the needed dc component. For this reason, dc restorer circuits are not commonly used in black and white
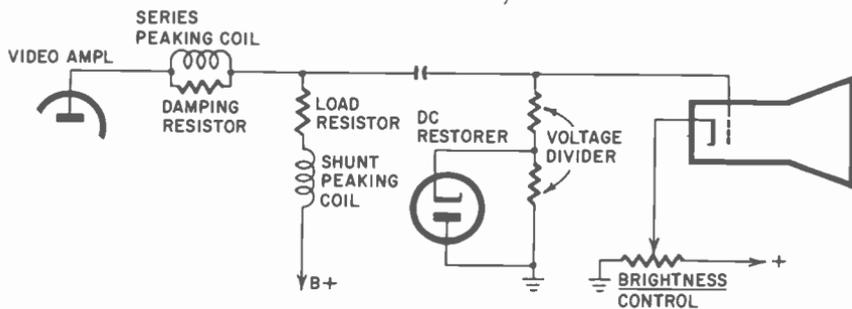
Fig. 809. *Simplified schematic of a typical dc restorer circuit.*

receivers being currently manufactured. (They are being used in color tv sets.) When used, the dc restorer rectifies a tapped-off portion of the video signal and adds the rectified voltage to furnish the lost dc component. Fig. 809 shows a simplified schematic of a typical dc restorer circuit.

Sound and sync takeoff

The 4.5-mc FM sound signal is developed in the video detector (Chapter 7). In some sets, the 4.5-mc signal is removed at that point and sent on its way through the FM if section of the receiver. In most modern receivers, it is permitted to go through the video amplifier to benefit from the amplification provided by the tube. Look again at Fig. 803 and you'll see that we extract the 4.5-mc signal by using T154 in the plate circuit of the video amplifier V106-a.

Fig. 810 is a simplified schematic that shows two methods used for removing the 4.5-mc sound signal from the video amplifier plate circuit. In Fig. 810-a, it is absorbed by a sound takeoff transformer. In Fig. 810-b, the sound signal is tapped by a direct connection to the video amplifier plate; a trap offers a high impedance at 4.5 mc and prevents the sound signal from sneaking into the picture tube.

117

Synchronizing information must also be taken from the signal. But sync is removed in a way that is very different from the removal of the 4.5-mc sound signal. To obtain sync, we take a *sample* of the entire video signal—a small amount of video voltage is tapped off in the video amplifier plate circuit. This voltage is sent to a tube in the sync section that separates the horizontal and ver-
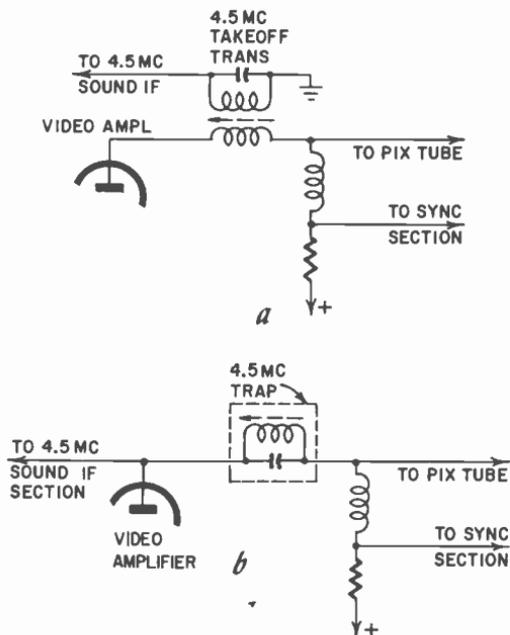

Fig. 810. *Two methods for removing the 4.5-mc sound signal from the video amplifier plate circuit. (a) 4.5-mc sound takeoff transformer absorbs signal. (b) 4.5-mc trap prevents sound signal from getting into picture tube.*

tical sync information. Shown in Fig. 810 is a popular method for removing a sample of the video signal for use by the sync section.

Video-amplifier — picture-tube coupling

The video amplifier can be coupled to the picture tube through a capacitor or directly. Capacitive coupling is also called ac coupling. When there is no capacitor between the plate of the video amplifier and the driven element in the picture tube, the term dc coupling is used to describe the method used. In Fig. 811-a, ac coupling is shown in a simplified schematic; Fig. 811-b shows a

stripped-down version of dc coupling. Although ac coupling is widely used, it might be worth while to take a careful look at the dc coupling circuit. You can see that the picture-tube control grid is necessarily rather positive because it is directly connected to the plate of the video amplifier. But notice the voltage-divider source of positive voltage. The cathode is even more positive. Therefore, the control grid of the picture tube is negative with respect to cathode. This principle is used in all dc amplifiers, as explained in Chapter 5.

AC COUPLING TO PICTURE TUBE CATHODE
a

DIRECT COUPLING TO PICTURE TUBE GRID
b
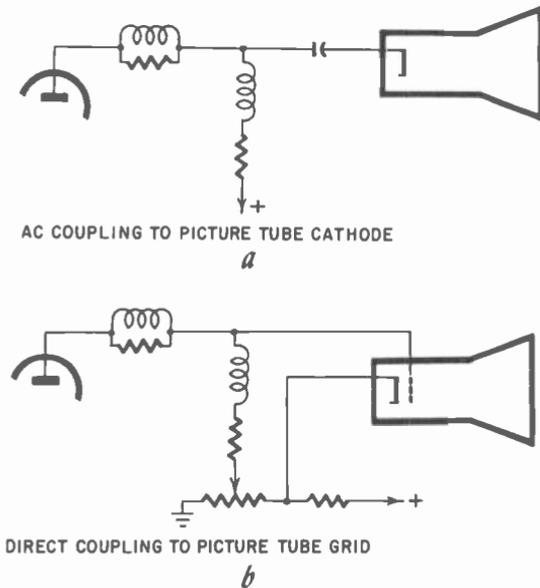
Fig. 811. *Simplified schematic showing: (a) ac coupling to picture tube cathode; (b) dc coupling to picture tube grid.*

Either the cathode or control grid of the picture tube may receive the video signal. When the signal is fed to the control grid, the signal is negative-going. When the signal is fed to the cathode, the signal is positive-going. By far the most popular method used in recent years is ac coupling to the cathode of the picture tube.

Video amplifier phase reversal

When we examined the video detector we emphasized that the demodulated output was negative going. Phase inversion in the single-stage video amplifier flips the signal into the proper polarity for driving the cathode of the picture tube. This doesn't mean that we cannot use a single tube video amplifier for driving the

picture-tube control grid. In such cases, the detector is transposed so that its output is positive going. In those rare cases where a receiver uses two video amplifier tubes, either positive- or negative-going video signals can be obtained, depending entirely on the polarity of the output of the picture detector.

Windup

In a typical television set, the video amplifier receives both the picture and sound signals from the video detector. (In some receivers, the 4.5 mc is removed at the video detector and fed to the sound section). Designed to amplify a broad band, the video amplifier sends a strong positive-going video signal to the cathode of the picture tube. To provide good high-frequency response, series and shunt peaking coils are used. To make sure the very low frequencies get through the video amplifier, large coupling capacitors and a large cathode bypass capacitor will usually be seen in the circuit. Sometimes you'll find a bass-boost circuit used to preserve the lows. The contrast control, found in the video amplifier of most newer sets, determines the amount of video signal fed to the picture tube. A contrast control may adjust the gain of an amplifier or be in the form of a potentiometer that picks off a portion of the video signal fed to the picture tube.

Another control, the brightness adjustment, is invariably in the video amplifier stage. By determining the grid bias of the picture tube, the brightness control adjusts the number of electrons in the picture tube's scanning beam. In the video amplifier stage, 4.5-mc traps are often used to keep the 4.5-mc signal out of the picture tube.

A dc restorer, which is nothing more than a diode with a grounded plate and a cathode connected through a voltage divider to the picture tube grid, is often used to maintain a voltage at a certain level to serve as a reference for the proper shades of grey between black and white.

Both the sound and the sync may be taken from the video amplifier stage. The 4.5-mc sound is often taken from the plate circuit; sync is removed by taking a sample of the video signal and sending it to a separator circuit. Television receivers of recent design use ac coupling from the video amplifier to the picture tube. However, sets with dc coupling from the video amplifier to the picture tube can also be found.

Whether the sound is taken from the video detector, amplifier or the receiver has a split-sound system, it is possible for the sound to

interfere with the picture unless the tuner is properly adjusted (tuned) to pick up the television broadcasting station and the sound traps in the video and video if amplifiers are properly aligned. The symptom of sound interference is in the form of horizontal bars in the raster that increase and decrease in thickness and blackness in step with the sound modulation (Fig. 812). The sound bars will usually be more apparent when picture information is not on the screen; that is, when the screen blanks out during scene changes.

While sound bars are basically a servicing problem, they are descriptive of the effects of improper tuning and alignment. Other defects can be the cause of sound bars. Some can be as simple as mechanical vibration of the speaker being transmitted to the tuner oscillator tube or as obscure as audio signal voltages getting into the tuner or video circuits because of a defective component or ground connection.
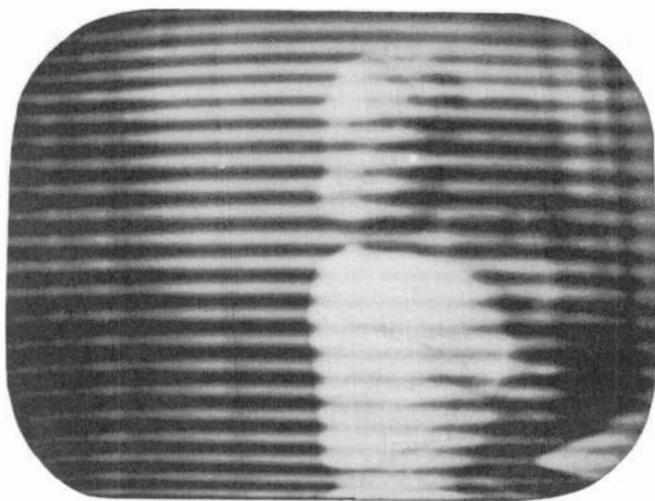
Fig. 812. *Sound bars are most commonly caused by an improperly adjusted local oscillator in the tuner. Sound bars are more pronounced when picture signals are not being transmitted or during scenes of low contrast.*

When the sound appears in the raster due to misalignment or tuning, it is visible as a 4.5-mc signal modulating the electron beam of the CRT just as any picture information would. Of course, this is really more complex than just that—there are sidebands and beat frequencies to be taken into account, but we can neglect them to simplify the explanation.

QUESTIONS

1. What is the frequency amplification range of a video amplifier?

2. What is the effect of the plate load resistor on the frequency response of a video amplifier?

3. What is a shunt peaking circuit? Why is it used?

4. What is a series peaking circuit? Why is it used?

5. How does stray capacitance in the video amplifier affect its response curve?

6. What is the effect of phase distortion on the picture?

7. Describe the formation of a square wave.

8. Describe a bass-boost circuit. How does it work? Why is it used?

9. What effect does poor contrast have on the picture?

10. What effect does excessive contrast have on the picture?

11. What causes excessive contrast?

12. Describe two ways of connecting a contrast control.

13. How does a brightness control circuit work?

14. Describe the interaction between contrast and brightness control circuits.

15. What is meant by ac coupling? Dc coupling?

9

QUICK REVIEW NUMBER 1

● ●

WE have passed through quite a few circuits while following the television signal in its travels in the receiver. We have watched the signal grow from a tiny voltage at the antenna to its husky amplitude capable of driving a big picture tube. But before moving on, let's take a brief backward glance and review the material we have covered thus far.

We learned, at the outset, that the picture you see when you watch TV is formed by just one tiny and sharp spot of light which streaks across the screen with phenomenal speed. So fast does the spot move that it traces 525 lines in just 1/60 second. You see all 488 visible lines (37 lines are blanked) as a complete picture. Lines are interlaced, all the odd lines are traced, then all the even lines, then the odd lines again, and so on. With interlaced scanning, the screen is blanked 60 times per second; you don't see the screen flicker, yet the band space required by the signal is held to a minimum.

The spot traces the picture by changing in brightness as it moves. When a black portion of the picture is traced, the spot is shut off. The spot glows dimly when dark gray appears, brighter with light gray and very bright when white appears on each line in your picture. The intensity of the spot—hence the picture—is under the complete control of the signal transmitted by the broadcast station, and synchronization of the signal is likewise controlled by sync pulses in the signal.

A beam of electrons, emitted by the cathode of the picture tube, forms the spot of light. A phosphor screen inside the front of the picture tube glows when struck by the electron beam. High voltage applied to an aquadag coating inside the picture tube attracts the beam of electrons to the screen. The electrons are focused into a narrow beam by either an external focusing coil (or mag-

net), or electrostatically, Fixed-focus tubes are also popular. The intensity of the beam is governed by either a negative-going signal voltage applied to the grid of the picture tube or a positive-going signal voltage applied to its cathode.

In a picture tube with an aluminized screen, the aluminized coating over the phosphor prevents damage to the screen caused by ions. If the tube is not aluminized, an ion trap is used to deflect the overweight ions. Only the lightweight electrons are directed to the phosphor screen.

A large-screen picture tube employs electromagnetic deflection. A sawtooth current in the horizontal deflection coils swings the beam from side to side. A sawtooth current in the vertical deflection coils moves the beam down as it is deflected sideways. The gentle slope of the horizontal sawtooth is the trace period; the steep slope is the retrace period. Similarly, the gentle and steep slopes of the vertical sawtooth are the trace and retrace periods.

Vestigial-sideband transmission is used in transmitting the television signal. The upper sideband is 4.5 mc wide and carries all the television information. Almost all of the lower sideband is suppressed to conserve band space.

The picture portion of the television signal, existing in the form of a radio frequency that varies in amplitude, carries picture and sync information. Horizontal sync consists of square pulses that ride on top of the blanking pedestals. For vertical sync, a long, serrated pulse is included in the signal, preceded and succeeded by six equalizing pulses to insure proper interlace.

The television signal grows as it travels

A television antenna picks up many television signals which take the form of voltages in the antenna. Can the voltages light an electric bulb? Certainly not. Will you feel a slight shock if you touch the antenna wire? Of course not. Can you measure the voltages with a conventional ac voltmeter? No. Yet, the television signal voltages are there, but weak.

In Fig. 901, we've enlarged one of the signals in the antenna and show the signal sliding down the transmission line on its way to the tuner. The tuner selects a channel, amplifies the signal and changes its frequencies to intermediate frequencies. Notice in Fig. 901 that the selected frequencies of channel 2 are 59.75 mc for sound and 55.25 mc for the picture. These are the assigned frequencies transmitted by the broadcast station. But notice the frequencies that leave the tuner: the picture is 45.75 mc and the

sound 41.25 mc. These intermediate frequencies were developed by beating (heterodyning) the signal frequencies with the oscillator frequency in the mixer. The intermediate frequencies thus formed represent the oscillator frequency minus the broadcast station's signal frequencies. You change any selected channel to
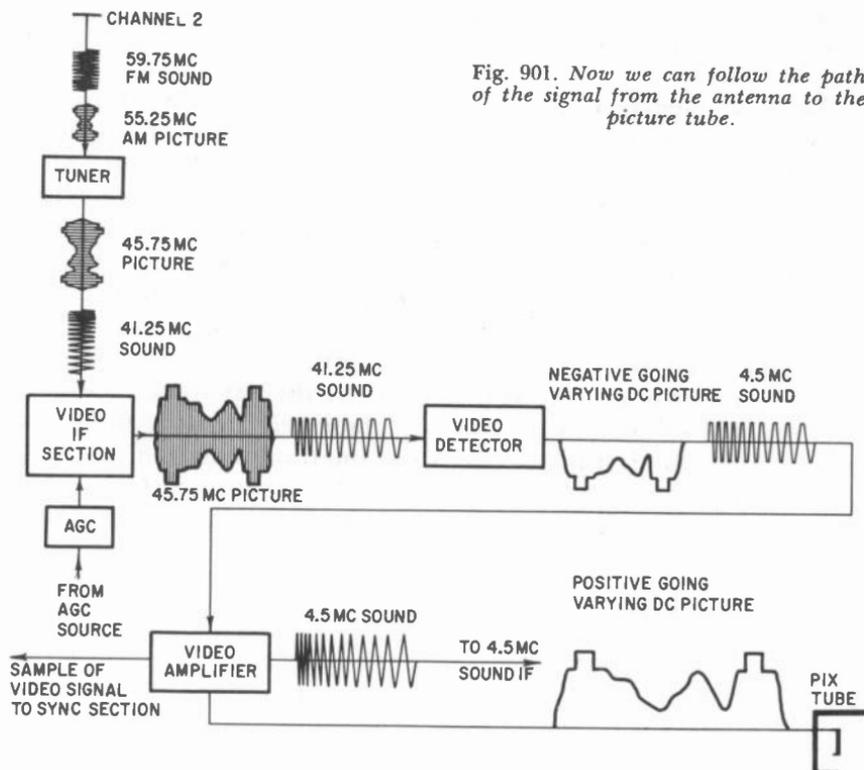

Fig. 901. *Now we can follow the path of the signal from the antenna to the picture tube.*

CHANNEL 2

59.75MC
FM SOUND

55.25MC
AM PICTURE

TUNER

45.75MC
PICTURE

41.25MC
SOUND

VIDEO
IF
SECTION

AGC

41.25 MC
SOUND

45.75 MC PICTURE

VIDEO
DETECTOR

NEGATIVE GOING   4.5 MC
VARYING DC PICTURE SOUND

FROM
AGC
SOURCE

SAMPLE OF
VIDEO SIGNAL
TO SYNC SECTION

VIDEO
AMPLIFIER

4.5 MC SOUND

TO 4.5 MC
SOUND IF

POSITIVE GOING
VARYING DC PICTURE

PIX
TUBE

45.75-mc picture and 41.25-mc sound when you click in the channel.

The video if section amplifies the picture and sound if signals. An automatic gain control (agc) circuit, acting as an automatic contrast control, compensates for the difference in the strength of channels received. There are simple agc systems and better ones, such as the widely used keyed agc that gets its signal-strength information from the sync pulses, which are transmitted equal in amplitude.

What does the video detector do? The answer can be found in Fig. 901, which shows the video detector input and output signals. Also, in the video detector, the 41.25-mc sound if beats with the 45.75-mc picture if to produce a difference frequency of 4.5

125

mc. This new sound if is fed to the sound section of the receiver either directly or through the video amplifier.

Our picture and newly-converted 4.5-mc sound-signal if (assuming that the sound if has not been taken off at the detector) are amplified further in the video stage which feeds a positive-going signal to the cathode of the picture tube, the 4.5-mc FM to the sound if section and a sampling of the video picture signal to the sync circuits.

We have mentioned sync somewhat briefly so this is a topic that now requires more detailed study. But before we do so, let us understand clearly why a television set, unlike AM or FM receivers, requires this particular type of signal. At the television station, in the camera tube, an electron beam busily sweeps back and forth, changing the light impressions it picks up into tiny electrical voltages. The scanning beam in the home receiver must be "slaved" to the scanning beam in the television camera. All of the pulses that are transmitted are designed for this specific function. If you have ever been impressed by the rhythmic cadence of well-trained soldiers as they march absolutely in step, think how much more wonderful it is that all of the thousands and thousands of television receivers have picture tube scanning beams which move line by line in sync with their "leader"—the scanning beam in the camera.

10

HOW THE SYNC SECTION WORKS

• •

T HE sync section in a television receiver contains these circuits: 1). Sync separator; 2). Differentiator; 3). Integrator; 4). Horizontal automatic frequency control (afc).

You can see the relationship of these circuits by looking at Fig. 1001. The sync separator receives a sample of the composite video
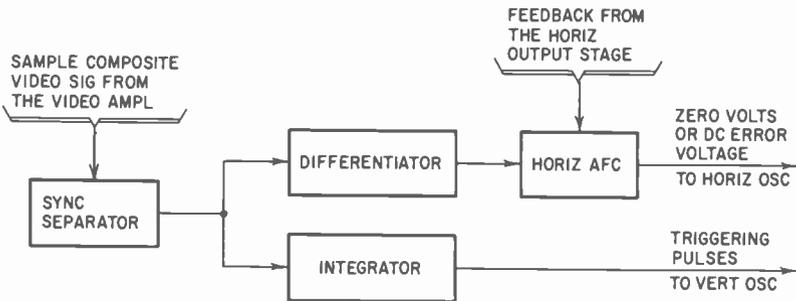
Fig. 1001. *Block diagram showing relationship of circuits in sync section of TV receiver.*

signal from the video amplifier. The sync separator, as its name implies, removes the sync pulses from the video signal and feeds them to both the differentiator and integrator. The differentiator triggers the horizontal afc, which also receives a feedback signal from the horizontal output stage. The integrator sends its output signal to a vertical oscillator.

Processing the composite video signal

In Chapter 3, we did a lot of talking about the composite video signal. A detected composite video signal is a varying voltage that

127

has: 1). Horizontal sync pulses; 2). Picture information between almost all the horizontal sync pulses; 3). A vertical sync interval during which a serrated (notched) vertical sync pulse appears with six equalizing pulses *before* the vertical pulse and six equalizing pulses *after* it. The picture information, we know, is fed to the picture tube (cathode or grid) so it can control the intensity of the scanning beam.

The scanning beam in the picture tube must be simultaneously swept horizontally and vertically, and it must be synchronized. In other words, the camera's scanning beam and the receiver's must always correspond in position. The sync pulses give the information needed by the receiver to synchronize the scanning beam in the picture tube. But we need circuits to remove the sync pulses from the composite video signal. The *sync separator* does this. This circuit chops off all sync pulses.

We also need circuits that know the difference between horizontal and vertical pulses, and can separate the two. For this we can use a simple circuit called a differentiator that responds only to the horizontal frequency of 15,750 pulses per second. All sync pulses are fed to the differentiator, but this circuit recognizes only the horizontal pulses, equalizing pulses and the notches in the serrated vertical sync pulse. In response to these, it develops sharp spike-shaped pulses that are slaved to the 15,750 pulses per second transmitted by the broadcast station.

The differentiator pays no attention to the frequency of the long vertical pulse. But does this vertical pulse go unnoticed? Certainly not! Another circuit, called the integrator, also receives all pulses sliced off by the sync separator. The integrator ignores all horizontal pulses, recognizes only vertical sync pulses and develops a rather sloppy-looking wave in response to the 60-pulses-per-second transmitted for the vertical frequency. The integrator feeds its wave to a vertical oscillator that controls vertical sweep.

Before we go into circuit detail, let's briefly review the manner in which the sync section deals with the video signal: The sync separator removes sync pulses. A differentiator develops spikes in response to horizontal sync pulses, serrations in the vertical sync pulse and equalizing pulses. An integrator develops a voltage wave in response to each vertical pulse. Fig. 1002 shows a simple block diagram of a portion of the sync circuit, and input and output signals of the differentiator and integrator.

Sync takeoff point

In every television receiver, there is a point at which the de-

tected composite video signal is extracted, destined to have its sync chopped off. The signal can be sampled right in the video detector but, more commonly, we like to take advantage of the gain furnished by the video amplifier. So you'll usually find a sync take-off point in the video amplifier (Fig. 1003). As you can see in the diagram, the video signal is removed between the video amplifier's plate load resistor R2 and peaking coil L2. The video signal travels through series resistor R3, which limits the amount of video signal tapped off; sufficient video energy must be left for the feed to the picture tube. C1 is inserted in series to keep
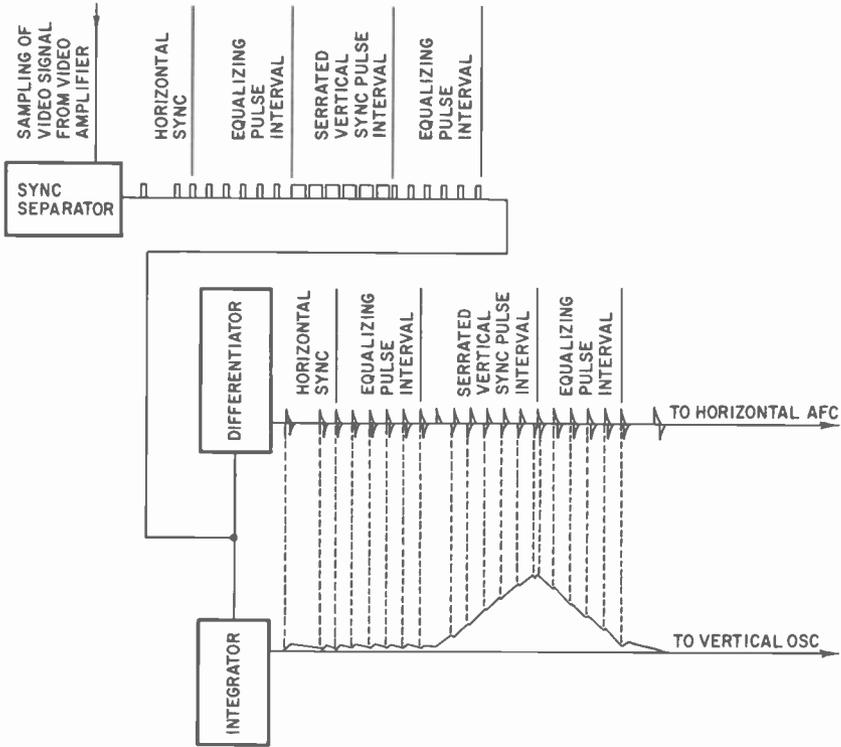
Fig. 1002. *Block diagram showing waveforms found in sync section. Sync separator removes video signals, passing sync pulses only. Integrator and differentiator separate the vertical and horizontal pulses.*

B-plus out of the sync input. To sharpen the sync pulses, the parallel combination of R4 and C2 is wired into the sync line.
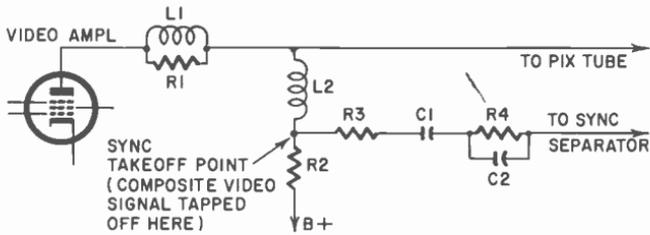
Fig. 1003. *The composite video signal is tapped off between the plate-load resistor R2 and peaking coil L2.*

Diode sync separator

Although the diode separator isn't used much these days, we'll devote a little space to it for your information. The circuit can
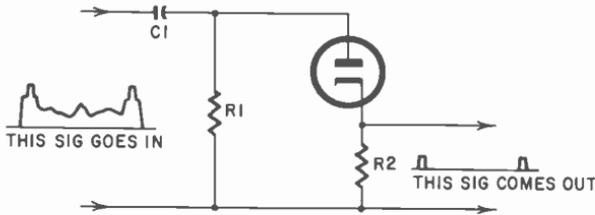
Fig. 1004. *Diode sync separator circuit.*

be seen in Fig. 1004. A resistor-capacitor bias arrangement, C1 and R1, is used to bias the diode.

A positive-going composite video signal is applied to the plate of the diode separator through C1. Current flowing through the diode passes down through R1, making the top of R1 negative. The voltage across R1 charges C1. The time constant of this R1–C1 combination is such that the tube is held cut off for all video (picture) voltages. The sync pulses, however, are sufficiently positive to take the diode into conduction. Therefore, an output appears only during sync pulse intervals.

C1 and R1 act just like a grid leak, but although this term is used in connection with the diode, it is somewhat of a misnomer since the diode has no grid.

Triode sync separator

Triode sync separators are currently used quite a bit by receiver manufacturers. A triode circuit has the advantage of providing some gain with a lighter load on the circuit supplying the composite video signal input. The triode sync separator circuit is simple and works well. Fig. 1005 will help you understand how the circuit works. Fig. 1006 shows how the circuit feeds the differentiator and integrator.

130

Grid-leak bias is used. With this type of bias, the incoming signal furnishes the bias voltage. A positive-going video waveform is supplied to the sync separator input (Fig. 1005). The positive voltage on the control grid results in grid current (electron flow from cathode to grid). Capacitor C1 charges to the polarity shown in the diagram. When the video signal becomes less positive, as it
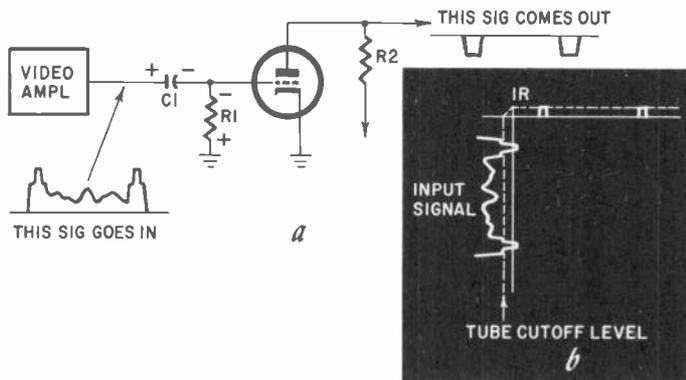
Fig. 1005. *Triode sync separator circuit. Note the difference in signal polarity and strength coming out of triode circuit and that out of the diode circuit of Fig. 1004.*

does when video information is on the signal, C1 discharges through R1. The voltage developed across R1 makes the grid
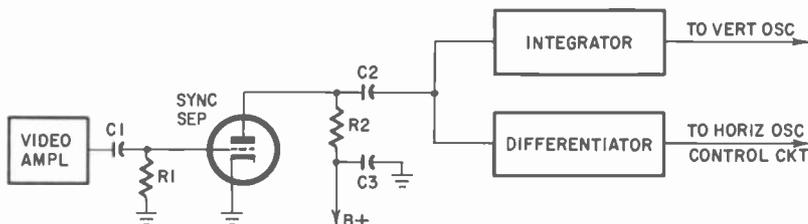
Fig. 1006. *This circuit diagram shows how the sync separator feeds the sync component of the composite video signal to the integrator and differentiator circuits.*

negative with respect to cathode. This negative voltage is the grid-leak bias voltage, and the R1–C1 time constant is such that the tube remains cut off between sync pulses. However, sync pulses are sufficiently positive to overcome the bias (and charge C1 anew each time). This operation is exactly like the diode we just described, with the control grid substituting for the diode plate. For this reason, the grid draws current only during sync pulse intervals, at which time a negative-going voltage pulse appears in the plate circuit.

If you measure the plate voltage on the sync separator and notice that it is rather low, don't be alarmed. The plate voltage is normally low on the sync separator because it also operates as a limiter. Low plate voltage causes plate-current saturation with a rather small amount of input signal amplitude. Because the plate current doesn't rise after saturation, the sync pulses come out with their tops neatly sliced at the same height.
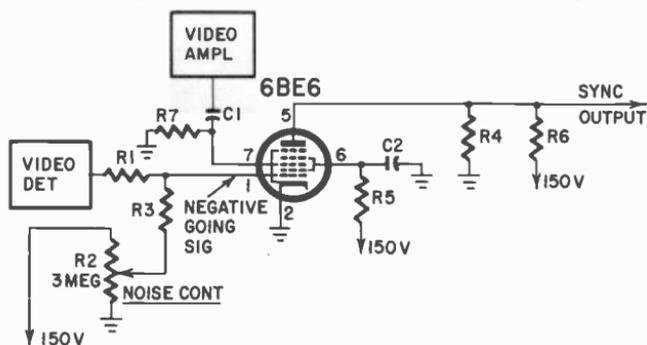
Fig. 1007. *Pentagrid sync separator designed to squelch noise pulses that trigger the sweep oscillators.*

Sync separator and noise clipper

A sync separator circuit designed to squelch noise pulses (to keep them from triggering the sweep oscillators) is shown in Fig. 1007. This arrangement also has the added feature of furnishing a high-level sync output; usually, additional amplification is not needed.

A pentagrid tube is used with this circuit. As with the triode sync separator, a positive-going video signal is fed to the tube — not to the control grid, however, but to the pin 7 grid. This signal is fairly strong, and the sync-separation process is based on the same principle used in the basic triode sync separator. (The tube uses grid-leak bias supplied by C1–R7.)

For noise-elimination purposes, a negative-going video signal extracted from the video detector is fed to the control grid (pin 1) of the pentagrid amplifier. This signal is very weak — so weak, in fact, that it has little effect on the output other than to reduce it slightly. (The noise control is adjusted so that the bias on the control grid (pin 1) is close to zero.) But if a strong noise pulse comes along, it will drive the tube into cutoff. During this instant, there is no output pulse of any kind. Therefore, there is no noise in the output either. You might imagine that the instantaneous loss of sync would affect the picture adversely, but the quantity

of noise ordinarily present does not cause the sweep oscillators to wander off frequency.

Sync amplifier or sync output tube

In many receiver designs, the sync separator output is too weak to be usable, so the sync pulses (now removed from the composite video signal) are sent through a sync amplifier tube (also called a sync output tube). This tube does a twofold job. It amplifies the sync and further cleans the pulses so that they are crisp and clear-cut before being fed to the differentiator and integrator circuits. The tube is grid-leak-biased and makes use of plate saturation to clip the sync peaks.

Differentiator and integrator

The circuit that recognizes only horizontal pulses is called a differentiator or high-pass filter. The circuit that uses the vertical
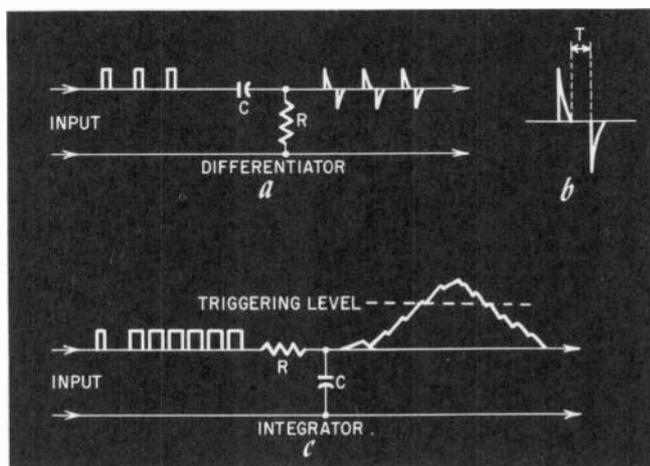
Fig. 1008. *(a) Output pulses of differentiator are sharp spikes. (b) Spikes enlarged to show rapid rise and fall time. (c) Integrator circuit has a long time constant, charges and discharges very slowly. Triggering level is point at which the vertical oscillator frequency is locked.*

pulses is called an integrator. Both are simple. For example, just a series capacitor and shunt resistor constitute a differentiator. An integrator consists of a series resistor and shunt capacitor, al-though several series resistors, interspersed with shunt capacitors, are often used.

Let's have a look at our simple differentiator. (Fig. 1008-a). Notice the sharp output pulse you get in response to the sync

133

square-wave input. You get the sharp spikes because C and R have a short time constant. When the square pulse is applied, current rushes into the capacitor. The voltage that appears across R, therefore, has a fast rise time. When the capacitor is fully charged (and this happens quickly because of the short time constant), the voltage (across R) takes an immediate drop because no more current rushes into the capacitor. This drop is the downward curve of the positive-going spike. Fig. 1008-b shows an enlargement of the spikes produced by one horizontal sync pulse. Although no current moves into the capacitor during the interval marked T, no current flows out either. But in the interval between sync pulses, the capacitor discharges through R, current flows in the opposite direction and we have a negative-going spike identical in shape to the positive-going one.

Both the differentiator and integrator circuits receive the same pulse train. During transmission of the equalizing and vertical sync pulses, the horizontal oscillator continues to receive horizontal sync information because the leading edges of equalizing pulses continue to provide the spike-shaped voltages. Each notch (serration) in the long vertical sync pulse does the same. For this reason, an uninterrupted chain of spikes, at the rate of 15,750 per second, is fed to control the frequency of the horizontal oscillator.

As for the low-pass filter or integrator (Fig. 1008-c), simplicity is the word that describes its theory of operation. Like the differentiator, the integrator also receives all pulses. The short-lived horizontal sync pulses and the equalizing pulses charge the capacitor, but the charge leaks off during the long time gap between pulses. This means, then, that the integrator does not respond.

Because the integrator has a long time constant, the capacitor charges during the entire interval when the long-time serrated vertical pulses are present. The capacitor tries to discharge during the notches in the serrated vertical sync pulse, but it can discharge only a little in that short time. (The little, downward sloping steps in Fig. 1008-c are due to this partial discharge of C because of the spacing or serrations between pulses.) Along comes another segment of the vertical sync pulse and the capacitor takes on more of a charge, adding to what is already stored. (The word integrate means to sum up or combine, and that is exactly the function of capacitor C in Fig. 1008-c.) Each segment of the vertical sync pulse builds the charge progressively higher until the *triggering*

level is reached. The triggering level is the point at which the vertical oscillator is locked in frequency. (The vertical oscillator's behavior is a subject to be discussed in a later chapter).

Obviously, an important consideration in integrators and differentiators is the resistor — capacitor time constants. Differentiators are designed with a time constant so short that the charge on the capacitor leaks off through the resistor between each horizontal sync pulse. The time constant for the integrator is calculated so that the entire charge can't leak off through the resistor in one cycle.

Horizontal automatic frequency control (AFC)

The scanning beam in a picture tube must be swept at exactly the same frequency as the beam in the camera at the broadcast station — the beam that picks up the picture information.

We'll study oscillators in a later chapter, but for now, a preview is in order. It's not hard to build an oscillator that operates at 15,750 pulses per second (the horizontal sweep frequency). It is more difficult, however, to construct an oscillator that won't drift in frequency. The problem of locking in the receiver oscillator frequency is solved by the use of sync pulses transmitted by the broadcast station. But the correct sweep frequency in the receiver is not enough. The receiver's scanning beam must be *perfectly in phase* or in step with the beam in the camera. In other words, when the beam in the camera scans the first line of picture information, the beam in your picture must do the same. Also, the beam in your receiver must be at the same point as the beam in the camera on each line at each instant.

Many years ago, when television was young, the horizontal oscillator was locked in frequency and phase by direct triggering, as is the vertical oscillator. The system worked fine when a noise-free signal was received. Lamentably, the noise pulses usually did appear in most locations, and since noise pulses look a lot like horizontal sync pulses; the horizontal oscillator couldn't tell the difference. Noise would knock the horizontal oscillator off frequency and the picture would be horribly scrambled. Horizontal oscillator frequency-control systems (feedback and error-voltage systems) were developed which did not involve direct triggering of the oscillator. There are many types of circuits using the error-voltage principle. To understand how this method of frequency control works, let's use a mechanical analogy.

Suppose we want a system that will automatically control the speed of a train. Let's say we want the train to go at 60 miles an

135

hour. In the locomotive, a throttle does the same job as the gas pedal in your car — adjusted by the locomotive engineer, it controls the speed of the locomotive. Let's assume that the train goes faster when you turn the throttle to the right and slower when you turn it to the left.

To design an automatic speed-control device, we first need a unit that senses the speed of the train. Suppose our sensing unit is a special generator attached (through a gearing arrangement) to the wheels of the locomotive. When the train goes 60 miles an hour, the generator puts out zero volts. When the train goes faster, the generator puts out a positive voltage. As the train increases its speed, the generator's positive-voltage output increases. Assume that this voltage is fed to a servo motor attached to the throttle. When the servo motor receives a positive voltage, it turns the throttle to the left. This slows the train until it reaches a speed of 60 miles an hour. With the train running at 60 miles per hour the voltage fed to the servo motor drops to zero; the servo motor stops turning.

When the train slows to a speed below 60 miles an hour, the generator puts out a negative voltage. The more the slowdown, the greater the negative voltage. This voltage, fed to the servo motor, causes the throttle to be turned to the right. When this happens, the train increases speed. When the train reaches a speed of 60 miles an hour, the negative voltage from the generator becomes zero. The servo motor no longer turns; the train continues at 60 miles an hour.

Because we have decided that the correct speed is 60 miles an hour, we can say that any other speed is in *error*. Therefore, the voltage produced by the special generator is called an *error voltage* — it indicates that an error has occurred.

The principle involved is a form of inverse (negative) feedback. It is a stabilizing feedback because, by automatically nullifying an error in either direction, it stabilizes speed. If the servo motor were incorrectly wired so that the throttle turned to the right (the speedup direction) when the train increased its speed, a runaway condition would result. This can be compared to positive feedback that causes oscillation or instability in a circuit.

Now let's see what our train analogy has to do with horizontal afc. We will see that the same principle applies.

In Fig. 1009, we have a block diagram of the basic horizontal afc system. The sensing device is the phase detector (or phase discriminator, if you prefer.) The phase detector receives hori-

zontal sync information from the sync separator. Another input to the phase detector arrives by way of a feedback loop from the horizontal output stage. The phase detector compares the horizontal frequency, which arrives by way of the feedback loop, with the frequency of the horizontal sync pulses. If the fre-
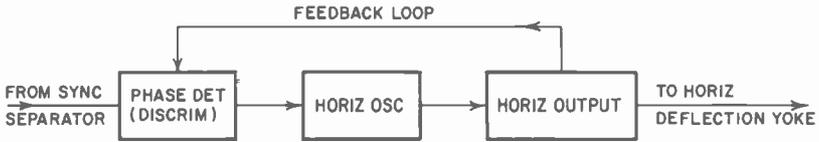

Fig. 1009. *Block diagram of basic horizontal afc system.*

quency of the horizontal oscillator is identical to the frequency of the horizontal sync pulses, the phase detector output voltage is zero. If the oscillator drifts low in frequency, the phase detector supplies a negative error voltage. Applied to the horizontal oscillator, this negative voltage increases the frequency of the horizontal oscillator. If the oscillator drifts high in frequency, the phase detector puts out a positive error voltage which slows down the horizontal oscillator.

The polarities of the error voltages just given refer to the circuit shown in Fig. 1010-a. There are other types of circuits. Some phase-detector – oscillator circuits are designed to work with a negative voltage for oscillator slowdown and a positive voltage for speedup. These polarities are required in the Synchroguide afc system, among others.

G-E horizontal afc

The diagrams of Fig. 1010 provide much information. Notice the two diodes in a specially-designed tube and the signals received by the diodes.

The two diodes are effectively connected in parallel with regard to the incoming sync pulses. As a result, sync pulses are applied equally across diodes 1 and 2. Equal currents flow through each diode and through load resistors R250 and R251. Because the currents oppose, the equal voltages developed across R250 and R251 are of opposite polarity; they cancel and the output is zero.

Let's assume that a sawtooth voltage is fed back to the phase detector but sync pulses are not present. The sawtooth voltage is applied across diodes 1 and 2. Effectively, half the sawtooth voltage is across each diode. When diode 2 conducts on the positive

137

part of the sawtooth wave, diode 1 is cut off; when diode 1 conducts on the negative part of the sawtooth wave, diode 2 is cut off. Because the currents of both diodes will be equal but opposite in polarity, the equal but opposite voltages applied across R250 and R251 will cancel. The output will be zero.

The incoming sync pulses alone will produce a zero-volt output, as will the sawtooth waves alone.

When both diodes receive the sync pulses and sawtooth feedback signal at the same time, as is the case during normal opera-
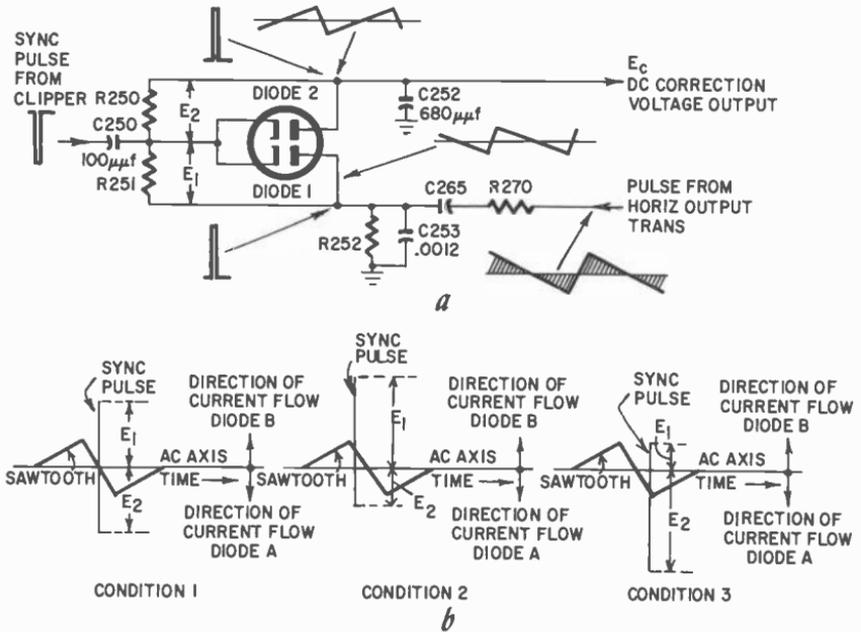
Fig. 1010. *Horizontal afc system. Correction voltage is developed if horizontal oscillator frequency and horizontal sync pulses are not in agreement.*

tion, both diodes conduct at the same time. As shown in Fig. 1010-a, the sync pulse has a higher amplitude than the sawtooth wave. The sync pulse charges C250 to the peak sync voltage. When the sync is removed, the capacitor slowly discharges until the next horizontal sync pulse charges it again. The positive-going sync pulses applied to the cathodes serve to bias the diodes to a value which is never less than the peak sawtooth voltage. This bias allows the diodes to conduct only during that portion of the sawtooth wave that occurs at the instant of the sync pulse. Therefore, only that portion of the sawtooth wave applied to the diodes

at sync pulse time will have any effect in determining the output of the phase detector (Fig. 1010-b).

Condition 1. Horizontal multivibrator frequency correct. The sync pulse occurs while the retrace of the sawtooth passes through its ac axis. E1 equals E2 and the output of the phase detector is zero. Therefore, no correction voltage is produced. The frequency of the horizontal multivibrator is unaffected.

Condition 2. Horizontal multivibrator frequency too low. The sync pulse occurs before the retrace passes through its ac axis. E1

Fig. 1011. *Hartley oscillator circuit. Varying capacitor C1 changes the frequency of the oscillator.*
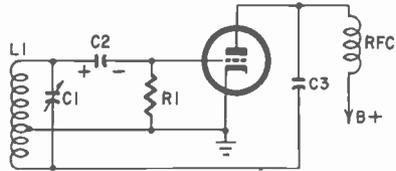
is greater than E2. The output of the phase detector is negative. Applied to the horizontal multivibrator, this negative voltage increases the multivibrator's frequency.

Condition 3. Horizontal multivibrator frequency too high. The sync pulse occurs after the retrace passes through its ac axis. E1 is less than E2. The output of the phase detector is positive. Applied to the horizontal multivibrator, this positive voltage slows down the multivibrator.

The horizontal oscillator controlled by the phase detector, a cathode-coupled multivibrator, is discussed in Chapter 11 and is shown in Fig. 1107.

Because the voltage at the phase detector output controls the horizontal oscillator frequency, the slightest tendency toward drift or out-of-phase condition results in an immediate correction. A constant force is exerted by the phase detector and feedback-loop combination toward the state of balance. Thus, the receiver horizontal oscillator locks in frequency and phase with the horizontal oscillator in the television broadcast station, inexorably and mercilessly enslaved by sync pulses.

Synchrolock horizontal afc

If you are like most electronics enthusiasts, the use of the words "Hartley oscillator" brings a warm glow to your heart as you nostalgically recall that old workhorse in Fig. 1011. How well do you remember C1 which, when varied, changes the frequency of the oscillator. Ah, memories!

It seems as though the inventor of the Synchrolock horizontal afc circuit remembered the Hartley oscillator because this circuit is the source of the 15,750-cycle frequency in the Synchrolock system. This system is different from others because the Hartley produces sine waves, not square waves, as do the multivibrator and blocking oscillator. But before you read on, look at Fig. 1012, the Synchrolock circuit.

The Hartley oscillator sends its sine-wave signal along to two places. It feeds an output signal to a discharge tube, through C10. The discharge tube forms the sawtooth signal. The oscillator also feeds a signal back to a phase discriminator through a discrimi-
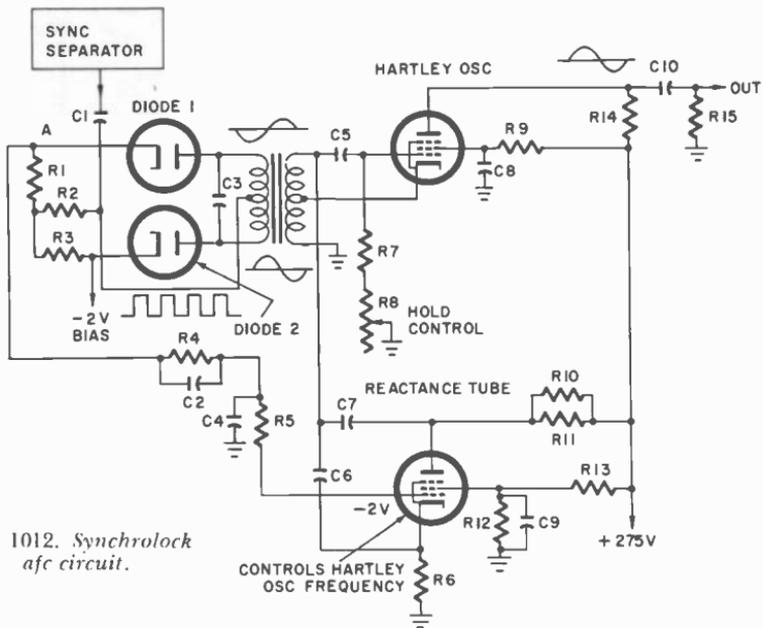
Fig. 1012. *Synchrolock afc circuit.*

nator transformer. This puts sine waves on the plates of the phase discriminator diodes. The sine wave on the plate of diode 1 is 180° out of phase with the sine wave on the plate of diode 2, as shown by the waveforms. With nothing further added, equal currents will flow through R1 and R3. The currents cancel each other and the control voltage at point A (with respect to ground) is zero.

But now something is added. To the center tap of the discriminator transformer, positive-going sync pulses are fed through C1 from a sync separator or sync amplifier stage. The sync pulses, because they are inserted at the center tap, are superimposed on

140
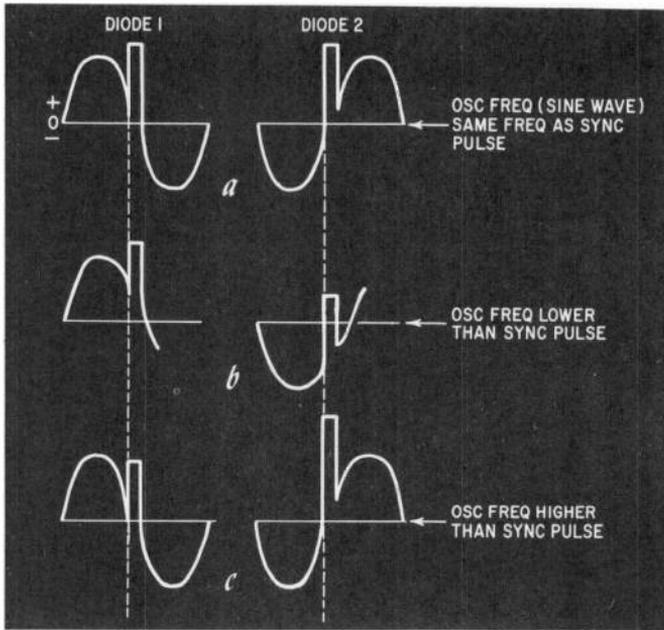
Fig. 1013. *(a) Sync-pulse frequency is exactly the same as the oscillator frequency. (b) Lower oscillator frequency than sync pulse causes diode 1 to conduct more than diode 2. (c). Higher oscillator frequency than sync pulse causes diode 2 to conduct more than diode 1.*

both sine waves — the sine wave on the plate of diode 1 and the sine wave on the plate of diode 2. On each sine wave, the sync pulse is positive-going and each sync pulse is of equal strength. The sync pulses are in phase with each other but, as mentioned, the sine waves are not. Therefore, on diode 1, the sync pulse appears on the falling slope of the sine wave; on diode 2, on the rising slope of the sine wave. You can see this in Fig. 1013-a. A careful look at the position of the sync pulses, when the sync-pulse frequency is exactly the same as the oscillator frequency, shows you that an equal amount of voltage is added to each diode. Under this condition, the balance of the discriminator is not disturbed and we still have a condition of zero volts at point A.

Suppose we let the oscillator shift in frequency and see what happens. For example, a lower oscillator frequency causes more sync voltage to be added to diode 1 and less to diode 2. As a result, diode 1 conducts more than diode 2, and a positive voltage appears at point A. This is shown in Fig. 1013-b. If the oscillator shifts higher in frequency, the opposite occurs (Fig. 1013-c.) Diode 2 gets more sync voltage. The unbalance causes a negative volt-

age to appear at point A. The voltage at point A is fed to a reactance tube. The reactance tube adjusts the frequency of the Hartley oscillator into exact sync. This, in turn, forces the discriminator back into a state of balance.

Here's a simplified explanation of how a reactance tube can control the frequency of the Hartley oscillator. Fig. 1014 shows a capacitor (C1) in series with a variable resistor. This combination is shunted across tank coil L1 of the oscillator. As you vary the resistance you change the effective capacitance across the tank of the oscillator. Now let's go back to Fig. 1012 for just a moment and find C6 and R6. These correspond to C1 and the variable
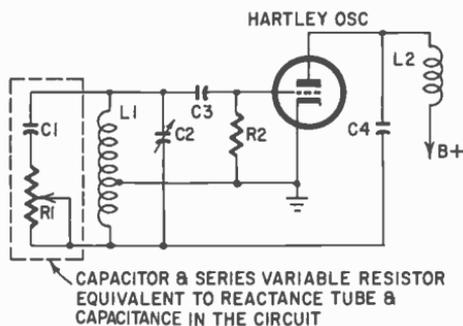
Fig. 1014. *Equivalent reactance-tube circuit. C1 in combination with variable resistor R1 aids in controlling the frequency of the Hartley oscillator.*

resistor in Fig. 1014. The variable portion of R6 is the reactance tube whose resistance varies inversely with the amount of current flowing through it. The amount of current through the reactance tube (hence its resistance) is governed by the control voltage from point A of the discriminator.

Synchroguide or pulse-width horizontal afc

An efficient and economical afc system is the Synchroguide or pulse-width system. One twin triode is used for the generation of the horizontal frequency (15,750 pulses per second) and automatic control of the frequency. The first half of the twin triode is the control tube; the second half is a blocking oscillator. Fig. 1015 shows the circuit.

When you control a blocking oscillator's grid bias voltage, you control its frequency. For example, make the blocking oscillator's grid *less* negative and you raise the oscillator's frequency. Make the blocking oscillator's grid *more* negative and you *lower* the oscillator's frequency. In studying the pulse-width afc system, let's keep our objective in mind: we want to control the blocking-oscillator frequency by adjusting its grid-bias voltage.

In Fig. 1015, note R5. This resistor provides cathode bias for

V1-a. Its value is such that V1-a would be cut off if a signal were not fed to V1-a's grid. Notice that the top of R5, point A in the diagram, also feeds the blocking-oscillator grid. Developed at point A is the control voltage for the blocking oscillator — the voltage that keeps the oscillator on frequency. This leads to the question: how is the control voltage produced at point A?

The signal fed to the grid of V1-a consists of two combined
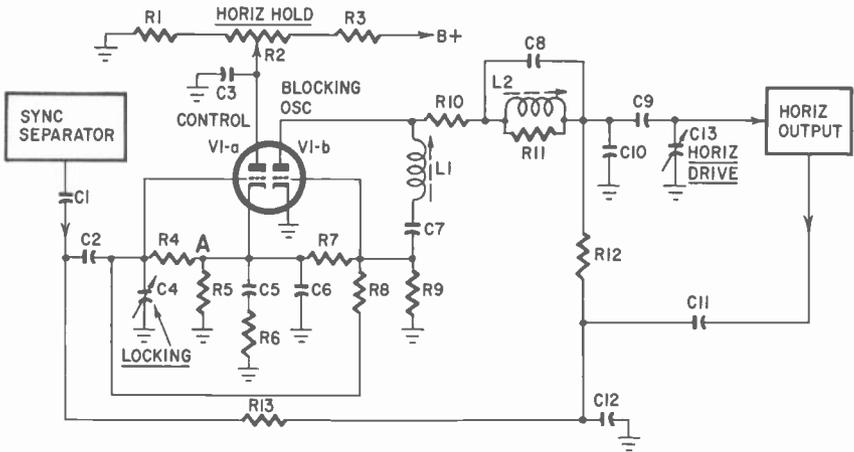
Fig. 1015. *Circuit diagram of Synchroguide afc system. V1-a is the control tube; V1-b the blocking oscillator.*

signals. One is the horizontal sync-pulse signal fed from a sync separator. The other is a parabolic wave fed back from the output of the blocking oscillator. This parabolic wave is formed by taking the output sawtooth wave of the blocking oscillator and integrating the sawtooth with the help of C12. When the parabolic waves combine with the incoming horizontal sync pulses the combinations look like the waves in Fig. 1016-c. Notice the rectangular pulse sitting on top of the parabolic wave. This part of the wave is above V1-a's cutoff level. Neither the horizontal sync pulses nor the fed-back parabolic waves alone are sufficiently positive to overcome V1-a's cutoff condition. Only when the two coincide is a sufficiently positive pulse formed — the portion above the line in Fig. 1016-c. The amount of current that flows through V1-a is determined by the width of the pulses fed to V1-a's grid. The wider the pulses, the more current through V1-a. Therefore, a train of narrow pulses will cause V1-a to conduct less; a train of wider pulses will cause V1-a to conduct more.

Now we come to the method of control. A pulse on top of the

parabolic wave is made narrower by an increase in oscillator frequency. You can see why this is so by examining Fig. 1016. Notice that the coincidence of the two signals (sync and parabolic) is such that wider pulses are formed by a reduction in oscillator frequency and narrower pulses are formed by an increase. The voltage at point A varies accordingly. Specifically, a *frequency*
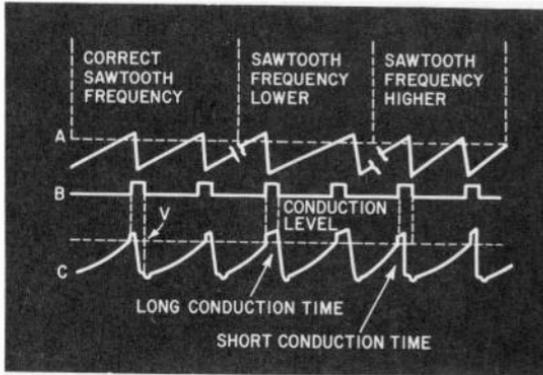
Fig. 1016. *Illustration shows how varying the frequency at V1-a's grid (Fig. 1015) makes the sync pulses either narrower or wider, thus increasing or decreasing the current at V1-b's grid and keeping the oscillator at one frequency.*

slowdown makes *wider* pulses at V1-a's grid. A greater average current flows through V1-a. A *more negative* voltage develops at point A. Fed to the V1-b grid, this more negative voltage *lowers* the oscillator frequency. The reverse occurs when the oscillator frequency tries to speed up. *Narrower* pulses appear at V1-a's grid, and the voltage at point A becomes *less negative* because a lesser average current flows through V1-a. Fed to the V1-b grid, this less negative voltage *increases* the oscillator frequency. The overall effect is to keep the oscillator at one preset frequency, controlled by the incoming horizontal sync pulses.

A resonant circuit, L2 and C8, provides a flywheel effect for better stability. Shunt resistor R11 lowers the Q; the L2 – C8 combination is made less critical. The combination of R6 and C5 forms an anti-hunt circuit. The term "hunting," when applied to an automatic control circuit, refers to the shifting above and below the correct frequency, gradually less and less, until the correct frequency is reached. (The circuit hunts for the correct frequency instead of finding it immediately).

The horizontal hold control, a variable resistor that adjusts the plate voltage of V1-a initially sets the oscillator frequency (15,-

750 pulses per second) by setting the amount of current through V1-a. Once set, the frequency stays put. Horizontal locking control C4 adjusts the phase of the sync pulses and parabolic waves so that the two signals coincide properly at the desired oscillator frequency. A drive control C13 at the output of the circuit, adjusts the amount of output signal fed to the horizontal output stage.

Windup

The purpose of the sync section is to derive, from the composite video signal, synchronizing information for two oscillators; the vertical and horizontal. A composite video signal is the input to the sync section. These are the outputs: (1) A 60-pulse-per-second wave, fed to the vertical oscillator, controls the vertical sweep frequency; (2) In the most popular type of horizontal afc, zero volts or an error voltage, fed to the horizontal oscillator, controls the horizontal scanning frequency.

Now that we have come this far, our next job is to pay a little more attention to the vertical and horizontal oscillators.

QUESTIONS

1. What is the function of a differentiator?

2. Describe the operation of a diode sync separator.

3. Name one possible sync takeoff point.

4. What is an advantage of a triode sync separator over a diode?

5. What type of bias is used by the triode sync separator?

6. Describe the operation of an integrator circuit.

7. What is an advantage of a pentagrid sync separator?

8. Why is horizontal afc necessary?

9. What is an error voltage?

10. What is a phase detector? How does it work?

11. What is the function of the reactance tube in the Synchrolock circuit?

12. How does the sync separator dispose of the picture information portion of the composite video signal?

13. What is the difference between the waveform output of a differentiator and an integrator?

14. Why is a low voltage used on the plate of a sync separator?

15. How are noise pulses prevented from reaching the input of the horizontal oscillator?

11

HOW THE SWEEP SECTION WORKS

● ●

I T may seem as though we have been approaching the sweep systems—vertical and horizontal—by a somewhat devious route. Up to now we have been concerned with the techniques for slaving or controlling the frequency of the vertical and horizontal oscillators. These oscillators, though, are just a part of the complete vertical and horizontal sweep systems.

The vertical sweep feeds a sawtooth current to the vertical deflection coils at the rate of 60 sawtooth pulses per second. This
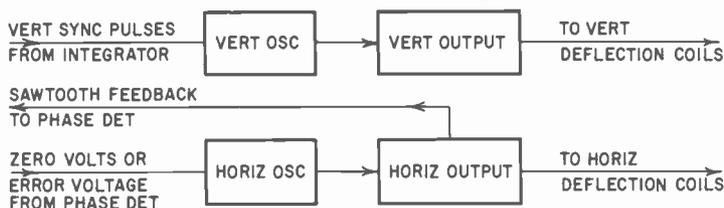
Fig. 1101. *Block diagram of the horizontal and vertical sweep sections of a TV receiver.*

sawtooth current, by creating a sawtooth magnetic field, pulls the beam down and then retraces the beam to the top of the screen.

The horizontal sweep supplies a sawtooth current to the horizontal deflection coils at the rate of 15,750 sawtooth pulses per second. This current, by creating a sawtooth magnetic field, pulls the beam across the screen and then quickly retraces it.

Before reading more, study Fig. 1101. Here you see a sweep

section in block-diagram form. What could be simpler than a vertical oscillator that feeds a vertical output stage? And what does the vertical output stage do? It feeds the vertical deflection coils. The horizontal part of the sweep section is hardly more complicated because it too contains a horizontal oscillator and a horizontal output stage. Naturally, the horizontal output stage sends its output to the horizontal deflection coils. (The high voltage for the picture tube is furnished by the horizontal sweep section but this is such an important function that we are going to consider it separately, in the next chapter.)

The vertical oscillator frequency is controlled by sync pulses received from the integrator. The horizontal oscillator is frequency-controlled by an error voltage from the phase detector.

Oscillators

Two basic oscillator types used in television sweep sections are the blocking oscillator and the multivibrator. Both are called *relaxation oscillators*. This is another way of saying that they produce square waves, not sine waves.

Either a blocking or a multivibrator type can be used as a vertical oscillator. The vertical oscillator will have a free-running frequency of approximately 60 pulses per second. Either type can also be used as a horizontal oscillator. The horizontal oscillator will have a free-running frequency of approximately 15,750 pulses per second.

When the set is on, both oscillators run continuously to keep the beam constantly in motion, whether or not a station is tuned in.

Basic plate-coupled multivibrator

You can examine the circuit of a basic plate-coupled multivibrator in Fig. 1102-a. Notice that the plate of V1 connects to the grid of V2 through a capacitor. Notice, too, that the plate of V2 connects to the grid of V1 through another capacitor. The circuit is actually a resistance-coupled amplifier with a feedback loop. You can see this if you ignore, for the moment, the feedback from the plate of V2 to the grid of V1.

During one cycle of operation, the circuit goes through four conditions: First, there's an extremely rapid change from V1 conducting to V2 conducting. This is followed by a long period during which V1 is cut off and the circuit is relaxed. Next, a second violent change occurs as V1 instantly goes into conduction. This drives V2 beyond cutoff. Finally, a relatively long period follows during which V2 is cut off and the circuit is again relaxed. Then the

cycle repeats. The vertical side of a square wave represents the extremely rapid change when one tube cuts off and the other conducts. The flat tops or bottoms of the square waves are the long relaxation intervals between the instantaneous switch from conduction of one tube to the other.

Let's explain step by step exactly what happens to current and voltages when the plate-coupled multivibrator operates. To make the discussion easy to follow, we'll use numbered paragraphs.
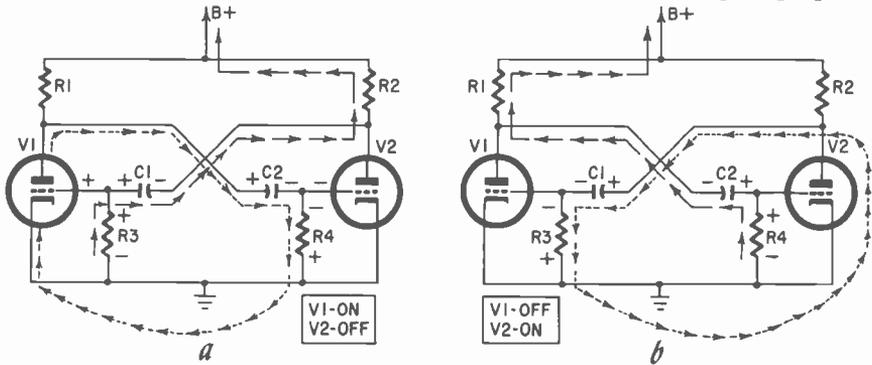
Fig. 1102. *Circuit diagram of a basic plate-coupled multivibrator. (a) Operation of multivibrator with V1 conducting and V2 cut off. (b) Operation with V2 conducting and V1 cut off.*

Under a numbered paragraph, you may find a subparagraph that explains some basic electronics theory. This information is included to help in case you may have forgotten a few principles.

1. Note how C2, the coupling capacitor, is connected. One side of it is wired to the ground or minus side of the B supply through R4. The other end of the capacitor is attached to the positive side of the B supply through R1. The capacitor becomes charged. The same is true of C1 which is connected in a similar manner.

What happens when the unit is first turned on? The cathodes won't get hot immediately. Result—very little current through the tubes and maximum voltage on the plates. The coupling capacitors, though, are connected directly to the plates, so have an ideal opportunity of charging to almost full supply voltage.

2. When voltage is first applied to the tubes, current tries to flow through both tubes at the same time. From the circuit diagram, it would seem as though equal current would flow through each and nothing further would happen. Because the characteristics of two tubes of the same type are never perfectly identical, one tube will get a head start on the other and carry slightly more current.

149

3. Let's assume that V1 takes the lead. When current increases through V1, its plate voltage drops (becomes less positive or—saying the same thing—more negative).

If you wonder why plate voltage drops when the tube conducts, realize that a tube acts as a low resistance when it conducts heavily. Therefore, the tube in series with the plate load resistor can be thought of as a voltage divider. When the tube acts as a lower resistance, a greater portion of the power supply voltage develops across the plate load resistor. Consequently, the voltage on the plate drops (the plate is closer to ground potential).

4. The low voltage on the plate of V1 is now less than the charge on C2, therefore, C2 discharges through R4. The complete C2 discharge path is through R4, to ground and around through V1 to its plate. This path is shown in dashed lines in Fig. 1102-a.

5. The C2 discharge current through R4 makes the grid end of R4 negative with respect to ground.

6. The negative grid voltage on V2 reduces the current through that tube. As a result, V2 acts as a very high resistance and the plate voltage of V2 goes up (becomes more positive) .

The reason the V2 positive plate voltage rises is the reverse of that given in the paragraph under step 3. If a tube is cut off, it acts as an insulator. Under this condition, the full B-plus voltage will appear on the plate.

7. The increase in voltage at the plate of V2 charges capacitor C1 to a new higher voltage; current flows toward the capacitor through R3. The solid lines in Fig. 1102-a shows this current path.

8. The top of R3 becomes positive with respect to ground because of this current, putting a positive voltage on the grid of V1. As a result, what was originally a slight rise in current through V1 becomes an enormous current increase.

9. An instantaneous runaway condition exists because we now have two forces acting simultaneously to increase the current through V1. The grid of V2 becomes more negative while the grid of V1 becomes more positive.

10. The current in V2 drops to zero because the tube's grid voltage goes far beyond cutoff. Therefore, V2's positive plate voltage equals the power supply positive voltage. There is no drop across R2 because no current flows through V2.

11. With V2 cut off, C1 is fully charged and no more current can flow into it. As a result, no further current passes through R3, the voltage across this resistor dropping to zero. This removes the positive bias on V1.
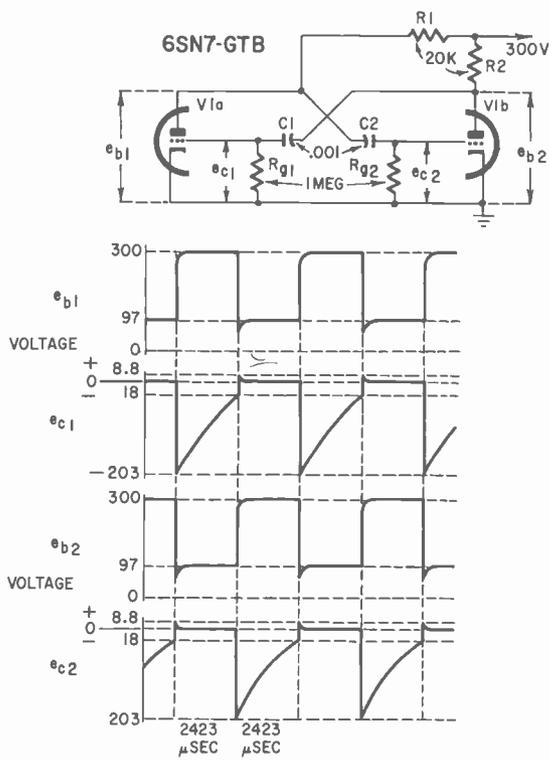
Fig. 1103. *Basic plate-coupled multivibrator circuit (top) and associated waveforms for grids and plates.*

12. Although the bias on V1 has now moved in a negative direction, the tube continues to conduct. Therefore, capacitor C2 continues to discharge. During C2's discharge interval, the current shown in dotted lines in Fig. 1102-a maintains V2 in a cutoff condition. This is the flat-top period when no changes occur in the circuit except for the slow discharge of C2.

13. As C2 discharges, the voltage across it is reduced. Consequently, the voltage across R4 is reduced. When the voltage across R4 reaches a point above V2's cutoff voltage, a tiny amount of current trickles through V2. The instant this happens, the circuit reverses; V2 conducts fully and V1 is cut off. This happens for the same reason V1 originally developed an instantaneous full on condition (as described at the start of this discussion) when V2 was instantaneously cut off. The runaway condition repeats; only this time, it's V2 that carries the current.

151

Let's run briefly through the circuit change that takes place during the flipover. The moment current trickles through V2, the plate voltage of V2 drops slightly. What happens? Capacitor C1 starts to discharge through R3. The dashed line in Fig. 1102-b shows the C1 discharge path. This puts a negative voltage on the grid of V1. V1's plate current is reduced. Naturally, V1's plate voltage goes up. C2 charges because of the increased positive voltage on the plate of V1. The C2 current charge path is shown in solid lines in Fig. 1102-b. Notice that the flow through R4 puts a positive voltage on the grid of V2. As with the first cycle, when V1 took the lead in carrying the current, V2 carries all the current and V1 is cut off. As before, another flat portion
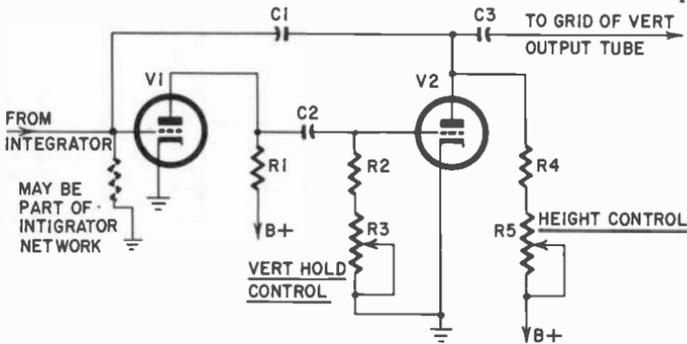
Fig. 1104. *Typical multivibrator used as a vertical oscillator in a receiver.*

of the square wave is reached. The flat portion remains until the charge held by C1, which holds V1 cut off, drops because this capacitor discharges through V2. Then the cycle repeats.

Thus, the free-running multivibrator flips back and forth indefinitely as long as power supply voltage is applied. A steady stream of square waves is produced by the circuit and the frequency and pulse duration are determined by the time constants of the capacitor—resistor combinations. To be specific, the time required for C2 to discharge through R4, and the time required for C1 to discharge through R3, determine pulse duration and frequency.

Fig. 1103 shows the relationship between V1 and V2 plate and grid voltages. Plate voltage from either tube, can be used as a square wave output.

Directly synchronized plate-coupled multivibrator

When used to supply the vertical sweep frequency, the plate coupled multivibrator is triggered by the output of the integrator.

The sync pulses, applied directly to the multivibrator, lock in the multivibrator frequency. However, when used to supply the horizontal frequency, the multivibrator is synchronized not by pulses, but by a dc error voltage.

Now that we've completed a study of the basic circuit, let's look at a typical multivibrator used as a vertical oscillator in a receiver. Fig. 1104 shows this circuit. This schematic is drawn in a manner different from the basic multivibrator discussed earlier but, if you examine it carefully, you'll see that Fig. 1102 is a foundation circuit for Fig. 1104. However, the latter has a frequency control (vertical hold control) and an output amplitude
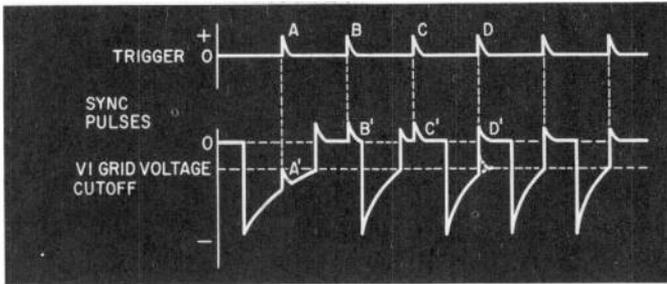
Fig. 1105. *Trapezoidal waves produced by the vertical multivibrator (and its peaking circuit) and vertical synchronizing trigger pulses.*

control (height control). Also, Fig. 1104 is drawn to make a re-sistance-coupled amplifier with a feedback loop easy to see.

As in Fig. 1102, we can alter the frequency of the multivibrator by changing the values of the R-C components, R1-C1 or R2-C2. A variable resistor is put in series with R2 and it is this control that is used for setting the oscillator at or close to its correct operating frequency. Without R2, the setting of R3 would be rather critical.

Fig. 1105 shows the trapezoidal waves produced by the vertical multivibrator (plus peaking circuit) and the vertical sync trigger pulses. Trigger pulses are positive and are applied to the grid of V1 in Fig. 1104. For convenience, these pulses have been lettered A through D. These same sync pulses, superimposed on the pulses produced by the multivibrator, are lettered A¹ through D¹. The diagram shows what may happen when the sync pulses are first applied to the multivibrator trigger input, and how the sync pulses bring the multivibrator under their domination. (Formation of trapezoidal waveforms is described on page 161.)

As chance would have it, the first positive sync pulse, A, comes

along at a time when the grid is very negative. Nothing happens. Blissfully ignorant, V1 doesn't know it has been hit by a sync pulse. The multivibrator, at its own frequency, is enjoying its freedom as it merrily churns out pulses, never suspecting that this frequency freedom will be short-lived. Along come sync pulses B and C, which fail to bring the multivibrator under control because they arrive when the V1 grid is positive. But wait! Look at pulse D. This pulse arrives when it (being positive) can overcome the negative condition of the V1 grid. This spells the end of the multivibrator's free-running state because, from here on, the sync pulses tell the multivibrator when to flip. The sync pulses exert perfect control over multivibrator frequency.

Cathode-coupled multivibrator

Now that we've chased the electrons through a plate-coupled multivibrator, we're in a good position to tackle another multivibrator circuit—the cathode-coupled. As you can see in Fig. 1106,
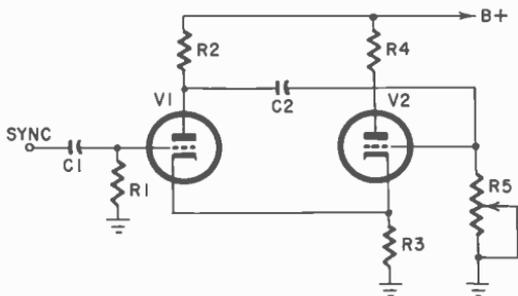
Fig. 1106. *Cathode-coupled multivibrator circuit.*

the plate of V1 is connected to the grid circuit of V2 through a capacitor, as with the plate-coupled multivibrator. The feed from V2 to V1, though, instead of being through a capacitor, is accomplished through use of the common cathode resistor, R3. At first glance, this may be hard to visualize, so let's examine the action in the circuit step by step.

1. Voltages are applied to the circuits.

2. Current flows from ground (B minus) through R3, V1, V2, R2 and R4 to the B-plus supply. Capacitor C2 charges. Both tubes are biased through the effect of common-cathode resistor R3. Therefore, the current flow through both tubes is reduced somewhat.

3. Because of the current flow through V1, the plate resistance of this tube is lowered. Capacitor C2 finds a discharge path through

V1 and current flows out of C2 toward ground and up through V1 to the B-plus supply. As a result, a negative voltage develops at the top of R5.

4. The negative voltage at the top of R5 cuts off V2.

5. V2 stays cut off as C2 discharges. But as the charge on C2 drains out, the grid of V2 becomes less negative, and current starts to trickle through the tube.

6. When current flows through V2, positive voltage increases across R3. As as result, the grid of V1 becomes more negative; the plate of V1 becomes more positive.

7. Because C2 is connected to the plate of V1, C2 receives the new higher positive voltage on its plate side and the capacitor charges. Because the flow of charging current is from ground up through R5, V2's grid is driven positive.

8. V2 conducts heavily because of the positive-going voltage on its grid.

9. The heavy current flow through R3 biases V1. Now we have the condition where V2 is on and V1 is off. By following the remaining steps, you will be able to see how the circuit flips back the other way—V2 will then be off and V1 on. Remember, charging current continued to flow into C2 as the plate of V1 became more and more positive, until V1 reached the cutoff point.

10. When V2 reaches cutoff, the biasing current through R3 diminishes. When this happens, the grid of V2 becomes less negative. A point is reached where V2 starts to conduct again.

11. The instant V2 begins to conduct, its plate voltage drops, C2 finds a discharge path (as in step 3), and current flows out of C2 through R5, R3 and around through V1 to the B-plus supply.

12. A negative voltage appears on the grid of V2, the tube cuts off and the cycle repeats.

Dc error voltage controls frequency

Shown in Fig. 1107 is the cathode-coupled multivibrator used as a horizontal oscillator. The phase detector that controls this oscillator was described in Chapter 10.

The first triode, V109-a, conducts throughout the operating cycle while the second triode, V109-b, conducts only during retrace time. Because the cathode of each triode is connected to ground through a common resistor, R260, the operating bias of V109-b is affected by any cathode voltage developed by the conduction of V109-a.

V109-a's grid is bypassed to ground and is not part of the feedback loop. Therefore, this grid is used as the controlling element

of the system. If the correcting (error) voltages applied to the grid of V109-a are positive, the cathode voltage will increase. This extends the cutoff time of V109-b. Since we have now increased cutoff time before trace time occurs, the oscillator frequency is lowered.
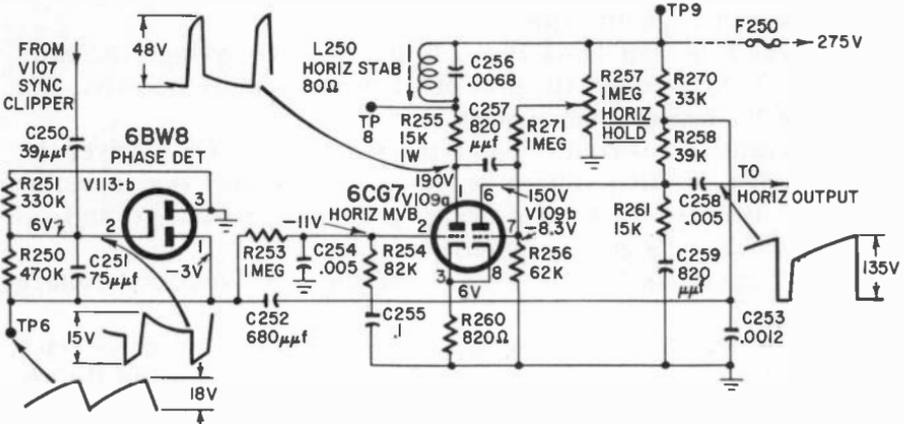
Fig. 1107. *The error voltage from the phase detector controls the frequency of the cathode-coupled multivibrator. Appropriate waveforms are indicated.*

Similarly, any negative correction voltage applied to V109-a's grid lowers the cathode potential and shortens the time of the R-C discharge of the V109-b grid circuit. This also increases the firing rate and thus raises the frequency of the oscillator. The output of this oscillator is capacitance-coupled to the horizontal sweep output tube grid circuit.

The blocking oscillator

The blocking oscillator is commonly used for the generation of the vertical sweep frequency; a circuit diagram can be seen in Figs. 1108-a and -b.

When voltage is applied to the blocking oscillator plate, current surges through the tube and through the primary (P) of the transformer. A rising plate current causes a voltage to be induced across the transformer secondary (S). This makes the grid positive, current flow increases even more through the tube, and the grid becomes still more positive.

Fig. 1108-a shows this first part of the cycle. Capacitor C1 charges.

There's a limit to everything though, and there's a limit to how long current can continue to increase through a tube. When saturation is reached, plate current no longer rises. As you know, a transformer induces a voltage across its secondary only when a

current *changes* (increases or decreases) in its primary winding. When the tube current reaches saturation, the change ceases;
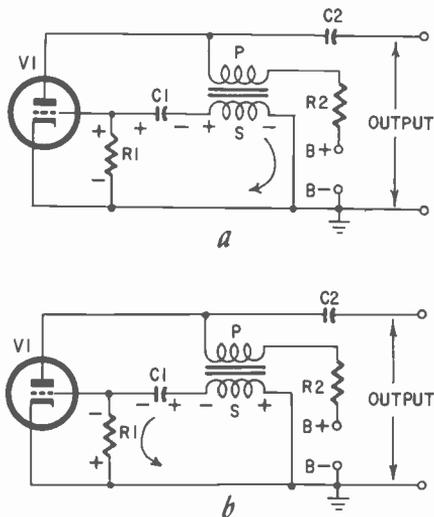
Fig. 1108. *Circuit diagram of a blocking oscillator. (a) First part of cycle shows capacitor C1 charge path. Current flow through tube reaches saturation. (b) C1's discharge path. At saturation, plate current no longer rises and C1 discharges through R1, repeating the cycle in (a).*

voltage is no longer induced across the transformer secondary. When the induced (feedback) voltage stops, C1 gets its big chance and discharges through R1. Because the current flows toward ground through the resistor, the grid end of the resistor becomes negative and biases the tube. Fig. 1108-b shows the C1 discharge path. As the capacitor discharges through the resistor, the negative voltage on the grid gradually becomes less negative. Finally, a time is reached when the bias is overcome, current flows through the tube, and the process is repeated. You can see the discharge curve of the capacitor in Fig. 1109-a. (Sync will be discussed later). Notice the gradual discharge of the capacitor and sudden block when the grid goes positive. Obviously, the blocking oscillator is so named because the tube blocks itself, over and over again. The time required for C1 to discharge through R1 is the time the tube remains cut off. Therefore, the discharge time (R-C time constant) determines the oscillator frequency.

The oscillator is a free-running type because we want it to keep working when the set is on, whether or not a station is tuned

in. This is necessary to keep the beam constantly in motion in the picture tube. When used as a vertical oscillator in the receiver, a means is provided for directly synchronizing it. The oscillator frequency is adjusted by means of a vertical hold control; many sets provide a size control which adjusts the oscillator output-wave amplitude.
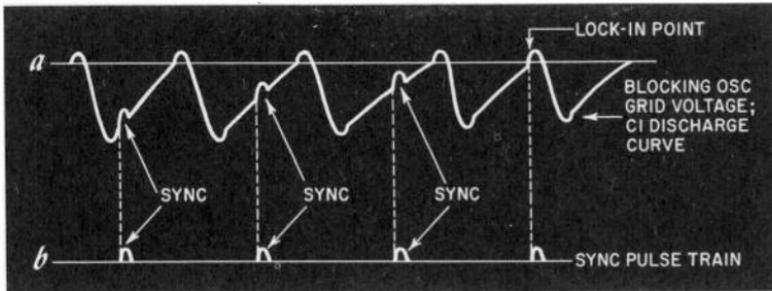
Fig. 1109. *Capacitor discharge curve (a) shows how sync pulses (b) ride in on grid-voltage waveform to lock in the oscillator.*

Blocking-oscillator synchronization

Turn on a free-running blocking oscillator and it will grind out pulses at a frequency determined by an R-C time constant. Fig. 1109-a shows the grid-voltage curve during tube conduction. Rather than wait for this pulse to occur, we can feed in positive sync pulses that will determine the tube conduction periods. Figs. 1109-a and -b show how the sync pulses ride in on the grid voltage waveform to lock in the oscillator. However, the R-C time constant (R1 and C1 in Fig. 1108) must be at approximately the vertical sync frequency (60 pulses per second).

In Fig. 1110 which typifies circuits used in TV sets, several variable resistors are shown. Because the value of R3 determines the speed at which C1 loses its charge, you can change the frequency of the oscillator by adjusting the resistance of R3. This variable resistor is the vertical hold control which sets the approximate frequency. In the output of the circuit shown in Fig. 1110 is a control that varies the plate voltage of the oscillator. If you increase the plate voltage, the oscillator will produce output pulses of greater amplitude. This will increase picture height; therefore, R4 is a height control.

Sawtooth formation

Have you ever seen a grocer slice a cheese? He can cut it to any desired shape. Well, a design engineer is an electronic grocer who

can slice and whittle pulses into almost any shape required. Whether the pulses need be square, sawtooth or trapezoidal in shape, they can be sliced to suit the occasion.

Earlier in this book, when the video waveform was under discussion, much was said about how the beam was swept. This
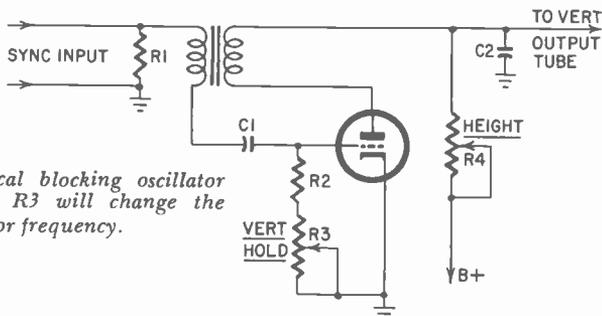
Fig. 1110. *Typical blocking oscillator circuit. Varying R3 will change the oscillator frequency.*

meant that a force in the picture tube moves the beam across the screen at a comparatively slow speed and back at an even faster rate. The beam is swept both horizontally and vertically by a sawtooth force. In each case, the sharp downward slope is the retrace of the beam.

In television, we have both sawtooth voltages and sawtooth currents. The relationship between the two is important. When a small-screen cathode-ray tube is used, such as in an oscilloscope sawtooth *voltages* are applied to the vertical and the horizontal deflection plates. With electromagnetic deflection, used in all large-screen sets, we need a sawtooth *current* through the horizontal deflection coils and a sawtooth *current* through the vertical deflection coils. When the current wave forms a sawtooth, the beam is swept in sawtooth fashion because the magnetic fields (horizontal and vertical) follow the sawtooth current. To cause a sawtooth current to flow through deflection coils, we have to apply a *trapezoidal voltage* to the deflection coils. This voltage is shaped like a sawtooth that sits on top of a square wave. However, before we explain the way in which a voltage is formed into a trapezoidal shape, let's first discuss the very simple way a sawtooth voltage is produced.

How a sawtooth voltage is formed

We use a capacitor to form a sawtooth voltage. The shaping of the wave is based on the very simple fact that when voltage is applied to a capacitor, the charge curve looks like the one in Fig. 1111-a. In other words, the capacitor initially charges very fast,

159

in an almost linear manner, but gradually tapers off as it nears its fully charged condition.

If you wired the simple circuit shown in Fig. 1111-b, you could manufacture sawtooth waves mechanically. The circuit consists
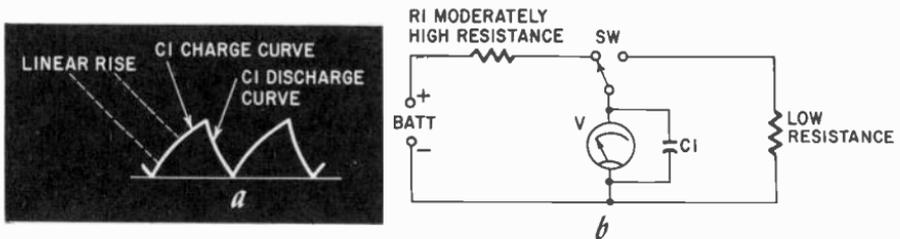
Fig. 1111. *Forming a sawtooth voltage. (a) Capacitor C1 charge and discharge curves. (b) Simple circuit designed to produce sawtooth waveforms mechanically.*

of a charge and discharge circuit for the capacitor. By throwing the switch to the position that connects the battery to the capacitor through a resistor, you charge the capacitor. The resistor slows the charging process somewhat. Turn the switch the other way and you rapidly discharge the capacitor. The reading on the voltmeter, if plotted on a graph, would show the relatively slow charge and very rapid discharge of the voltage wave. If you manipulated the switch slowly, your sawtooth wave couldn't be very linear because of the slowdown in charging rate as the capacitor approaches its fully charged state. The sooner you throw the switch to a discharge position, the more linear the upward slope.

Now, let's see how a sawtooth can be formed in the output circuit of a relaxation oscillator. For this, look at Figs. 1112-a and -b, which show a sawtooth-forming capacitor in the plate circuits of a multivibrator (cathode- or plate-coupled type) or blocking oscillator. Both sawtooth-forming capacitors are labeled C1.

In both oscillators, the sawtooth-forming capacitors charge during the time when their associated tube is cut off. In other words, when V2 in the multivibrator is cut off, C1 charges. When the blocking oscillator tube is cut off, C1 charges. The charge time, in both circuits, gives the upward slope of the sawtooth waves. In either the multivibrator or the blocking oscillator, when the tube conducts, C1 discharges through the tube. The discharge intervals give the fast downsweep to the sawtooth waves.

How the trapezoidal wave is formed

To cause a beam to be swept in a sawtooth pattern, a trapezoidal, not a sawtooth voltage wave, must be impressed across the deflec-

tion coils. This is necessary because we want a sawtooth current in the deflection coils. (A sawtooth current will produce the sawtooth magnetic field which moves the beam). Because of the inductive reactance in the deflection coils, the impressed voltage must be trapezoidal in shape to produce the desired sawtooth current. However,
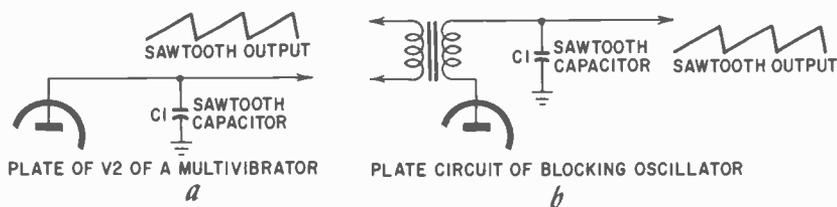
Fig. 1112. *Forming a sawtooth voltage in the output circuit of a relaxation oscillator. C1 is the sawtooth-forming capacitor in both the multivibrator (a) and the blocking oscillator (b).*

the vertical and horizontal deflection coils have different reactances, because of the difference in horizontal and vertical sweep frequencies. Therefore, the trapezoidal voltage applied to the vertical coils is shaped differently from that applied to horizontal deflection coils. The principle used to shape the deflection voltage is the same, however.

The arrangement used to form a trapezoidal wave is called a *peaking circuit*. It consists of a sawtooth-forming capacitor in series with a peaking resistor. The resistor sets a voltage point from which the capacitor charge begins. This happens because a portion of the voltage develops across the resistor. The capacitor starts its charge from a higher voltage level than when the full voltage is across the capacitor alone. The voltage across the resistor accounts for the pedestal upon which a sawtooth sits; the greater the value of the resistor, the higher the pedestal. The whole story is shown in Fig. 1113.

Horizontal ringing coil

If you check the grid-voltage waveforms of a basic multivibrator (Fig. 1103), or blocking oscillator (Fig. 1109-a), you'll see that the grid voltage rises gradually as it reaches the grid cutoff level. The circuit works better if, instead of rising gradually, the grid voltage rises sharply as cutoff is approached. If this happens, the instant of triggering is more precise and better stability results.

To produce the desired sharp rise of grid voltage, a *ringing coil* is often used in a horizontal oscillator stage. The ringing coil consists of a parallel capacitor–slug-tuned coil combination (C256 and L250 in Fig. 1107). The pulses produced by the horizontal

oscillator through shock excitation cause the ringing coil to produce sine waves at the horizontal frequency. The sine waves are superimposed on the oscillator grid-voltage curve. This changes the shape of the discharge curve to where the grid-voltage rise is sharp, not gradual, near the grid cutoff point. This produces greater stability at the horizontal frequency.
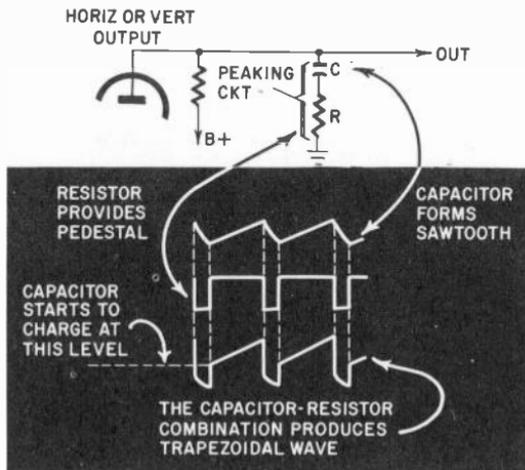
Fig. 1113. *Sawtooth-forming capacitor C in series with peaking resistor R shapes the trapezoidal voltage wave necessary to produce a sawtooth current for the deflection coils.*

How the vertical output section works

The trapezoidal voltage waveform produced in the output circuit of the vertical oscillator is intended for the vertical deflection coils. But the coils demand considerable current. (The larger the picture tube, the more current required by deflection coils. Wide-angle picture tubes, such as those with 110° deflection, demand still more). To supply voltage and current to the deflection coils, a vertical output tube is needed. Used as a power amplifier, it strengthens the trapezoidal wave and feeds it to a vertical output transformer. See Fig. 1114.

The primary winding of vertical output transformer L1 has a high impedance to match the plate circuit of the vertical output tube; secondary L2 has few turns (heavy wire) to match the low impedance of the vertical deflection coils. Instead of the two-winding type of vertical output transformer, an autotransformer can be used. In this case, the full winding is connected across the plate circuit of the vertical output tube and a tapoff connects to the vertical deflection coils. You'll find both types used extensively in sets of recent manufacture. And, as you undoubtedly know, the vertical deflection coils are to be found in the deflection yoke that fits around the neck of the picture tube. In the yoke, the

vertical deflection coils have horizontal deflection coils to keep them company.
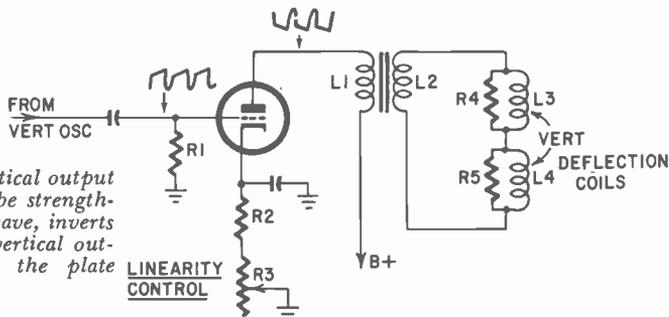
Fig. 1114. *Typical vertical output tube circuit. The tube strengthens the trapezoidal wave, inverts it and feeds it to a vertical output transformer in the plate circuit.*

The linearity control, R3, changes the point at which the tube operates on its characteristic curve to compensate for nonlinearity in the trapezoidal wave. Imperfections can exist in a circuit, and many may develop with time, but you want the best linearity possible to get a correctly proportioned picture.

Because the trapezoidal wave is a sharp one and loaded with power when it hits the vertical deflection coils, the wave can jolt the coils into oscillation. This is an undesirable condition known as ringing. To prevent this, damping resistors R4 and R5 are shunted across the vertical deflection coils.

Horizontal output stage

The horizontal output stage has the same function, with respect to the horizontal oscillator as has the vertical output stage with respect to the vertical oscillator. But the horizontal output stage does much more; it is also part of the high-voltage section.

Windup

A typical modern television set will have two relaxation oscillators. The vertical oscillator, operating at 60 pulses per second, may be a multivibrator or blocking oscillator. The horizontal oscillator, operating at 15,750 pulses per second, may also be either. Multivibrators can be plate- or cathode-coupled.

Sawtooth waves are formed in the output plate circuit by connecting a capacitor from plate to ground. Add a resistor in series with the capacitor and you get a trapezoidal wave. Trapezoidal waves are amplified by output tubes (vertical and horizontal) to produce the required trapezoidal voltage for the deflection coils. As a result, horizontal sawtooth currents and vertical sawtooth currents are produced.

QUESTIONS

1. Describe the formation of a trapezoidal waveform.

2. Where, in the vertical circuits, would you expect to find the vertical hold control? The vertical gain control?

3. From what circuit does the vertical oscillator receive its triggering pulses?

4. Why is a vertical power output tube necessary?

5. What types of oscillators are used in the sweep sections?

6. How is the horizontal oscillator frequency controlled?

7. What is a free-running frequency?

8. What type of deflection is used in television receivers? In oscilloscopes?

9. What component is used to help in the formation of a sawtooth voltage?

10. Why is a sawtooth current required in the deflection coils?

12

HORIZONTAL OUTPUT
AND HIGH VOLTAGE SUPPLY

● ●

YOU'RE absolutely right if you think the horizontal output stage could have been explained in the preceding chapter. However, we've decided to talk about the horizontal output stage combined with the high voltage supply for these reasons: First, the horizontal output stage is intimately involved with the production of high voltage for the picture tube. Second, the horizontal output stage moves the scanning beam in a very special manner, and this requires a special explanation.

In the first chapter, you learned that you see a picture traced by one spot of light when you watch tv. In this chapter, we want to tell you about the forces that push the spot so that it traces a horizontal line on your screen. These forces are: 1) Sawtooth magnetic energy, produced in the horizontal output transformer and fed to the horizontal deflection coils. *But, this energy does only part of the job.* 2) Oscillation developed in the horizontal deflection coils, through shock excitation. To stop oscillation at the proper time, a damper tube is used.

Confusing? Well, we learn more easily when we have something to visualize. So, to help you see the way the spot is moved horizontally, we're going to use an analogy involving a baseball and some baseball players.

Imagine that you are watching the scene shown in Fig. 1201. The baseball, which travels horizontally with respect to your viewing point, represents the spot on your tv screen which also travels horizontally to trace lines. (You don't actually see the spot because it moves too fast, but a moving spot is at work nevertheless.)

165

Next, we have the forces represented by our ball players. (After giving each player's name, we'll mention, in parentheses, the force or circuit he symbolizes.) To the left of center is that fielding great, Dizzy Damper (damper tube) wearing his faithful fielding glove. At center, meet Horace Zontal Output (horizontal output circuit) choking up on the bat in bunting position. At the right, we find Slugging Ozzie Lation (oscillation), his bat poised in readiness. Now, let's see what the boys are up to.

During training season, our stars of the diamond rigged up a special practice set-up. Observe the positions of our heroes. Dizzy Damper is a few paces from the wall, Ozzie Lation, in his familiar stance, is at the right, and old Horace Zontal Output is in the center, champing at the bit.

Now for action!

Horace bunts the ball toward Ozzie. Ozzie swats the ball to the wall. A dreaded slugger, Ozzie hits the ball so hard that it would bounce back (over Ozzie's head) into right field if it weren't slowed down. So, to slow the ball down, Dizzy Damper touches the ball with his glove. The ball, after bouncing off the wall, has just enough force to reach old Horace Zontal Output who again bunts the ball back to Ozzie.

Let's review the exciting action! Horace bunts the ball, Ozzie swats it back to the wall, and after the ball bounces off the wall, Dizzy touches the ball with his glove to slow it down so Horace can bunt it again.

Our ball players seem to be indulging in a lot of foolishness, but they want to show you how the beam is affected by the horizontal output system. Now, let's tie in the antics of our ball players with horizontal beam deflection.

You might think that a sawtooth wave from the horizontal output tube, by sending a sawtooth current directly through the horizontal deflection yoke, would move the beam completely from one side of the screen to the other. Not so. Actually, the sawtooth current from the horizontal output tube moves the beam across the second half (approximately) of the screen. (Remember our ball players — Horace Z. Output was stationed in the center). When the beam reaches the side of the screen, the sawtooth wave collapses. This is the fast retrace period when the beam streaks back to the opposite side of the screen. The sudden collapse of the sawtooth wave pushes the beam back, but the beam is pushed back even faster by the effects of oscillation in the yoke. (Our friend Ozzie Lation represented this effect in our baseball story).
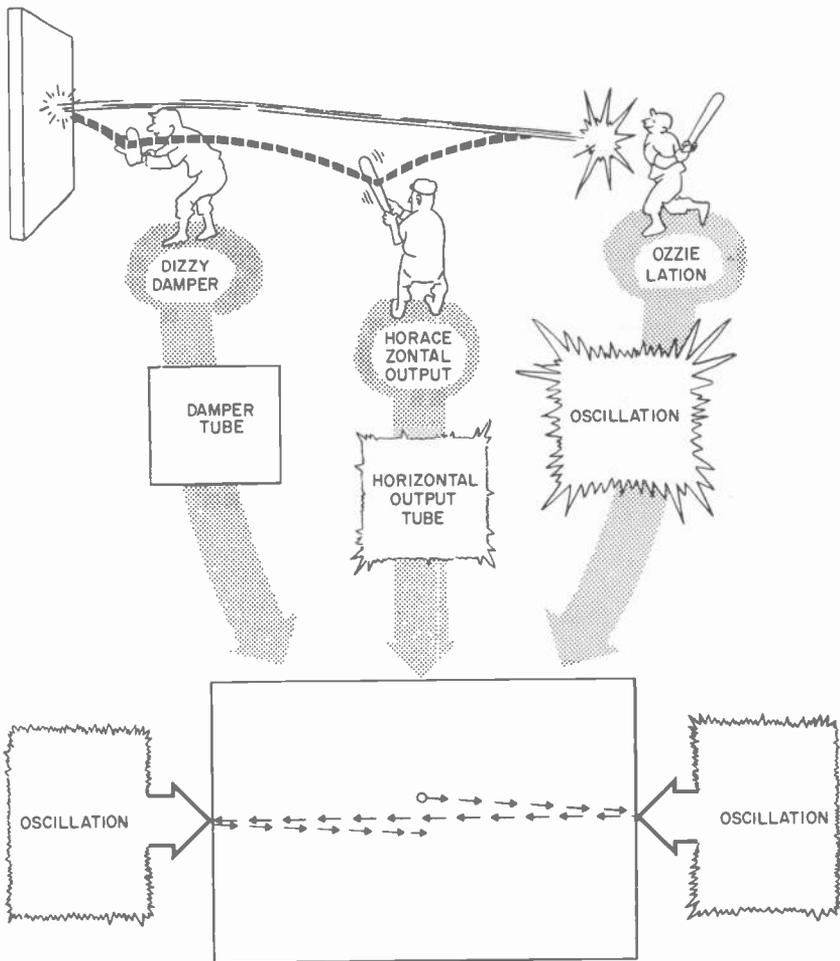
Fig. 1201. *Analogy to show how the electron beam is moved horizontally across across the CRT face.*

The sudden collapse of the sawtooth shocks the horizontal deflection coils into oscillation which pushes the beam back in just 7 microseconds. We want this oscillation and we make good use of it. The horizontal deflection coil is designed with a resonant frequency of 70 kc with the beneficial effects of oscillation, during retrace, in mind. Furthermore, the oscillatory action in the deflection yoke bounces the beam in a forward direction after retrace.

But we can have too much of a good thing. If given a chance,

167

the oscillatory effect would cause undesirable ringing — a high-frequency wave superimposed on the sawtooth. To prevent this, a damper tube is used. (In our analogy, old Dizzy Damper played the part of the damper tube). Because (during the trace period) the damper plate is positive with respect to its cathode, it conducts to load the circuit and damp any oscillation. The beam has just enough forward force to reach the center of the screen when along comes another horizontal drive pulse. The new horizontal pulse pushes the beam to the right side of the screen again when the sawtooth collapses, and the retrace and scanning process repeats.

How the autotransformer works

The transformer shown in Fig. 1202 is used for purposes of explanation only. The horizontal output autotransformer found in most receivers uses the same principles as the unit illustrated, but is tapped differently.

Our sample autotransformer (Fig. 1202) consists of one continu-
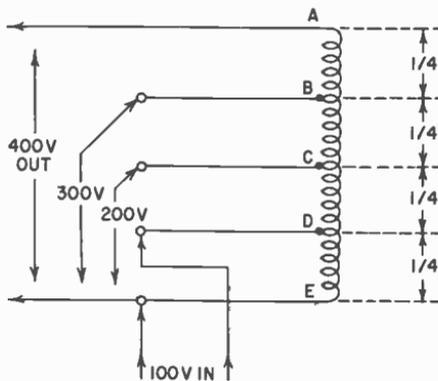
Fig. 1202. *Basic autotransformer principle.*

ous winding on an iron core. The winding is tapped along its length to divide the coil into four equal segments. The lowest segment is designated as D — E, the next higher segment as D — C, etc. Of course, we can also talk about larger segments. For example, A – C would refer to the upper half of the autotransformer, C – E to the lower half and A – E to the entire winding.

Although much higher voltages are used in the horizontal output stage, we'll use lower voltages and round numbers for simplicity in this explanation. Let's assume that 100 volts (ac) is fed into the lowest quarter segment, D – E. If so, 200 volts could be tapped off segment C — E because a 1-to-2 ratio exists. (Wind-

ing C — E is twice winding D — E.) From segment B — E we could get 300 volts. (B — E is three times D — E). From the entire winding A — E, we could have 400 volts because a 1-to-4 stepup ratio exists. Conversely, an autotransformer can be used to step down voltages. With say, 100 volts fed to the entire winding A — E, 25 volts could be tapped off D — E, 50 off C — E and 75 off B — E.

To tap from a segment to feed into a load, the load impedance should match the segment impedance for best power transfer.

As you'll see when you study the circuit details, various taps on the horizontal output autotransformer are used to step up voltages and transfer energy with correct impedance matching.
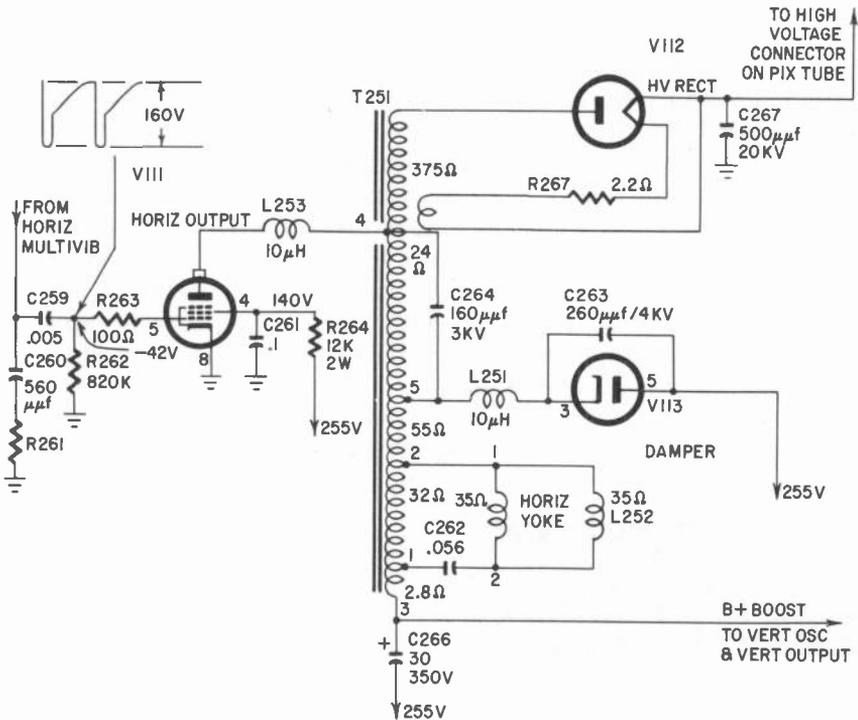
Fig. 1203. *Horizontal sweep output and high-voltage rectifier stages.*

Horizontal output circuit

So far, we have talked about the forces that push the beam horizontally but have said nothing about the circuits that do the pushing. Let's examine a horizontal output and high-voltage section in Fig. 1203.

In the output circuit of the horizontal multivibrator, the trape-

zoidal wave is formed by C260 and R261. You can see the shape of the wave in the diagram, with an arrow showing the point where the wave appears.

This voltage, applied to the grid-leak-biased horizontal-output tube, produces a sawtooth current in its plate circuit. The sawtooth is fed to tap 4 on the autotransformer.

Now look at taps 1 and 2 on the autotransformer. Note that the horizontal deflection coils are fed from these taps. The sawtooth current flows through the horizontal deflection yoke to sweep the beam during the scanning of the second half of each line. When the sawtooth current collapses, the deflection coils are shocked into oscillation. The oscillation (at 70 kc) helps sweep the beam back in the 7 microsecond retrace time.

Let's think back for a moment: During the sweep period, current flows in one direction through the deflection coils. Let's call this the trace direction of current flow. During retrace, the current reverses and flows in the opposite direction. Let's call this the fast retrace direction of current flow. Now, after the sawtooth retrace current is no longer present *because of oscillation,* the current bounces back to the trace direction again. When it does, the damper-tube plate is positive with respect to its cathode and the tube conducts. This puts a load on the autotransformer and damps oscillation after the beam has swept about half a line in the trace direction.

A quick glance at Fig. 1204 shows that the damper-tube current tapers off nonlinearly after tracing the first half of a line. Current from the horizontal-output tube starts in a nonlinear fashion.
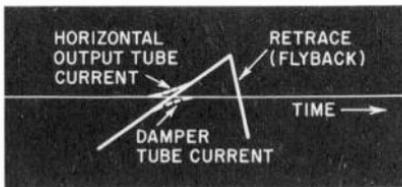
Fig. 1204. *The tapering of damper-tube current and gradual increase of horizontal amplifier current combine to produce a linear trace.*

The two waves combine, nullify each other's nonlinearity and, consequently, a linear trace is produced, as seen in the diagram.

The damper tube is inoperative during retrace because its plate is negative with respect to its cathode. Also, note the step-down ratio between the horizontal output (at tap 4) (Fig. 1203) and the deflection-coil connected between taps 1 and 2. The tap points on the horizontal output transformer are carefully chosen so that we get an impedance match between the transformer and

the horizontal deflection coils in the yoke. Also significant is the fact that a stepup relationship exists between the deflection coil
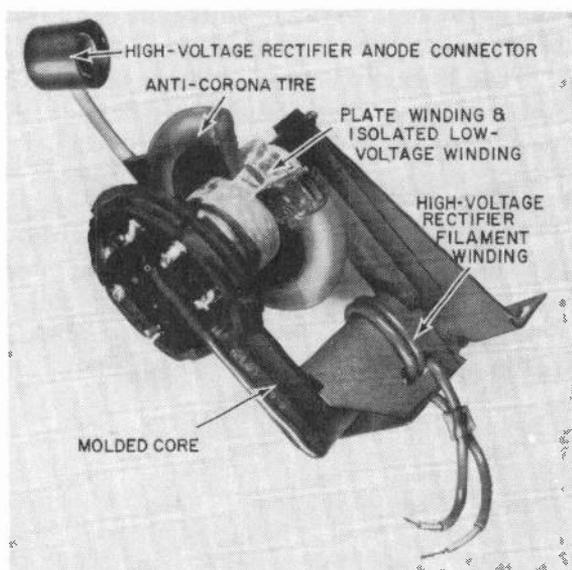
Fig. 1205. *Part of horizontal output transformer has been cut away to show construction.*

and the horizontal output winding. This means you get a greatly increased voltage back at the plate of the horizontal-output tube when current flows in the retrace direction. This is why, with a screwdriver, you can draw a high-voltage arc off the horizontal output tube-plate cap. The stepup ratio during retrace is the method used for obtaining high voltage for the picture tube.

Horizontal-output transformers, called "flyback transformers" by those who want to stress the high-voltage-producing qualities, come in various shapes and sizes. Fig. 1205 shows the construction of a horizontal output transformer while Fig. 1206 shows schematics and photos of both the isolation and autotransformer types.

Isolation or two-winding horizontal output transformer

Older sets used horizontal output transformers which had a secondary winding feeding the horizontal deflection coils (Fig. 1206-a). The circuit works according to the principles given earlier in the discussion of the autotransformer horizontal output circuit, except that the damper-tube connections are reversed. This is necessary because an isolated secondary reverses the phase of the voltage fed back to the primary.

171

Horizontal linearity control

In recent years, receivers have been designed so as not to require a horizontal linearity control. When used, the linearity control is usually in the form of a variable inductance in series with the damper tube, either in the cathode or plate circuit. Changing the inductance of the linearity control compensates for nonlinearity caused by imperfections when the damper current drops off and horizontal sweep current begins.

Horizontal width control

In Fig. 1207, the horizontal width control is shown shunting a portion of the horizontal output transformer secondary. By changing the inductance of the width-control coil, you change the deflection voltage swing fed to the horizontal deflection coils. In this way, the width of the picture is adjusted.
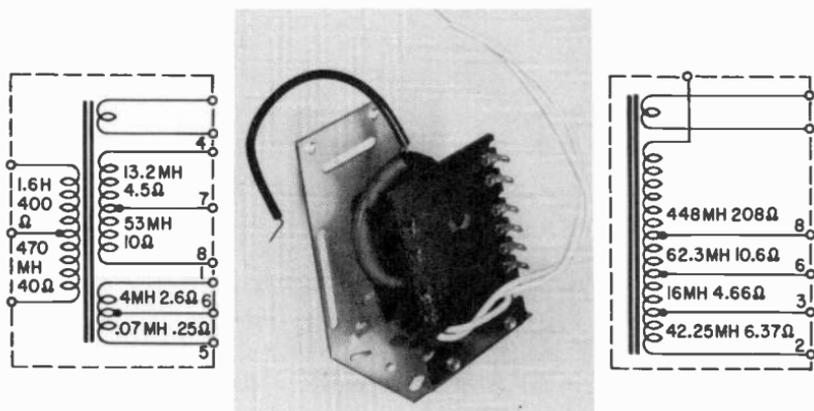
Fig. 1206. *Isolation and autotransformer types of horizontal output transformer.*

Horizontal deflection-coil shunting capacitor

To prevent nonlinearity at the left side of the picture, a capacitor is shunted across one of the horizontal deflection-coil windings. This capacitor compensates for distributed capacitance by equalizing the capacitance across both coils. (Fig. 1207).

Boost B-plus

The damper tube, busily doing its job damping oscillation during retrace, produces a byproduct which consists of a positive

voltage. This adds to the B-plus voltage produced by the low-voltage power supply. The additional voltage is called "boost B-plus." (Some manufacturers like the term "bootstrap voltage" and others label their boost B-plus as "B++").

A look at Fig. 1203 shows a damper tube in the horizontal output and high-voltage power supply section. When the damper
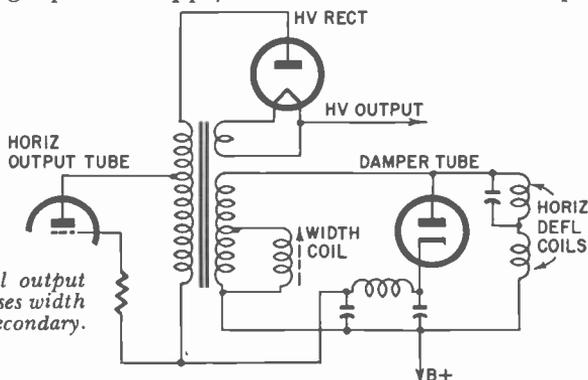
Fig. 1207. *Horizontal output transformer circuit uses width coil across tapped secondary.*

tube conducts, current flows through it, charging C266 to the polarity shown in the diagram. At the negative terminal of C266, the positive voltage is fed from the low-voltage power supply. Capacitor C266 acts as though it were a battery in series with the low-voltage supply. Therefore, the voltage across C266 *adds* to the 255 volts (from the low-voltage supply) to give a higher plus voltage . . . . . the boost B-plus.

In this circuit, boost B-plus is supplied to the vertical oscillator, vertical output and horizontal output plates. (The horizontal output plate is fed through the autotransformer). Some manufacturers feed boost B-plus to the audio output stage.

How the high-voltage power supply works

The high-voltage power supply is discussed here rather than in Chapter 14 (power supplies) because the high-voltage power supply is a part of the horizontal output system. The flyback type of high-voltage supply is used in all modern television receivers because the horizontal retrace energy (when the beam "flies back") supplies the high voltage. The best efficiency, economy and safety result.

In the discussion of "How the autotransformer works" you learned that an autotransformer is a continuous winding on an iron core. When you feed ac across a pair of taps on the winding (into a small number of turns), you can take the stepped-up voltage from a larger segment.

In the horizontal output transformer shown in Fig. 1203, the sudden collapse of the horizontal sawtooth current in the horizontal deflection coils causes current to flow back in the 1-to-2 ratio taps on the autotransformer. This flyback pulse is increased to about 14,000 volts over the full length of the autotransformer. The high-voltage rectifier diode rectifies the high-voltage pulses. Because the frequency is so high (15,750 pulses per second) very little filtering is needed. In fact, the capacitance between the aquadag coating in the picture tube and ground is enough to provide filtering action in most receivers. However, many receivers use a 500-μμf capacitor between the filament of the high-voltage rectifier tube and ground. Sometimes a 1-megohm filter resistor is used in series with the high-voltage lead.

Filament voltage for the high-voltage rectifier is obtained by a winding that couples inductively to the autotransformer. Just a little ac is picked up by the winding — enough to light the rectifier-tube filament. To prevent the filament from drawing too much current, 2.2-ohm resistor R267 is connected in series with the filament lead.

A matter of degree

Consider this question: "What is the difference between a 14,000-volt power supply in a television set and a 14,000-volt power supply in a transmitter?"

The answer lies in the amount of current each can furnish. The transmitter power supply produces current in the order of amperes and the television receiver power supply less than a milliampere. The transmitter power supply is very large and extremely heavy. The 14,000 volts in a transmitter is also dangerous because (since Ohm's law has never been repealed) the resistance of the human body determines the amount of current drawn if a person has the misfortune to contact a transmitter's high voltage. A transmitter power supply has plenty of current available.

If you accidentally touch the 14,000-volt lead in a television flyback supply, you'll most likely survive because dangerous amounts of current cannot be furnished by this type of power supply. Furthermore, the flyback power supply is deliberately designed to have poor regulation; good regulation is neither needed nor desirable. This means that the 14,000 volts will drop appreciably if you load it by touching the high-voltage lead. Nevertheless, certain people can suffer ill effects from exposure to

a television set's high voltage, and it is advisable to take precautions against accidental contact.

In the early days of television, non-flyback 60-cycle high-voltage power supplies were used. These conventional power supplies, with high-voltage power transformers, were very dangerous. This type of power supply is not used in modern sets but may be found in some "ancient" receivers.

Another type, the rf power supply, has been used in the past in small-screen sets. It has an oscillator that generates rf which is fed to the primary of an air-core transformer. The high-voltage rectifier-tube plate is connected to a secondary winding; the filament connects to another secondary winding. High voltage is taken from the filament and filtered by a pi-type capacitor-and-resistor network. Neither details nor diagram on non-flyback high-voltage supplies are given here because they are rarely, if ever, used today.

Voltage doublers and triplers in the high-voltage power supply have also had their share of popularity, but the standard flyback supply described earlier is the type now used universally. They are economical and work well.

Windup

An integral part of the high-voltage system, the horizontal output transformer receives the 15,750-pps trapezoidal pulse train from the horizontal output tube. Through ingenious circuit design, each trapezoidal wave causes a sawtooth magnetic field to push the beam across the second half of the screen. Oscillation in the horizontal output (flyback) transformer causes the beam to be retraced quickly. Oscillation continues to affect the beam by pushing it to about half the forward trace distance. Then, the oscillation is suppressed by the damper tube, and a new horizontal output trapezoidal wave again pushes the beam across the second half of the screen. The damper tube also serves to develop boost B-plus voltage.

A tremendous stepup in voltage is realized during retrace (flyback) when the horizontal sawtooth current collapses. The high voltage that develops across the full winding of the horizontal output autotransformer is rectified and fed to the high-voltage connector on the picture tube.

With high-voltage on the picture-tube high-voltage anode, with a video signal fed to the picture-tube cathode, and with the beam properly swept, we should see a picture.

QUESTIONS

1. What is an autotransformer?

2. How is correct impedance matching accomplished with an autotransformer?

3. How does the horizontal output tube get its plate voltage?

4. What components are used to help in the formation of a trapezoidal wave?

5. Why is it necessary for a trapezoidal current to flow through the deflection coils?

6. How does the high-voltage rectifier tube get its filament voltage?

7. Why is a relatively small amount of capacitance adequate as a high-voltage filter?

8. Does the high-voltage power supply have good regulation? What is one advantage of poor regulation?

9. Describe the operation of the horizontal width control. The horizontal linearity control.

10. What is the function of the capacitor shunted across one winding of the horizontal deflection coils?

11. What is boost B plus? How is it obtained? What circuit or circuits use this voltage?

12. Describe the method used for obtaining high voltage?

13. What is a damper tube? Why is it used? How does it work?

14. How does aquadag act as a filter capacitor?

15. Approximately, what amount of current is available in the high voltage supply?

13

HOW THE SOUND SECTION WORKS

● ●

TRY this simple experiment. Turn on a radio and turn up the volume. Hold a piece a paper several inches from the speaker, as in Fig. 1301. With your fingertips, can you feel the paper vibrate?

Here is what happens when you do this. The speaker cone travels back and forth to produce sound. To do so, the cone must
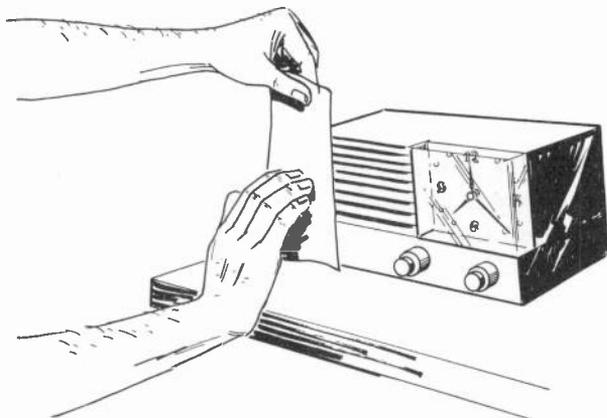
Fig. 1301. *The paper vibrates according to the sound pattern. Fingertips, touching paper lightly, can feel vibrations.*

move the air. Sound, therefore, results from motion of air. Not only can you feel the sheet of paper move but you can actually *see* it move if you turn the volume to maximum.

When the speaker cone produces sound, the motion of the cone

177

1000 CPS AUDIO OSCILLATOR

AMPLIFIER

SPEAKER

A 1000 CPS SINE WAVE TONE MAKES THE PAPER MOVE BACK AND FORTH IN THIS MANNER 1000 TIMES PER SECOND
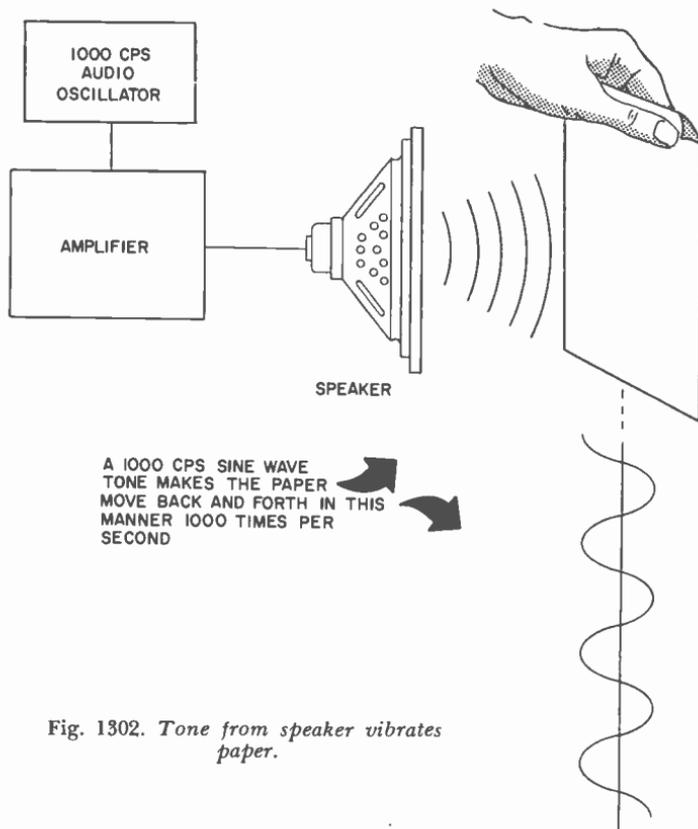
Fig. 1302. *Tone from speaker vibrates paper.*

follows a complex sound pattern. Your sheet of paper moves in sympathy; the paper vibrates in the same way as the speaker cone. To simplify our discussion of sound however, let's talk about simple tones, such as the 1,000-cycle tone produced by an audio oscillator. When this tone is amplified and fed to the speaker, the air is moved back and forth 1,000 times per second. Fig. 1302 shows how a sheet of paper will move when held in front of a 1,000-cycle tone source.

What is audio modulation?

Look closely at a sound recording. The wiggly groove was made by a cutting stylus that vibrated according to the sound pattern picked up by the recording microphone. Now let's shift our attention to a simple means of mechanically transmitting sound over a string. In Fig. 1303, two hobbyists are using a home-made telephone. The device, consisting of two tin cans connected by string

isn't very practical but it does work and it also illustrates a principle. The bottom of each can is perforated for a string that is knotted on the inside of the can and pulled tight.

The speaker's voice vibrates the circular bottom of the can according to the sound pattern of his voice. Because the string is tight, it vibrates in unison. In turn, the string causes the bottom of the listener's cup to vibrate according to the sound pattern and thereby reproduces the sound. We might say that the string is *audio-modulated.* We might also say that the groove in the record was *audio-modulated.*

When you speak over a telephone, you vibrate a diaphragm according to the sound pattern of your voice. This causes a voltage
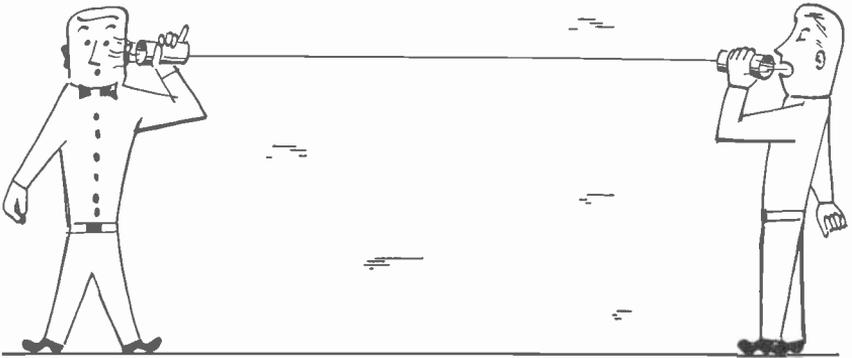
Fig. 1303. *Simple string telephone shows how vibrations are carried from speaker to listener. In an analogy, string might be considered* modulated.

to vary in strength in the same pattern. At the receiving end, a diaphragm in the earpiece vibrates, and your speech is reproduced. You *change* or *modulate* the voltage when you speak over the telephone.

When you modulate a transmitting medium (such as the voltage in the telephone line), you change it in a definite way. In AM broadcasting, the *amplitude* of an rf carrier is audio-modulated. This means that the strength of the rf carrier is changed according to the sound energy. But the carrier can be modulated in a different manner. By *changing its frequency* according to the sound pattern, the carrier is *frequency-modulated.* This is the method used in television for transmitting sound.

Frequency modulation

The idea of frequency modulation (FM) is a little harder to grasp than that of amplitude modulation because there's less

179

to visualize. However, we'll compare the frequency modulation of a carrier with the modulation of a telephone voltage to clarify the FM principle.

Earlier, we spoke of sound patterns. These are complex; simple one-frequency tones are not ordinarily transmitted. However, it's much easier to explain frequency modulation using a single tone as an example. Once you understand the principle behind single-tone frequency modulation, you will understand how a complex sound pattern can also frequency-modulate a carrier.

In Fig. 1302, we show a 1,000-cycle sine-wave tone. This tone can convey information in two ways — frequency and loudness. The height of each sine wave shows its strength. A loud tone has a top and bottom that extends more; a low-volume tone has a lower amplitude. The frequency or pitch is conveyed by the number of sine waves per second. The diagram doesn't show this, but a 1,000-cycle tone would contain 1,000 back-and-forth swings of voltage each second. If this 1,000-cycle voltage were sent over a telephone line, the earpiece at the receiving end would move back and forth 1,000 times a second to reproduce the tone. Now let's see how a carrier can convey sound information by frequency modulation.

To transmit sound by frequency modulation, the frequency of the carrier is varied above and below a center frequency. To transmit a 1,000-cycle tone, the frequency will swing above and below the center frequency 1,000 times a second.

Don't confuse the frequency of sound with the frequency of the sound carrier. The center rf sound-carrier frequency for each television channel has been assigned by the FCC. For example, the sound-carrier frequency of channel 2 sound is 59.75 mc. Channel 3 sound is at 61.25 mc; channel 4 at 67.25 mc, etc. These are *center frequencies*. When channel 2 is modulated, its 59.75-mc center frequency varies above and below 59.75 mc. *The number of times a second* the carrier swings above and below center is the audio frequency — the sound that accompanies the picture. If a 1000-cycle tone is broadcast, the 59.75 mc of channel 2 sound center frequency swings above and below 59.75 mc. When no sound is broadcast, the channel 2 sound carrier returns to rest at 59.75 mc. The swing above and below the center frequency is called *deviation*.

The loudness of the sound is conveyed by *how far* the center frequency deviates. The maximum deviation allowed by the FCC is 25 kc above and below center. (This is usually written as ±25

kc). This amount of deviation is also regarded as 100% modulation. For quieter sound, the frequency deviates less.

Let's return for the moment to the subject of the center frequency. The tuner changes any frequency received to the so-called video intermediate frequency (and we know that the video if includes sound). In most modern intercarrier receivers, the tuner changes the center sound frequency of any tuned-in channel to 41.25 mc. Therefore, throughout the video if stages of the receiver, 41.25 mc is the center sound frequency.

When the sound reaches the video detector, the sound and video carriers are heterodyned. Because sound and video are separated by 4.5 mc, a 4.5-mc sound beat frequency is produced. Therefore, the center sound frequency becomes 4.5 mc. As you can see, the center sound frequency for any given channel will exist in three forms. On the air it is the one assigned to the channel. After the tuner, the center frequency is 41.25 mc. After the detector, it is 4.5 mc. Next, the 4.5-mc frequency modulated if sound signal is fed to the sound if section, is amplified, converted to sound frequency voltages in a sound detector stage, amplified some more and then fed to a speaker.

Advantages of frequency modulation

The FM channel in a TV set or in an FM receiver produces sound that is relatively free of noise caused by static, ignition and similar forms of interference. Such interference modulates the *amplitude* — not the frequency — of the carrier. Static, ignition, noise, etc., do not change the carrier frequency. There is nothing about an FM signal that discourages AM noise; static amplitude-modulates an FM carrier as it does any other type of carrier. We realize the AM noise-elimination advantage in the receiver. FM receiver circuits are designed to respond only to changes in frequency, not to changes in amplitude. Although AM interference is present in the FM signal, the FM receiver refuses to recognize AM of any kind and produces sound only in response to changes in frequency.

In television, because the FM channel does not respond to amplitude modulation, the use of FM sound prevents AM interference from the AM video signal.

The width of a carrier, whether AM or FM, is determined by sidebands[1] created by the frequency of the audio signal that modulates the carrier. The higher the audio frequency, the wider the

[1] The sideband frequency is the carrier frequency plus (and minus) the audio frequency.

bandwidth needed to accommodate the modulated carrier. The FM carrier is allowed to deviate ±25 kc to transmit the loudest sound signals. This band space would accommodate five AM broadcast transmitters with a maximum modulating frequency of 5 kc each.

Sound takeoff

In every television receiver, ancient or modern, there's a place in the circuit where the sound signal must be separated from the picture signal. In early split-sound receivers, the sound was removed in the tuner or a stage later in the video if section. In modern intercarrier-type receivers, the 4.5-mc sound signal is sometimes removed in the video detector but more usually in the video amplifier stage.

The 4.5-mc sound if amplifier

After the 4.5-mc sound signal is picked off the composite video signal, it is amplified in a 4.5 mc sound if amplifier. In older sets that used a discriminator as an FM sound detector, it was necessary to provide limiting as well as amplification. The limiter served to put an end to any amplitude modulation that may have been in the FM signal. Limiting is not essential with either the ratio or gated-beam detectors. For this reason, limiters are not often used in the sound if section, but sometimes a manufacturer will include a limiter in the circuit anyway because an audio if amplifier can also function as a limiter. Primarily however, the 4.5-mc sound if amplifier serves to raise the level of the 4.5-mc FM signal and reject frequencies outside the FM if band.
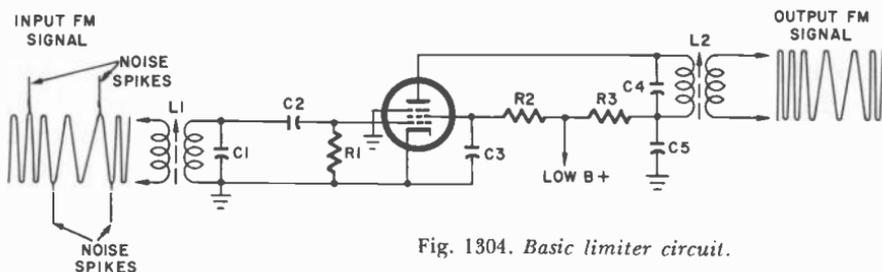
Fig. 1304. *Basic limiter circuit.*

Limiter

A limiter is a circuit that prevents the amplitude of a signal from rising above a predetermined level. Because noise and sync-pulse interference are in the form of amplitude modulation, the limiter slices these forms of interference.

When you examine Fig. 1304, you know you're looking at a limiter because grid-leak bias is used and the plate voltage is low.

The input FM signal, complete with wanted frequency variations and unwanted noise spikes, is fed to input tuned circuit L1 and C1. Because C2 and R1 are a grid-leak-bias circuit, the input signal establishes its own bias. The discharge of C2 through R1, between cycles, makes the top of R1 negative with respect to ground. This form of bias is also called signal bias because the strength of the signal determines the negative grid voltage. The bias circuit, therefore, is self-adjusting; the correct limiting level is maintained for signals which differ in strength.

In a normal amplifier, as you increase the amplitude of the signal fed to the control grid, you increase the amplitude of the output signal in the plate circuit. This is good if the amplifier is supposed to amplify. It will have a high plate voltage because this voltage determines, in part, the plate saturation point. Saturation refers to the plate-voltage level when the tube no longer amplifies a signal. The higher the plate voltage, the more amplification possible before saturation.

A limiter, however, is a special type of amplifier; its purpose is *not* to amplify an increase in signal amplitude in its grid circuit. For this reason, the plate voltage is held to a level that results in plate saturation if the signal at the grid rises in amplitude. A clean FM signal is fed from the C4–L2 tuned output circuit.

FM detector

The FM detector changes a frequency-modulated signal to an audio signal. The signal is then amplified and fed to the speaker.

In this study of TV circuitry, we're interested in three detector types — the discriminator, ratio detector and gated-beam detector.

Whenever electronics men talk about FM detectors, the conversation ultimately turns to phase, phase differences and vector diagrams. So let us consider phase and vectors before sailing into our study of FM detectors.

Phase and vectors

Our scene is anywhere during Spring. As a warm, gentle sun shines through a clearing in the park, we find our hero, Hector. A happy hobbyist, Hector likes to fly his gasoline-driven model airplanes. Because he's a kindly character, Hector agreed to pose for us so we can use an analogy to explain phase relationships.

As you can see in Fig. 1305, both of Hector's planes are attached to guide wires so they won't get away. With this arrangement each plane flies in a circle. Now suppose we are interested in the amount of time it takes for each of Hector's planes to fly a complete circle.

183
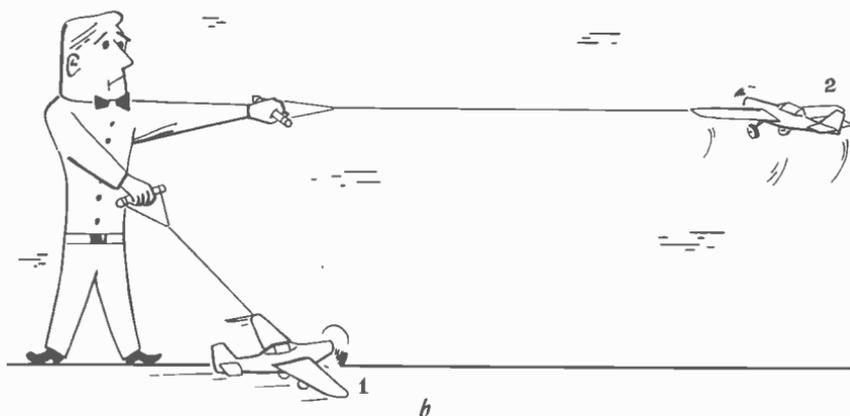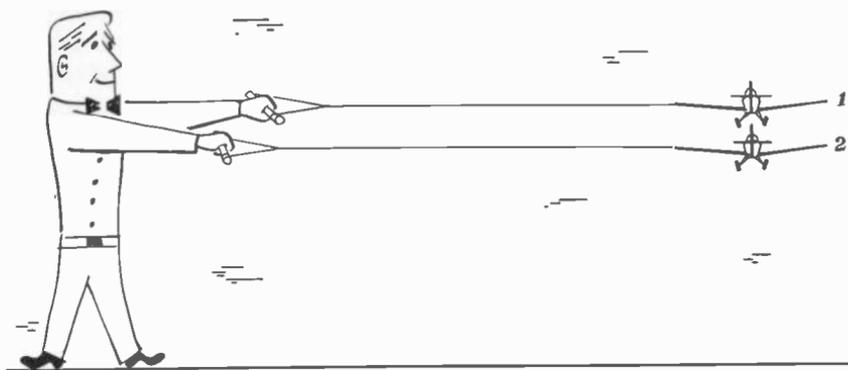
Fig. 1305. *Control-line airplanes are used in this analogy of in-phase (a), 90°
(b) and 180° phase shift (c).*

One way we can measure this time is in minutes; another way is
in degrees. These aren't novel or unusual techniques; look at
your wrist watch and you'll see that both hands travel in circles,
as do Hector's planes. When the minute hand travels from 12 to
3, we say it is "quarter past". Hector likes to state the time period
covered by each of his planes in degrees.

AMOUNT
OF PLANE I
FORCE

RESULTANT
FORCE

PLANE 2

AMOUNT OF
PLANE 2
FORCE

PLANES I&2 IN QUADRATURE,
EACH PLANE EXERTS SAME FORCE

a

RESULTANT
FORCE

AMOUNT
OF PLANE I
FORCE

PLANE 2

AMOUNT OF
PLANE 2
FOR CE

PLANES I&2 IN QUADRATURE
PLANE I EXERTS MORE FORCE

b

AMOUNT OF
PLANE I
FORCE

RESULTANT
FORCE

PLANE 2

AMOUNT OF PLANE 2 FORCE
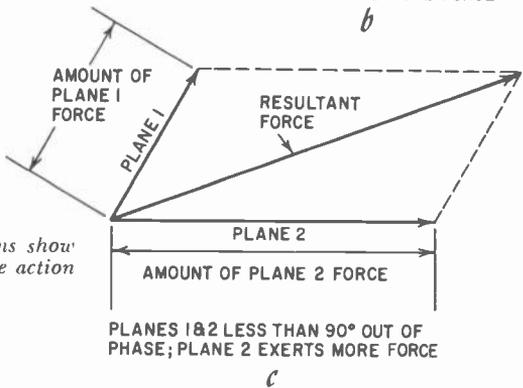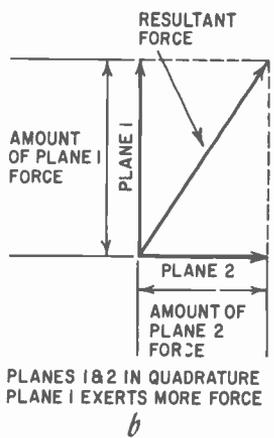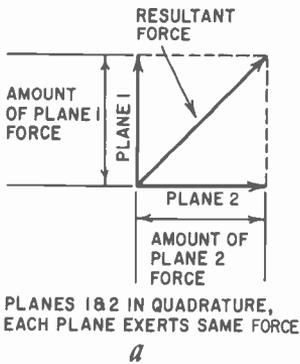
Fig. 1306. *Vector diagrams show the resulting forces of the action in Fig. 1305.*

PLANES I&2 LESS THAN 90° OUT OF
PHASE; PLANE 2 EXERTS MORE FORCE

c

Suppose both of Hector's planes traveled at the same speed and one plane was right underneath the other. We could say that both planes were *in phase* (Fig. 1305-a). Plane 2 would always be under plane 1 as both planes traveled the circular route. Next, let's think of other possibilities. Suppose both planes travel at the same speed but plane 2 is 90° (a quarter of a circle) ahead of plane 1. We could then say that the planes are *out of phase* with each other. If the speeds of the planes did not change, plane 2 would always lead plane 1 by 90°. When plane 2 is ahead by 90°, we say that plane 2 is in *quadrature* with plane 1 (Fig. 1305-b). The term quadrature is nothing more than a fancy way of saying 90° out of phase. You'll find the term bandied about later when you study the gated-beam FM detector.

Let's see what happens when Hector's planes fly at different speeds. Assume that plane 2 flies a little faster than plane 1. As both planes circle, plane 2 will lead plane 1 more and more. In Fig. 1305-b, plane 2 leads plane 1 by 90°. Because plane 2 will

continue to extend its lead, plane 2 will eventually lead by 350°. When it does, it will be right behind plane 1. Because plane 2 travels faster, planes 1 and 2 will soon be at the same point momentarily, after which plane 2 will again take the lead.

The speed of a plane can be compared to the frequency of an alternating voltage. Two alternating voltages of the same frequency could maintain a constant phase relationship. When two alternating voltages are different in frequency, their phase difference will change continuously. They will be in phase momentarily, after which the higher frequency will take the lead and continue to advance its lead.

We said a lot about the way the model planes travel, but we gave little thought to poor old Hector. He has to hold both wires, you know, and the planes exert a strong pull. Let's talk about this pulling force for a while. When plane 2 is directly under plane 1, both planes pull in the same direction. At this time, the force exerted by plane 1 *adds* to the force exerted by plane 2, and this puts quite a strain on Hector. Notice Hector struggle in Fig. 1305-a. Hector has to keep both feet firmly planted to keep from being pulled out of position by the combined, adding forces of the two planes.

If you wonder why Hector is confused in Fig. 1305-c, the reason is that the force exerted by plane 2 cancels the force exerted by plane 1. The planes are 180° out of phase. Hector still feels the pull of the planes, but the force yanking him out of position has been cancelled and so he has no trouble remaining in one spot. But what about Fig. 1305-b, where plane 2 is in quadrature with plane 1 ? What is the total force pulling on Hector? We can find this easily. The total force is called the *resultant* of two forces and we can find it by using a vector diagram.

Vector diagrams are shown in Fig. 1306. Assume that each plane has the same type of gasoline engine and, therefore, exerts equal pull, or *force*. Each line in the diagram, marked as plane 1 or plane 2, shows — not the length of guide wire — but the *amount of force* exerted by each plane. (The greater the force, the longer the line). To find the resultant force, we simply draw a parallelogram, as shown in dashed lines. The diagonal line from the center (of the imaginary circle that represents each plane's route) to the opposite corner of the parallelogram is the resultant force. Its length represents the resultant force exerted. If plane 1 has a more powerful engine than plane 2, but both planes are in quadrature, we get a resultant such as that shown in Fig. 1306-b.

If plane 2 has the more powerful engine and if the angle between the planes is less than 90°, the vector may resemble the one shown in Fig. 1306-c. As you can see, many combinations are possible. But the important fact is the manner in which we can find the resultant force.

The basic Foster-Seeley discriminator

During television's formative years, the Foster-Seeley discriminator was widely used as an FM detector. An FM sound signal is fed into the discriminator and an audio signal comes out. Today, you don't see any discriminators used as sound detectors because either the ratio detector or the gated-beam detector can be used more efficiently and economically. The discriminator has a disadvantage in that it responds to AM as well as FM signals. For this reason one or more additional limiting amplifiers must be used before the discriminator detector if the noise-squelching advantage is to be realized. But we cannot ignore the discriminator because discriminator theory is important — most horizontal afc systems are based on the discriminator circuit. Also, the basic principles of discriminator operation are used in the popular ratio detector. A good way to study the ratio detector is to have discriminator theory as background. Furthermore, variations of the discriminator are found throughout the field of electronics.

In the circuit shown in Fig. 1307, the output of the limiter is
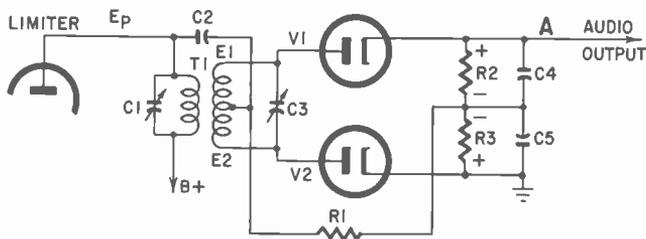
Fig. 1307. *Basic discriminator circuit used for the detection of FM signals.*

coupled to the discriminator input in two ways: (1) Inductive coupling — you tune both the primary and secondary of discriminator transformer T1 to the FM center frequency; (2) Capacitive coupling — capacitor C2 connects the plate of the limiter to the center tap of the discriminator transformer secondary.

A duo-diode is used as a discriminator tube (or two semiconductor diodes can be used). Resistors R2 and R3 are of equal value as are capacitors C4 and C5.

First, let's chase the electrons through each diode. Through V1, current flows from cathode to plate, through the upper half of the inductor portion of T1, through R1 and R2, finally getting back to the starting point or cathode of V1. Therefore, in Fig. 1307, the top of R2 is positive and the bottom negative, as shown.

Now for a look at the goings on within V2. Current flows from cathode to plate, through the lower half of the inductor section of T1, through R1 and R3. The polarity developed across R3 is shown in the diagram. If the currents through both diodes are equal, zero voltage exists between point A and ground because equal and opposite voltages develop across R2 and R3; the voltages cancel each other. If the current through V1 is greater, the voltage between point A and ground will be positive. Although the voltage drop across R3, negative with respect to ground, will cancel part of the total voltage, the positive voltage drop across R2 will be greater because the current flow through R2 is greater. Consequently, positive voltage will dominate at point A. The reverse condition will exist if V2 draws more current; the voltage between point A and ground will be negative. Therefore, as V1 and V2 alternately take the lead in drawing more current, an alternating voltage will be produced between point A and ground.

Now we come to the topic of phase relationships. For convenience in describing the voltages in the discriminator and how they relate to each other in phase, we'll use the abbreviation E_p for the FM signal voltage on the plate of the limiter. (The "p" stands for primary). Voltages are transferred from the limiter stage to the secondary of the discriminator transformer, T1, in two ways. Across the secondary we get electromagnetically induced voltages, E1 and E2. These two voltages are 180° out of phase and can easily be represented by a pair of lines going in opposite directions from a common center point. C2 transfers the signal capacitively, producing a voltage E_p at the secondary, in quadrature with E1 and E2. The voltage that appears on the plate of V1 is the *resultant* of E_p and E1 because these voltages are of different phase. As described earlier, you can measure a resultant voltage by drawing vector diagrams such as those in Fig. 1308. When you construct a parallelogram of force as shown in dashed lines in the vector diagram, the resultant is the diagonal line that slices the parallelogram in half.

In Fig. 1308 the length of each arrow represents a voltage level and the angles between the arrows are the phase angles (a phase

angle shows the phase difference between two alternating voltages). Now notice how the voltage levels of E1-a and E2-a (on the plates of V1 and V2) are affected by a change in the center frequency of the FM signal. Let's discuss three possible conditions: condition 1 — FM signal at center frequency; condition 2 — FM signal higher than center frequency; condition 3 — FM signal lower than center frequency.
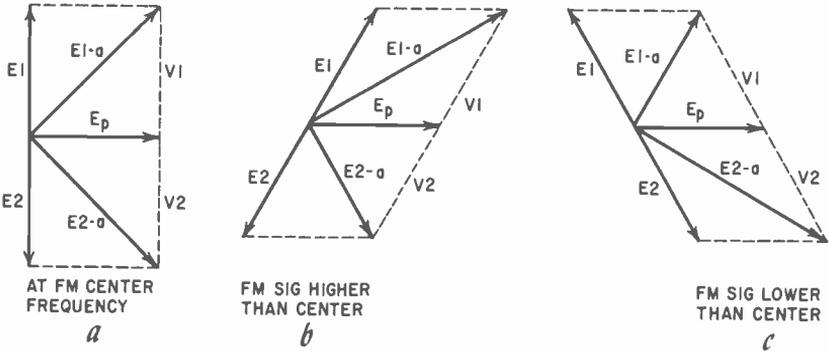
Fig. 1308. *Vector diagrams representing FM signal at center frequency (a), higher (b) and lower than carrier frequency (c).*

Condition 1: FM signal at center frequency. See Fig. 1308-a. The phase angle between E1 and E_p is 90°. We draw a parallelogram (a square in this instance). To find the resultant, we draw the diagonal E1-a.

The phase angle between E2 and E_p is also 90°. Again, we draw a parallelogram and the diagonal resultant.

As you can see in the vector diagram (Fig. 1308-a,) E1-a equals E2-a. Therefore, the voltage on the plate of V1 equals the voltage on the plate of V2.

Condition 2: FM signal higher than center frequency. See Fig. 1308-b. The phase angle between E1 and E_p is *less* than 90°. The phase angle between E2 and E_p is *more* than 90°. We draw parallelograms to find resultants. Notice that E1-a is longer than E2-a. Therefore, the voltage on the plate of V1 is *greater* than the voltage on the plate of V2.

Condition 3: FM signal lower than center frequency. See Fig. 1308-c. The phase angle between E1 and E_p is *more* than 90°. The phase angle between E2 and E_p is *less* than 90°. We draw parallelograms to find the resultants. Notice that E1-a is shorter than E2-a. Therefore, the voltage on the plate of V1 is *less* than the voltage on the plate of V2.

189
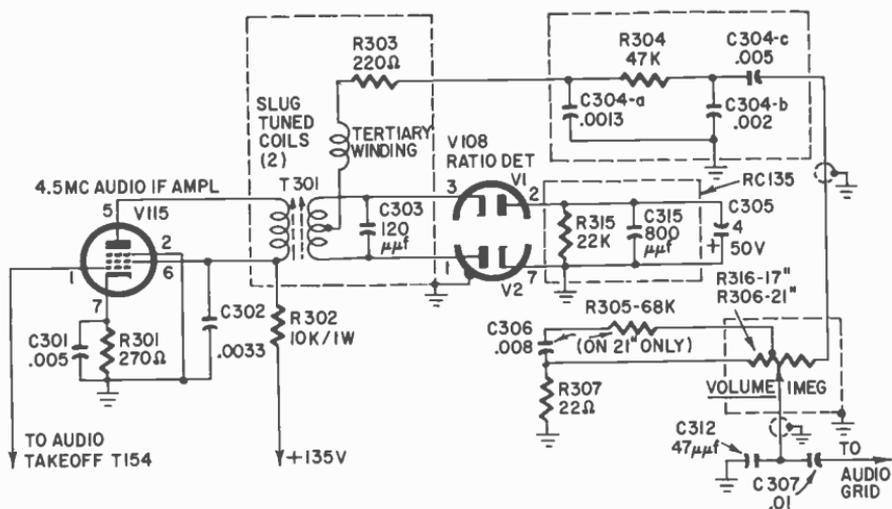
Fig. 1309. *Typical ratio-detector circuit.*

Now let's see how the voltage produced between point A and ground is changed. We'll return to our three possible conditions.

Condition 1: FM signal at center frequency. V1 and V2 each draw the same amount of current. Equal voltages of opposite polarities develop across R2 and R3. These voltages cancel to produce zero output between point A and ground.

Condition 2: Signal frequency higher. V1 draws more current than V2. The current through R2 is greater than the current through R3. With respect to point A and ground, the positive voltage across R2 is greater than the negative voltage across R3. The voltages add algebraically. Therefore, the total voltage between point A and ground is positive.

Condition 3: Signal frequency lower. V2 draws more current than V1. Current through R3 is greater than the current through R2. With respect to point A and ground, the negative voltage across R3 is greater than the positive voltage across R2. The voltages add algebraically. Therefore, the total voltage between point A and ground is *negative*.

Thus, an FM signal varying above and below center causes an alternating voltage to appear between point A and ground. This voltage swings positive and negative as the FM signal varies in frequency. Capacitors C4 and C5 eliminate rf. When the FM signal varies according to the complex sound pattern, the voltage between point A and ground varies above and below zero volts. This changing voltage is the audio voltage. If an earphone is con-
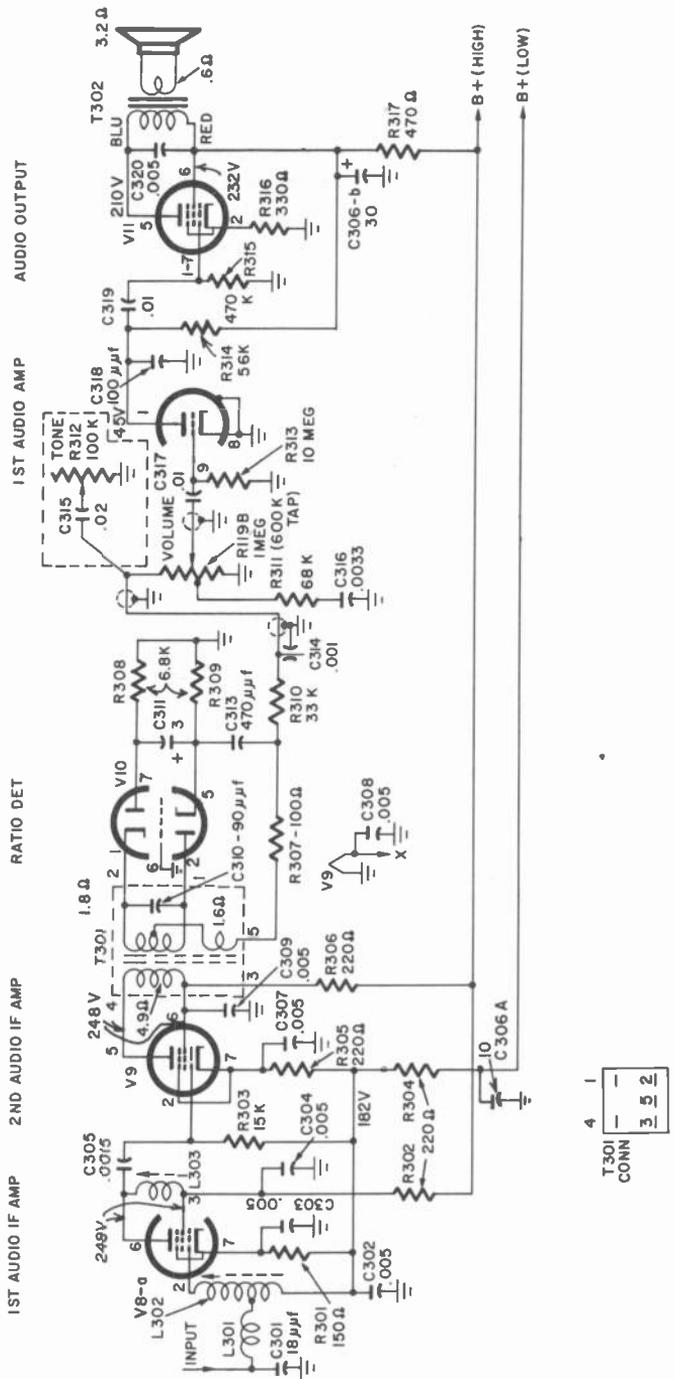
Fig. 1310. Complete sound section is typical of those found in many TV receiver models. Filament and B-plus supply connections will vary.

nected between point A and ground, sound will be heard. In the television receiver, the audio voltage is amplified and fed to a speaker.

Ratio detector

Discriminators are not used as FM detectors in modern TV receivers made by major manufacturers. You will find the ratio detector used extensively as well as the gated-beam detector. The ratio detector has an advantage in that it does not respond to amplitude variations. For this reason, it suppresses noise that is in the form of amplitude changes in the FM signal; a limiter stage is not essential. (In the discussion to follow, current flow and electron flow mean the same thing.)

Fig. 1309 shows a 4.5-mc sound if stage driving a typical ratio-detector circuit. You can get a good idea of the relationship of the ratio detector to the preceding and following circuits by examining Fig. 1310.

The ratio-detector circuit in Fig. 1309 resembles the discriminator but has several important differences. First of all, the transformer that couples to the ratio-detector input has a third coil called a tertiary winding. Another difference is the manner in which the diodes are connected. In the ratio detector, the top end of the input transformer secondary connects to a cathode of one diode; the bottom end of the transformer connects to the plate of the other diode. As you can see, the diodes are connected in a series-aiding arrangement. Both the primary and secondary of the input transformer are tuned to the FM center frequency. This frequency is 4.5-mc, as it is in all intercarrier receivers.

Appearing across the secondary of the input transformer, the if signal is fed through the diodes to charge C305 to the average if level. The if signal can only feed through during every other alternation when the cathode of the upper diode, pin 3, is negative and the plate of the lower diode, pin 1, is positive. Because of the direction of current flow, C305 is charged to the polarity shown in the diagram; this voltage is the stabilizing voltage and the capacitor (C305) is called the stabilizing capacitor. Its capacitance is high, (4 µf); therefore, C305 swamps amplitude modulation and sets a dc level for operating V1 and V2.

Tightly coupled to the primary of the ratio-detector transformer is the tertiary winding. This winding picks up the voltage across the primary and couples the voltage to both diodes. Now we have current flow in the ratio detector reminiscent of the current flow in the discriminator where opposing current flow caused a zero

voltage to appear at an audio output takeoff point when the 4.5-mc sound if was at center frequency. (This condition changed when the carrier was frequency-modulated). In the ratio detector, we also have opposing electron flows when the FM center frequency is fed through the detector.

Let's chase the electrons and see where they go. In V1, current flows from cathode to plate, through R315, C304A, R303, the tertiary winding, through the upper half of the T301 secondary and back to the cathode of V1. Note the direction of current flow through C304-a, R303 and the tertiary winding. Now let's shift our attention to the route taken by electrons through V2. Current flows from cathode to plate of V2, up through the lower half of the secondary of T301, through the tertiary winding, R303, C304-a (to ground) and back to the cathode of V2. Thus, we have two opposing flows of current as we did in the discriminator. In the ratio detector, we're interested in the opposing flow through C304-a. At the FM center frequency (4.5 mc), both flows of electrons are equal and hence produce a net voltage of zero at the top of C304-a. This capacitor functions as an audio signal load common to V1 and V2. (Technically speaking, current does not flow *through* C304-a, any more than current will flow through a coupling capacitor. C304-a does permit an electron displacement on one plate or the other.)

When the signal frequency rises above center, more current flows through V1 than V2. Voltage at the top of C304-a is positive because a heavier current flows *up* through C304-a toward the cathode of V1. When the signal frequency drops below center frequency, more current flows through V2 than V1. The voltage at the top of C304-a is negative because a heavier current flows *down* through C304-a toward the cathode of V2. Therefore, as a frequency-modulated audio signal is induced into the ratio-detector transformer, an audio voltage varying above and below zero volts appears at the top of C304-a. This audio voltage travels through R304 and C304-c to appear across the volume control. To adjust the volume, you tap off a portion of the audio signal fed to the audio output stage.

De-emphasis circuit

Let's consider R304 and C304-b, the simple combination that forms the de-emphasis circuit.

The FM signal contains some rather high audio frequencies. Normally, high audio frequencies do not have the amplitude of lower audio frequencies, hence don't modulate the carrier very

much, so the higher the audio frequency, the less it will shift the carrier frequency. This would be all right if it weren't for the lamentable fact that noise tends to drown out the high audio frequencies. To utilize the FM carrier more efficiently, the high end of the audio spectrum is boosted at the transmitter. The FCC has set the standard for high-frequency boost; the process is called pre-emphasis. Your receiver picks up a signal with high audio frequencies disproportionately strong. In the receiver, the high
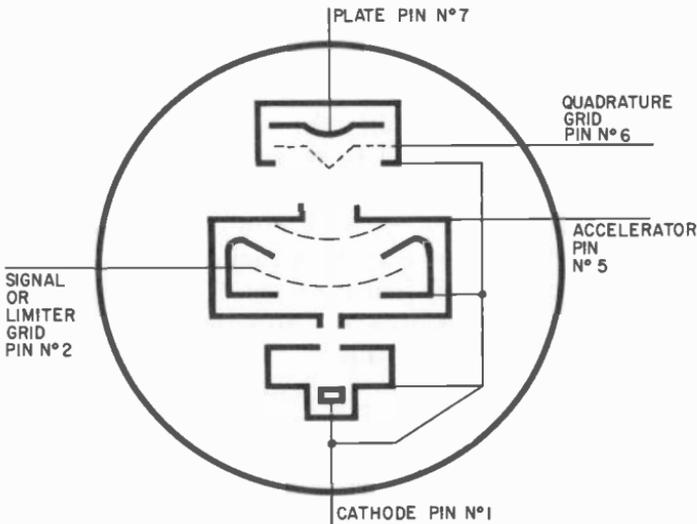
Fig. 1311. *Internal placement of elements in a gated-beam detector tube.*

audio frequencies must be reduced in level to nullify the boost given them at the transmitter. The de-emphasis network reduces the high end of the audio band to restore the correct high-to-low audio-frequency proportion.

Gated-beam detector

The gated-beam detector tube was invented as part of the constant battle to reduce manufacturing costs. The tube, and the circuit that is used with it, gives a high-level audio output. This eliminates the need for an audio amplifier before the audio output stage. Furthermore, the tube limits as well as detects.

The gated-beam detector tube has a unique construction as shown in Fig. 1311. The tube has two control grids (limiter and quadrature), heater, cathode, accelerator and plate. Low-voltage electron optics are used to shape and focus the electron beam within the tube. No external beam or focusing adjustments are

required; elements within the tube focus and shape the stream of electrons.

When you apply voltages to the tube, electrons are emitted from the cathode and focused into a flat beam. Because the electrons must pass through a narrow slot in the accelerator, only a limited number can get through. For this reason, saturation is quickly reached as the limiter grid voltage changes from negative to positive. Zero to $+2$ volts on the limiter grid causes plate-current saturation. This easy-to-saturate characteristic gives the limiting action. The tube is operated so that it ignores amplitude modulation; any amplitude-modulated noise appears in the plate-current saturation region. A few volts of negative voltage on the limiter grid causes cutoff. So the tube is easily saturated and easily cut off; a small positive-to-negative change of signal voltage alternately causes saturation and cutoff.

A small positive-to-negative change on the second control grid (quadrature grid) also causes saturation and cutoff. Either grid

Fig. 1312. *Basic gated-beam detector circuit performs the functions of limiter, detector and first audio amplifier.*

can cause cutoff if it goes slightly negative. Plate current will not flow through the tube unless both grids (limiter and quadrature) are positive *at the same time.* Thus, we have the gating effect from which the detector gets its name.

Self-bias is obtained by means of a variable cathode resistor. At a predetermined bias voltage, the tube starts to act as a limiter (amplitude modulation in the signal is sliced off). Because AM in the form of sync modulation, which produces a buzz, disappears at the limiting level, the variable cathode resistor is often called a buzz control or quieting control.

A typical gated-beam detector circuit is shown in Fig. 1312. The FM sound if signal of 4.5 mc is fed to the signal or limiter grid, pin 2. Due to alternate cutoff and saturation, the signal appears as flat-top pulses; the AM component is removed but the frequency variations remain intact. Connected to the quadrature

grid (pin 6) is a coil which, combined with its distributed capacitance, forms a high-Q parallel-resonant circuit. This circuit, tuned to 4.5 mc, is made to resonate at this frequency because of space-charge coupling within the tube.

When the 4.5-mc center (unmodulated) frequency is applied to the limiter grid, the 4.5-mc voltage on the quadrature grid *lags* the applied signal voltage by 90°. *Note that the 90° phase lag at the quadrature grid exists only when the applied signal is unmodulated.* When the applied FM signal increases in frequency (with modulation), the phase difference between quadrature grid voltage and applied signal voltage is *more* than 90°. When the applied signal decreases in frequency (with modulation), the phase difference between the two grids is *less* than 90°. This phase
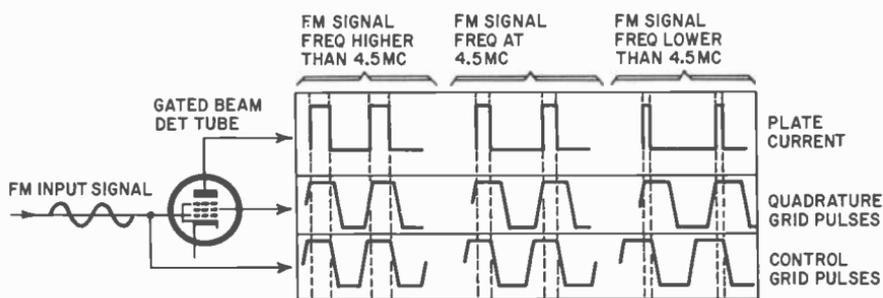
Fig. 1313. *How the overlapping pulses on control and quadrature grids gate current through the gated-beam detector tube. Dashed lines show overlap (coincident) periods when the FM signal is higher, at, and below 4.5 mc.*

change, which varies constantly as the signal is modulated, occurs because the reactance of the quadrature resonant circuit is different when the frequency is changed. Therefore, the phase of the voltage on the quadrature grid (with respect to the applied signal voltage) is determined by the frequency-modulated signal. This phase change is translated into a demodulated audio signal as follows:

As the applied signal is frequency-modulated, coinciding positive voltages appear on the limiter and quadrature grids for longer and shorter periods of time. Because plate current flows only when both grids are positive, the plate voltage also varies with modulation. Plate-current variations are in the form of pulses which vary

in width. When positive voltages coincide for shorter periods of time, the pulses are narrower. When positive voltages coincide for longer periods of time, the pulses are wider. The integrating circuit consisting of R3 and C2 (Fig. 1312) fills in the gaps between pulses to develop an average voltage across the plate load resistor. This voltage is the demodulated audio signal. See Fig. 1313.

Audio amplifier and audio output

If a gated-beam detector is used, the detector output is high enough to drive the audio output tube; no preceding audio amplifier is needed (Fig. 1314). If a ratio detector is used, one stage of audio amplification is required to drive the audio output tube. The output of the gated-beam detector (or sound discriminator) is fed through coupling capacitor C34. Volume control R14 enables the desired amount of audio to be taken from the detector output and to be fed to the audio output tube. Notice, too, the tone control circuit. This is nothing more than a capacitor with one end grounded and the other end connected to the audio
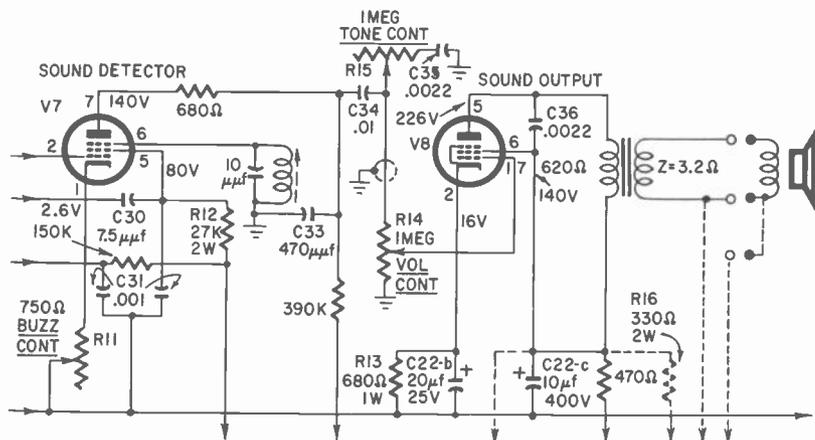
Fig. 1314. *Typical detector circuit used to replace limiter, detector and first audio amplifier. Detector drives power output tube, does not use audio driver stage.*

voltage line through R15, a 1-megohm variable resistor. When R15 is at minimum resistance, capacitor C35 shunts the high audio frequencies to ground. As the resistance of R15 is increased, the capacitor has less effect and more high audio frequencies appear in the output.

Some manufacturers feature deluxe television sets with high-quality audio output. Many chassis use push-pull audio amplifiers

driven by a phase inverter tube. The phase inverter provides audio drive of opposite polarities to the grids of the push-pull output tubes. These sets often have multiple speakers. A crossover network is used to feed the low audio frequencies to the speaker that is called a "woofer", because it reproduces low-frequency sound. The high-frequency speaker has been dubbed the "tweeter" by an anonymous wag.

The sound section won't work unless you feed it B-plus. In fact, the entire television receiver will do absolutely nothing unless it gets its vital B-plus. And how is B-plus obtained? From the low-voltage power supply, of course, and the next chapter tells the story.

QUESTIONS

1. What are the two ways in which a tone can convey information?

2. What is amplitude modulation?

3. Name two advantages of FM modulation.

4. In what circuit or circuits would you expect to find the sound takeoff.

5. What is a limiter? Why is it used? With what circuit is the limiter usually associated?

6. What is meant by phase? What is leading phase? Lagging phase? In phase?

7. What are vectors? How are they added?

8. What is meant by quadrature?

9. Describe the operation of a discriminator.

10. What is a de-emphasis circuit? Why is it used?

11. Describe the operation of the gated-beam detector.

12. What is a buzz control? Where is it used?

13. What is the center frequency of the sound if at the sound takeoff point?

14. What is pre-emphasis? Where is it used? Why is it used?

15. Name one advantage of the gated-beam detector.

14

THE LOW-VOLTAGE SUPPLY

● ●

To supply dc to the circuits throughout the television receiver, three sources are used: (1) low-voltage power supply; (2) boost B-plus supply; and (3) high-voltage power supply.

We list the three separately for convenience. Actually, the low-voltage power supply is the only one that is relatively independent; the other two depend upon the low-voltage supply. Boost B-plus also relies upon the damper tube. Because the high-voltage supply and boost B-plus are so much a part of the horizontal output system, these power sources were discussed together in Chapter 12.

Low-voltage power supply

When you turn your set on, you feed ac to the low voltage power supply. Your set may have a power transformer with a duo-diode rectifier tube. If so, the low-voltage supply undoubtedly has a full-wave rectifier circuit — all the tube filaments in the set are connected in parallel. At the output of the low-voltage supply, there's probably a voltage-divider arrangement from which dc voltages are tapped and fed to various circuits in the set.

The receiver may not have a power transformer in the low-voltage supply. Instead, a line-connected selenium or silicon rectifier may be used. The filaments of all the tubes in the set may be wired in series.

Full-wave-rectifier low-voltage power supply

A typical full-wave-rectifier low-voltage power supply with a power transformer is shown in Fig. 1401. Let's start at the input

and follow the ac through the power supply; then, let's see where the dc goes.

The ac plug connects to an interlock arrangement. When you remove the back of the set, you automatically disconnect the power cord. This is supposed to stymie the untutored tinkerer who doesn't know he can expose himself to high voltages. Service technicians use cheater cords to defeat interlocks. A cheater cord is nothing more than a power cord that isn't riveted to the back of the set. The interlock does serve a purpose when Aunt Minnie wants to take the tubes to the supermarket self-service tube tester.

When you close the switch (S801), you send ac into the primary of the power transformer T801. R801, required by Underwriters Labs for safety, is a static discharge resistor that will drain off a charge caused by lightning.

The duo-diode is a full-wave rectifier. Its output is pulsating dc. Notice in Fig. 1401 that there are four dc voltages available. The 300-volt B-plus bus feeds the audio output tube because this stage requires a relatively large amount of current (to feed power to the speaker) but does not demand a great amount of filtering. For this reason, there is no filter resistor between the filament of the full-wave rectifier and the 300-volt takeoff point. The 100-μf filter capacitor C801 provides the filtering needed by the audio output tube.

The next B-plus output is the 260-volt line. This receives the additional filtering benefits provided by R802 and C802. The tuner is supplied from the 260-volt line. The audio output screen grid, second sync separator and the horizontal output stage are also connected to this voltage tap. The 165-volt feed line is better filtered. Circuits that require this additional filtering and lower voltage are the video if strip, audio if and first sync separator. The lowest B-plus output feeds 145 volts to the audio amplifier stage. This stage demands the most filtering because it tends to be hum-sensitive; the slightest hum in the B-plus line will be amplified if not well filtered.

We've discussed the low-voltage power supply in Fig. 1401 in some detail because it is an excellent example of a supply with several voltage takeoff points. Each feed line provides a different voltage level. The highest-voltage output furnishes the most current with the least filtering. Lower-voltage outputs provide more filtering and less current. Low-voltage supplies used in other TV sets may have fewer output lines but work on the same principle. The parallel-voltage arrangement of the receiver tube filaments, tuner filaments and pilot lamp is also typical.

200

Semiconductor low-voltage power supplies

Selenium, silicon and germanium are frequently used as rectifiers in place of diode electron tubes. The method for determin-
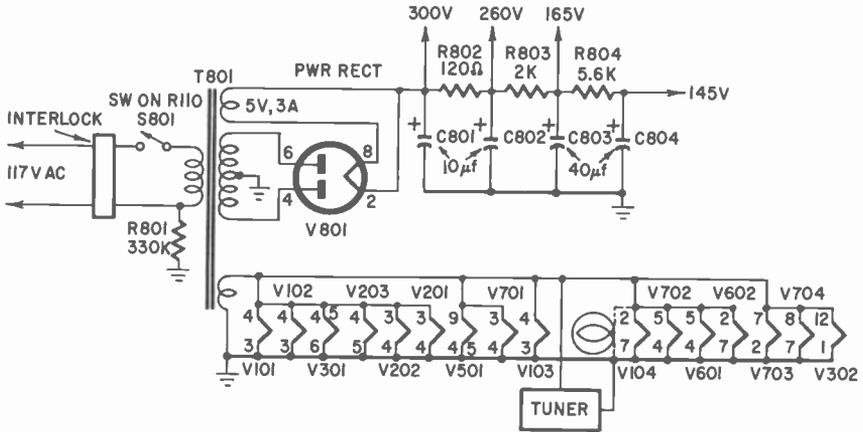
Fig. 1401. *This circuit shows distribution of filament and B-plus voltage.*

ing the direction of current flow through a semiconductor diode is simple. Look at a semiconductor diode symbol. It looks like an arrow pointing to a line, doesn't it? Well, current flows the *other* way — not the way the arrow in the symbol points.

You may wonder why this semiconductor diode symbol was
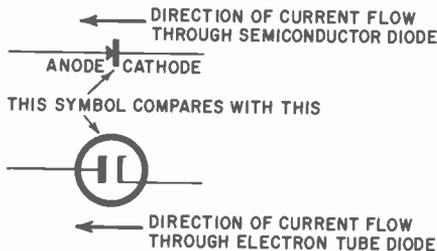
Fig. 1402. *Don't be fooled by the semiconductor diode symbol. Current flows as indicated by the arrow on top.*

standardized in this form; it seems to be drawn backward. The reason for this paradox is the so-called "conventional current flow" theory. When electricity was originally discovered, it was assumed that current flowed from plus to minus. Later, when the electron tube was invented, it was learned that a stream of electrons flowed through the tube from minus to plus. Old physics books clung to the plus-to-minus theory, evidence to the contrary

notwithstanding, and many good people still like to think of a flow of electricity from plus to minus.

In this book we use "electron flow" and "current flow" as being the same thing and we have it flowing from minus to plus because that's what it does. Our aim is to make it as easy as possible to visualize circuit theory correctly. Fig. 1402 shows the diode electron-tube equivalent of a semiconductor diode.

In popular receivers of recent vintage, the simple half-wave rectifier isn't used. If the manufacturer prefers a transformerless low-voltage supply, he uses a voltage multiplier, generally a doubler.

Voltage-doubler rectifiers

There was a time many years ago when folks thought you had to have a transformer to double ac voltage. "Not so," exclaimed a
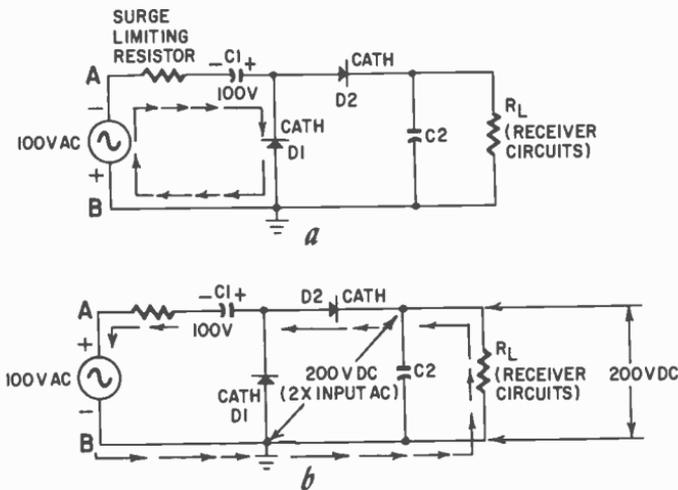
Fig. 1403. *Basic half-wave voltage-doubler circuit. Arrows indicate paths of current for each half-cycle.*

bright fellow, "we can double an ac voltage by using some diodes and capacitors." And so the voltage doubler was born.

In recent years, manufacturers have found the voltage doubler to their liking because it is inexpensive, lightweight and does a good job. Voltage doublers are used in low-voltage power supplies in portable TV sets as well as in console models.

The voltage-doubler power supply's theory of operation is simplicity itself. A look at Fig. 1403 tells the whole story. Let's assume, for simplicity, that the input ac voltage is 100. During the first cycle of ac input voltage, when point A is negative and point

Fig. 1404. *Typical half-wave voltage doubler. Note filament and B-plus power distribution in this transformerless circuit.*

B positive, current flows through diode 1 (Fig. 1403-a). Capacitor C1 charges to 100 volts with the polarity shown in the diagram. During the second cycle of ac input voltage, current flows in the direction shown in Fig. 1403-b. Capacitor C1 cannot discharge through diode 1 because the cathode of the diode is positive with respect to the anode. Capacitor C1 acts as a battery in series with the input ac; the charge in the capacitor adds to the ac input voltage. A voltage of approximately twice the input ac voltage appears as dc output . . . is rectified by diode 2 and filtered by C2. In practice, the dc output is slightly less than twice the input.

Filament (heater) hookup

If you know someone who's a stickler for definitions, he'll insist that "heater" should be used only if the tube has a cathode and "filament" applies to tubes that use the filament as an emitter. True. However, you'll find the terms used interchangeably, cathode or no. We use "filament" here in referring to tubes with or without cathodes because the term is widely used as such in manufacturers' literature and elsewhere.

When a set uses a transformer low-voltage power supply, the filaments are connected in parallel. If one tube has a burned-out filament, the rest are not affected and stay lit. If the set uses a voltage-doubler type of low-voltage supply, the filaments are series-connected in late model sets. (Some earlier sets used a

203

special filament transformer with filaments in parallel even though a power transformer was not used in the low-voltage supply). You can compare the parallel and series arrangements by examining the typical series-filament hookup in Fig. 1404 and the parallel filament circuit in Fig. 1401.

A typical voltage distribution system

Earlier, we discussed a low-voltage supply (Fig. 1401) and its B-plus output lines. Now let's study the voltage feed lines in another typical receiver, but this time let's include the high-voltage and boost B-plus feed. The manner in which voltage is distributed throughout the set is important in servicing because dynamic voltage checks constitute one of the best ways of tracking trouble.

Let's work with a simple block diagram and partial schematic that shows us only the topics of interest. The diagram is Fig. 1405. Only the arteries that carry voltage are shown; all components (capacitors and resistors) are omitted except the brightness control.

In the low-voltage power supply, there may be a voltage-divider resistor with taps, or several resistors may be used in a voltage-divider hookup. There may be a higher-voltage takeoff before a filter choke or resistor to feed higher voltage to points that require higher voltage with less filtering.

Our low-voltage supply (in the typical set being discussed) can be considered as having five outputs: (1) an audio output plate B-plus line (235 volts); (2) a low-B-plus line (130 volts); (3) an audio output screen B-plus-line (230 volts); (4) a high-B-plus line (265 volts); (5) a vertical output plate B-plus line (255 volts).

The low-B-plus 130-volt output feeds: (1) V6-b, the sound limiter plate; (2) V9, the first if plate and screen; (3) V10, the second if plate and screen; (4) V11, the third if plate and screen; (5) V4, the sync separator plate and screen; (6) V6A, video output *screen only*. Plate voltage for V6A is obtained from the 265-volt line to provide maximum output consistent with the plate dissipation rating of the video output tube. Its screen voltage is taken from the low-B-plus (130-volt) output because this line is filtered by a large capacitor. (As mentioned earlier, parts such as resistors or capacitors are not shown in Fig. 1405). This extra filtering is needed to prevent *uncontrolled* degeneration in the video output screen circuit at video frequencies. In this circuit, a contrast control (not shown) provides a certain amount of *controlled* degeneration in the screen circuit because the contrast control (in this
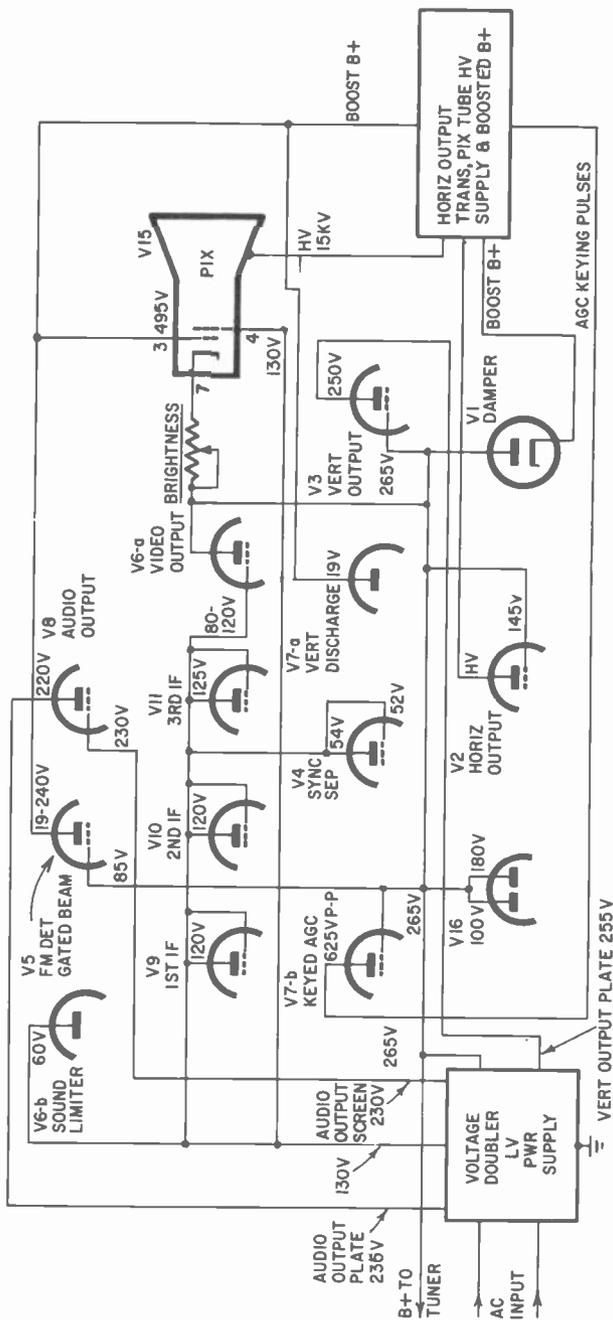
Fig. 1405. Voltage distribution in a typical TV receiver. Only plates and screen grids are shown. Resistors and capacitors are omitted for simplicity.

set) varies the screen voltage. Adjustment of this control changes the gain of the video output tube. In this way, you adjust the drive to the cathode of the picture tube.

To prevent interaction between the vertical output circuit and other circuits in the receiver, a separate B-plus 255-volt output exists. The high-B-plus 265-volt line feeds V5, the FM gated-beam detector, (pin 5) only. Voltage is taken from the 265-volt line to take advantage of extra filtering in this line. This is done because the gated-beam detector is sensitive to any undesired signal components at its accelerator grid. The extra heavy filtering gets rid of this potential problem. By the time the voltage reaches pin 5 of V5, it is reduced to 85 volts by resistors.

Other high-B-plus (265-volt) feed points are: (1) tuner; (2) V7B, keyed agc screen; (3) V3, vertical output screen; (4) V16, horizontal multivibrator plates; (5) V2, horizontal output screen; (6) V6-a, video output plate; (7) cathode of the picture tube through the brightness control; (8) V1, damper tube. Boost B-plus is superimposed at this point.

Boost B-plus voltage is fed to the vertical discharge plate of V7A. This tube receives boost plate voltage because a high plate impedance must be seen by this tube and a high plate voltage is needed. Boost voltage is also fed to V5, the gated-beam detector plate. This tube receives boost voltage at its plate to furnish adequate plate voltage for increased output at high impedance.

The high voltage applied to the picture tube is 15 kv, conventionally derived from the horizontal output transformer and the high-voltage rectifier.

15

TRANSISTOR PORTABLE TV

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S EVERAL manufacturers have made monochrome portable television receivers. One of these weighs just 15 pounds. A function switch enables you to select the mode of operation. In the battery position, the set draws about 4.5 watts. In the ac position, the chassis is isolated from the line by its own built-in stepdown power transformer. This transformer is also used to supply energy for recharging the battery in the charge position.

This portable uses 21 p-n-p transistors, 14 semiconductor diodes and a picture tube. Two electron tubes are used in the high-voltage rectifier circuit.

A short note on transistors

Each transistor in this receiver has three elements. In the schematics, one element looks like a heavy line. This is called the *base* and can be compared to the control grid in the electron tube. The line that points to the base (or away from it) with an arrowhead is the *emitter*. You can compare the emitter to the cathode in an electron tube. The third element, shown as a line going into the base (with no arrowhead), is the *collector*. This element works like the plate in an electron tube.

Of course, there are many differences between transistors and electron tubes. The comparisons given here between the elements of a transistor and those in a tube are not completely true, but they are a simplified way to look at a transistor in its circuit.

The transistor tv receiver

Looking at the block diagram of Fig. 1501, it would be quite difficult to tell the difference between the transistor and vacuumtube chassis. A new feature is the *energy cell* (a rechargeable battery) in the power input circuit.
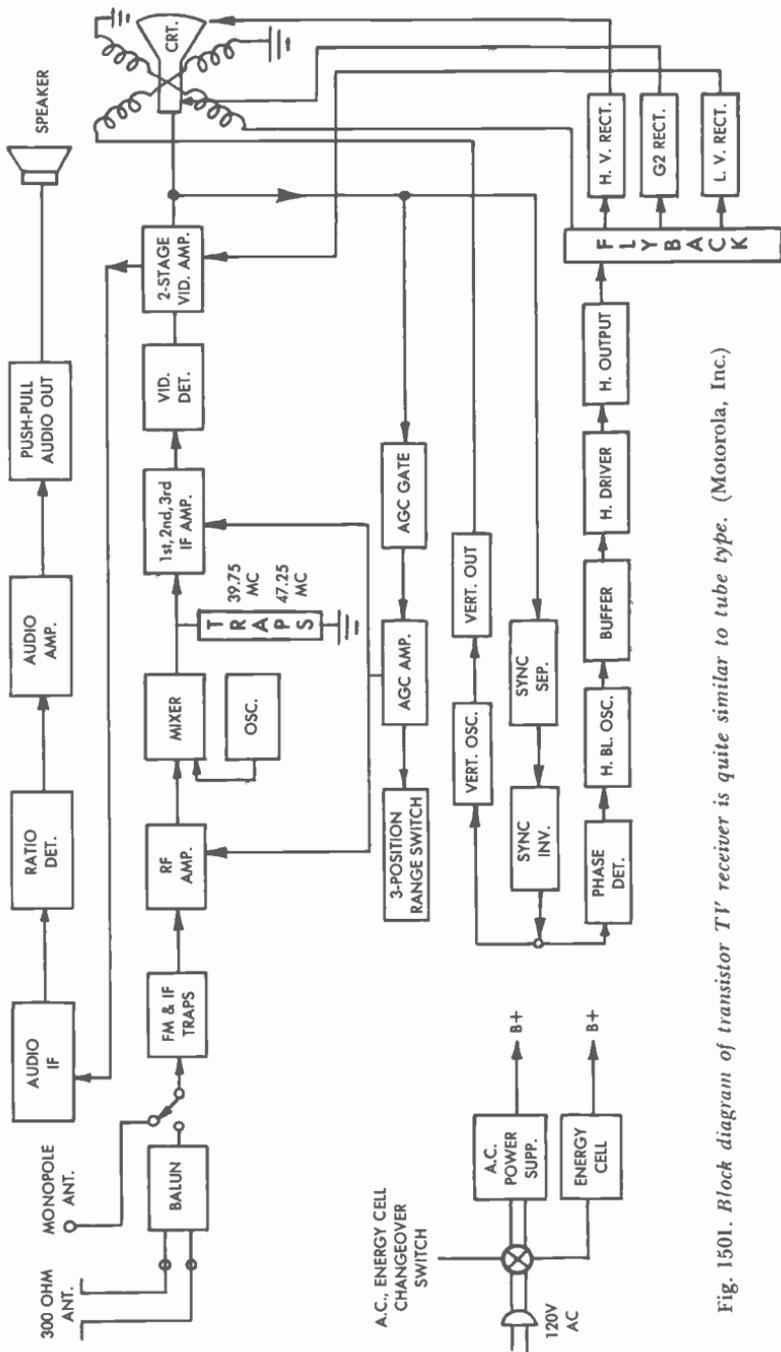
Fig. 150I. Block diagram of transistor TV receiver is quite similar to tube type. (Motorola, Inc.)

One of the differences between transistor receivers is the size of the picture tube used. In an effort to reduce the overall size and weight, to make a personal portable, one manufacturer used an optical system (Fig. 1502) to magnify the image on the screen of a 2-inch picture tube. The other manufacturers retained the
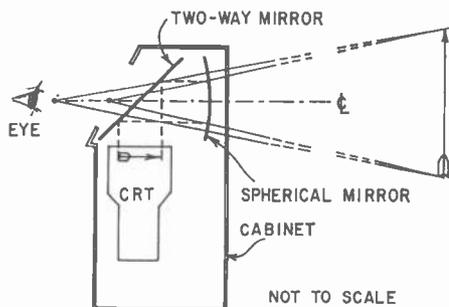
Fig. 1502. *Optical system for 2-inch CRT increases the apparent size of the viewed image.*

familiar direct-view system and used tubes up to 19 inches across the diagonal.

The positioning of the controls and service adjustments (Fig. 1503) are what would be expected on most vacuum-tube tv receivers. These receivers have been designed with quite accessible controls. The large-screen receiver has most controls conveniently located on the top panel (Fig. 1504) including a three-position agc area selector.

Waveforms

While there are differences in the circuitry between vacuum-tube and transistor TV receivers, the waveforms to the speaker, yoke and picture tube (Fig. 1505) must be the same. This, in turn, makes the waveforms of many of the stages that feed the output stages similar to the familiar ones of vacuum-tube circuits. The bandwidth response curve for the if amplifiers are duplicates, of course. It becomes quite obvious that, once the operational theory of the transistor has been mastered, and the circuit requirements of the television receiver are understood, the repair of the semiconductor circuitry will present no great problem.

Tuner

A tuner circuit used in a transistor portable is shown in the schematic diagram, Fig. 1506. The three transistors are called micro-alloy diffused transistors (abbreviated MADT). "Micro-

alloy diffused" tells how the transistor is made. This type of transistor is designed especially for high-frequency use.

The input to the T1561 rf amplifier is a single-tuned parallel-resonant circuit matched to the rf amplifier's input impedance and inductively tapped at the 75-ohm point for the monopole antenna. Notice the neutralizing capacitor, VC1, which may remind you of the one used in the Standard Coil Neutrode tuner shown in Fig. 504 and explained in Chapter 5. Out-of-phase feedback through the neutralizing capacitor in both Philco and
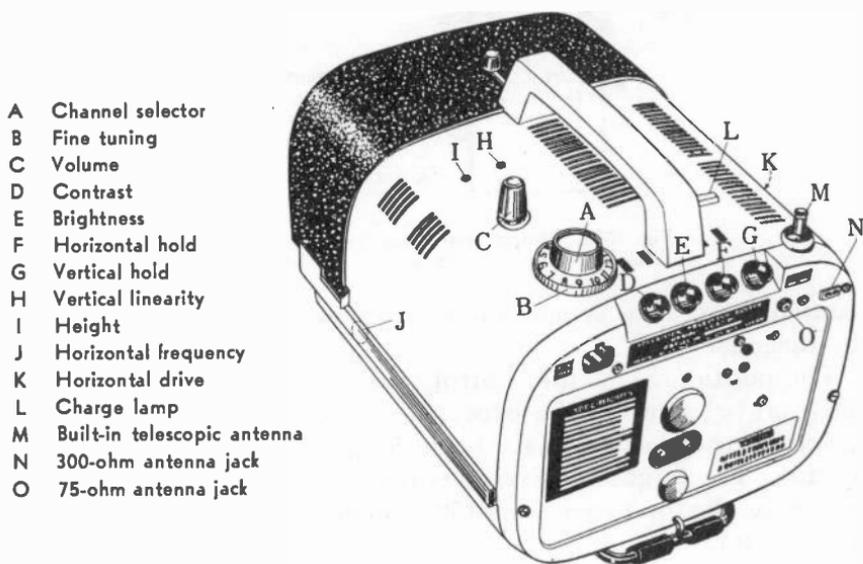
A   Channel selector
B   Fine tuning
C   Volume
D   Contrast
E   Brightness
F   Horizontal hold
G   Vertical hold
H   Vertical linearity
I   Height
J   Horizontal frequency
K   Horizontal drive
L   Charge lamp
M   Built-in telescopic antenna
N   300-ohm antenna jack
O   75-ohm antenna jack

Fig. 1503. *Even the rear of the case would require more than a quick glance to distinguish between tube and transistor TV receiver.* (Sony Corp.)

Standard Coil tuners gives high gain with stability. A common-emitter circuit is used in the rf amplifier stage.

Between the rf amplifier and the T1600 mixer you'll find a double-tuned bandpass circuit which is matched to the rf amplifier. The T1597 oscillator can be regarded as a common-base amplifier in which additional capacitive feedback has been added between collector and emitter to sustain oscillation.

Video if

Generally, in the video if strip, you'll find three or four transistors designed for high-frequency service. A grounded-emitter circuit is used for maximum gain. To get a broad response stagger tuning is used.

Because the input and output impedances of a transistor are extremely low, more efficient trap circuits are needed to prevent adjacent-channel picture and sound interference. This is accomplished by a balanced T-trap for adjacent-channel sound interference (Fig. 1507). To get rid of adjacent-channel picture interference, series-tuned traps are used.
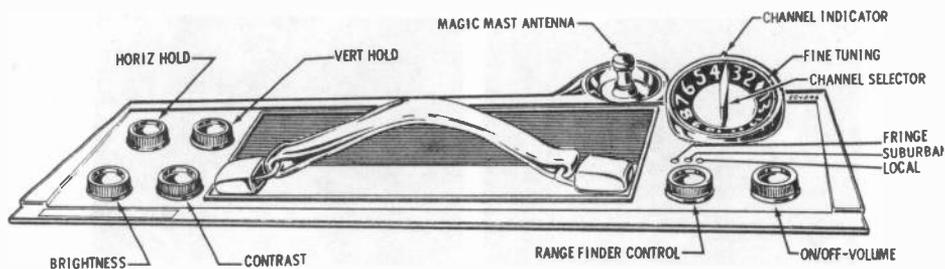
Fig. 1504. *Controls on this large-screen transistor portable are convenient to operate.* (Motorola, Inc.)

Agc

To obtain agc action in a transistor stage, two techniques have received considerable attention. These are forward and reverse agc. In the reverse mode, the emitter and collector currents decrease with increasing signal strength; in the forward mode, emitter and collector currents increase with signal strength. A voltage which goes negative as the signal increases is applied to the base of the first and second if transistors. This results in a large voltage drop across the emitter resistor. Less voltage appears across the transistor so the gain of the stage decreases. In the third stage, the base–emitter diode is biased in the reverse direction as the signal increases. As the collector–emitter voltage does not change, the gain of the stage decreases.

The reason for using both forms of agc is that the output impedances of the stages vary with agc. Thus, when the emitter current increases in a stage operating in the forward mode the bandwidth of the stage increases, whereas in a stage that is operating in the reverse mode, the bandwidth decreases, for an increase in emitter current. Thus, to maintain constant bandwidth for varying signal conditions, employing both forms of agc action is an aid.

In another transistor TV chassis, the rf amplifier and the first two if stages are under the influence of a keyed, amplified agc circuit. The output of the circuit is controlled by the setting of the range switch. Signals up to 500 millivolts can be handled with-

211

out distortion. The delayed agc is of the forward-biased type. This helps weak signals come through and prevents strong signals from overloading. The agc voltage applied to the bases of the transistors biases them toward saturation to reduce their gain in proportion to the strength of the signals received.
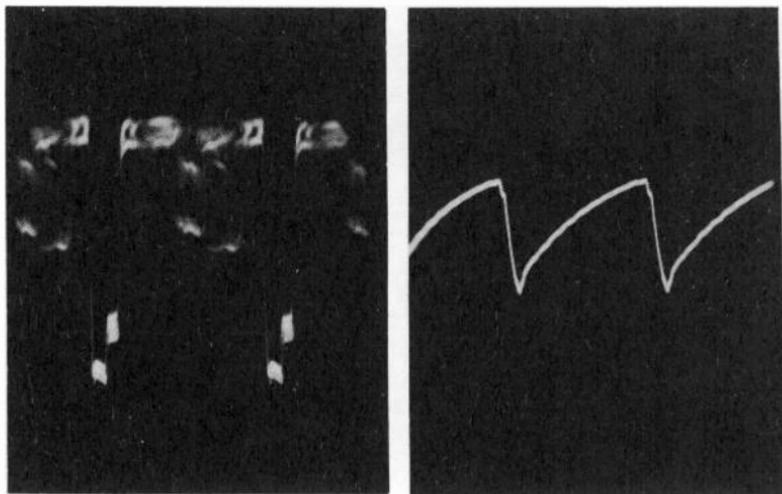
Fig. 1505. *Video, sync and sweep waveforms will be almost identical to the familiar scope patterns in tube type TV receivers.* (Philco Corp.)

Video detectors

A conventional diode detector feeds a two-stage video amplifier in all the chassis. The additional diode in the schematic of Fig. 1508 feeds noise pulses to the sync amplifier. In another circuit, a transformer-coupled diode in the last video if provides an agc voltage.

Video amplifiers

The first video amplifier feeds the signal to the base of the second as an emitter follower. This gives a better impedance match between the video detector and the picture tube cathode.

In Fig. 1508 agc is obtained from the collector of the first video stage. A three-position range switch in the collector circuit of the first video stage controls the collector voltage to the tuner and the agc to the if strip.

The video output stage has its collector returned to −12 volts and its emitter returned to +12 volts. If there is no signal to the base, the collector voltage normally runs at about zero volt. Thus, in the presence of a signal, the collector can swing from

Fig. 1506. Tuner schematic for transistor TV is no more complicated than tube type.

+12 volts to −12 volts, resulting in a maximum drive of 24 volts to the 2-inch picture tube.

Sound system

Basically, for all chassis the sound from the first video amplifier is amplified in a 4.5-mc sound if stage which drives a limiter. Lim-
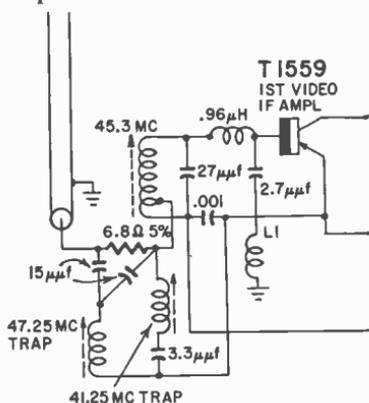
Fig. 1507. *Extremely low transistor input impedance requires a balanced T-trap in the input to the video if amplifier strip.*

iting is accomplished in this stage by driving the collector of the limiter from saturation to cutoff. The balanced diode detector feeds the audio driver which, in turn, drives a pair of push-pull class-B output transistors. The audio output is approximately 150 milliwatts from a 3-inch speaker.

High-voltage

Small-screen (2-inch and 8-inch) transistor TV chassis use a voltage-doubler high-voltage power supply. Large-screen receivers have more sweep current through the yoke windings and as a result are able to provide heavier retrace-current pulses.

Additional windings and semiconductor rectifiers provide other voltages. Focus electrode voltages from 100 to 300 are obtained this way, as well as the boost voltages for transistor circuits, such as the video amplifier.

Picture tubes (CRT)

The gun-structure of the CRT is special in all cases.

The 19AEP4 picture tube utilizes a standard 19XP4 bulb with a gun structure extensively modified for most efficient transistor operation. Filament power requirements are reduced to 12.6 volts at 150 ma to avoid excessive drain of the energy cell. The electron gun is designed to permit low G2 voltage (100 volts) without increasing spot size or defocusing the picture. The low G2 voltage, in turn, permits a full-contrast range with only 50 volts of video

driving signal. This is well below the maximum output of the transistorized video amplifier that feeds the 19-inch picture tube.

For the optical system a 2-inch 30° deflection, electrostatic focus tube is used. Heater for the cathode only consumes 1 watt. A 12-volt heater is used for the 8-inch CRT.
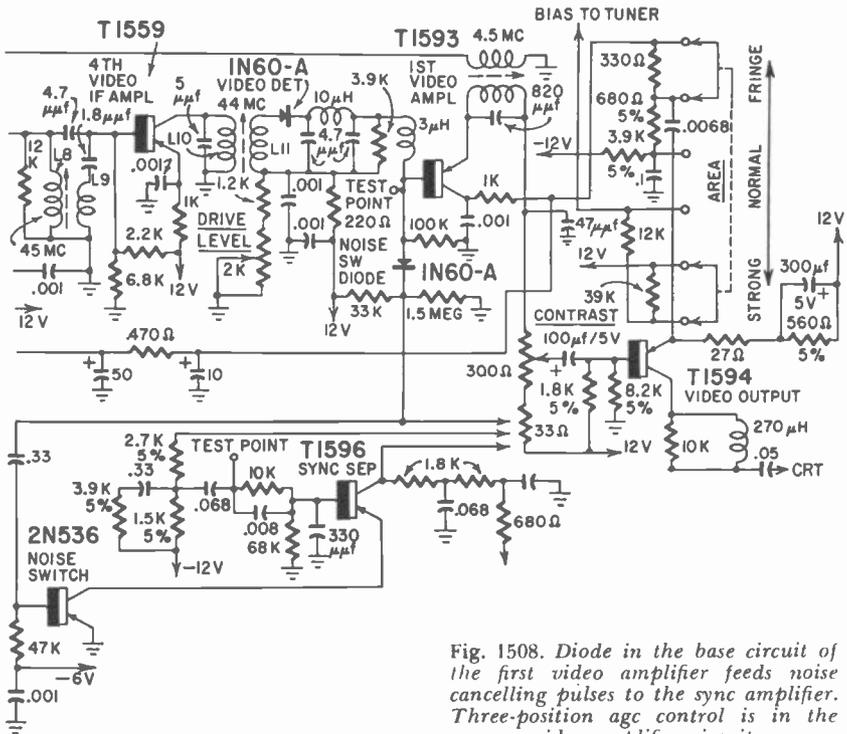
Fig. 1508. *Diode in the base circuit of the first video amplifier feeds noise cancelling pulses to the sync amplifier. Three-position agc control is in the video amplifier circuit.*

Time required to recharge the cells is approximately three or four times the discharge time, that is, if the receiver will operate for 4 hours from the internal power source it will take 12 to 16 hours to recharge the cells.

Service manuals

The information contained in most of the manuals is quite complete. Printed-circuit boards are illustrated and most, if not all, parts are identified.

Schematics have component values indicated. Voltages and many waveforms are available either on the schematic or in accompanying tables.

Servicing

Mechanically the portables are as compact as possible. As with tube type receivers some degree of disassembly is required for any servicing. Since most component replacement requires access to both sides of a printed-circuit board, its removal will often be necessary and is usually illustrated in the manuals in detail.

Low-voltage power supply

When the transistor TV receiver is operated from the ac line, a low-voltage transformer is used. A full-wave rectifier furnishes operating voltages for all transistors except the final video amplifier. In addition, the low-voltage power supply recharges the energy cell when the set is plugged into the line outlet and turned off. The low-voltage power supply is transformer-operated, with a full-wave rectifier and capacitor input filter.

One power-supply circuit uses a transistor as an active filter in place of a bulky filter choke. This has the double advantage of giving adequate filtering and a degree of output regulation. This regulation function is used specifically to prevent the current variations of the class-B audio stage from affecting the operating voltages to the other stages.

16

QUICK REVIEW, NUMBER II

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A FTER a delicious evening meal, as dusk settles and a cool eve-
ning breeze plays against the windowpane, what does the
average family do? Watch television, of course.

Father rushes over to the set (establishing squatter's rights be-
fore the children do) turns the switch and the current surges into
the low-voltage power supply. Filaments glow, B-plus is distrib-
uted hither and yon throughout the TV circuitry, and the ver-
tical and horizontal oscillators go to work.

The horizontal oscillator, busying itself producing pulses at
the rate of 15,750 a second, sweeps the beam sideways. Of course,
the pulses are first changed into trapezoidal waves by a sawtooth-
forming capacitor in series with a resistor. This is done in the
horizontal oscillator output circuit. And, naturally, the trape-
zoidal waves are amplified considerably by a horizontal output
tube. The trapezoidal waves are applied across the horizontal de-
flection coils to produce the 15,750-pps sawtooth current that
flows in the deflection coils. Needless to say, the horizontal out-
put stage does more than merely amplify trapezoidal waves. Dur-
ing retrace (or flyback), the return surge of horizontal scanning
current produces sharp voltage pulses in a small segment of the
horizontal output transformer. This voltage, stepped up tremen-
dously to create a very high voltage, is rectified by a high-voltage
rectifier to supply high voltage to the picture tube.

Producing pulses at a 60-pps rate, the vertical oscillator also
controls the beam in the picture tube. Trapezoidal waves formed

in the output circuit of the vertical oscillator are amplified by a vertical output tube. The vertical output transformer matches the vertical output plate circuit to the vertical deflection coils; the beam is pulled down and retraced vertically while it is swept sideways.

What's this? Our screen is lit, but we have no picture! Junior must have turned the channel selector this afternoon while mother was busy with the housework. Although the channel selector is set at a non-active channel in the area, the horizontal and vertical sweep circuits continue to sweep the beam. The horizontal and vertical frequencies are *approximately* 15,750 and 60 pulses a second, because neither oscillator is synchronized now.

Let's turn to an active channel to see what's on TV tonight.

The moment we select a channel, the amplitude-modulated picture signal and frequency-modulated sound signal take command. After processing in the video detector, the positive-going video signal is fed to the cathode of the picture tube, a 4.5-mc sound if is fed to the sound section and a sample video signal is fed to a sync separator. The sync separator slices off the vertical and horizontal sync pulses and feeds them simultaneously to an integrator and differentiator. The integrator supplies vertical sync pulses to the vertical oscillator to trigger the oscillator *directly*. The differentiator feeds horizontal sync pulses to a phase detector. The phase detector synchronizes the horizontal oscillator by means of an error voltage. A feedback loop from the horizontal output stage to the phase detector gives this circuit a sample of the sawtooth portion of the horizontal output signal. The phase detector compares the frequency of the output sawtooth waves with the frequency of the incoming horizontal sync pulses. If the horizontal oscillator is perfectly synchronized with the incoming horizontal sync pulse signal, the phase detector has no correction voltage for the horizontal oscillator. If the horizontal oscillator tries to drift in frequency, the phase detector produces an error voltage that immediately brings the oscillator into sync.

We've tuned in a perfectly synchronized picture of a lovely vocalist. We'd certainly like to listen to her voice, so let's turn up the sound.

Singing into a microphone, our vocalist modulates the frequency of the television-signal sound carrier. The tuner in our receiver changes the station's FM signal to a 41.25-mc FM signal. In the video detector, the video and sound signals beat with each other to produce a 4.5-mc FM signal. The 4.5-mc FM signal, ex-

tracted from the video detector or the video output stage, is built up by a 4.5-mc sound if amplifier and is fed to a sound detector. Most sets use either a ratio detector or gated-beam detector. The ratio detector requires a stage of amplification before the audio output tube, while the gated beam has sufficient output to feed directly to the grid of the audio output tube. Theoretically, any noise that amplitude modulates the signal gets its head chopped off by the ratio detector or gated-beam detector. But in an imperfect world we cannot expect perfection — and that goes for detectors as well. Thus, some manufacturers feel it is advisable to use a limiter stage immediately ahead of the detector.

Our vocalist's dulcet tones are changed to an audio voltage by the sound detector, amplified by the audio output tube and fed to the speaker.

Conclusion

"There's a way to do it better . . . find it!"

These are the words of Thomas A. Edison who harnessed electricity, a natural force that has existed on earth since the beginning of time. Endlessly searching for a better way, dedicated men followed Edison by finding new ways to use electricity. The invention of the electron tube opened a new world of electronics. Man learned to communicate through space by developing the radio transmitter and receiver. At first, they communicated in code by keying the rf carrier on and off. Later, they added speech and music by audio-modulating the rf carrier. Radio could be used for entertainment as well as for communications. With the invention of the cathode-ray tube, which used an electron beam to produce light on a screen, they asked, "Can we control the beam to produce a moving picture? Can we transmit the picture through space"? Early attempts were crude. But, there was "a way to do it better." It remained to be found.

Television seemed a futile hope many years ago and technical obstacles seemed insurmountable. Yet, through the evolution of ideas, through study, research, creativity, inspiration, and plain hard work, the better way was found and a dream became a reality.

Television is a pleasant branch of electronics; it was developed to entertain, enlighten, and serve mankind.

QUESTIONS

[These questions cover chapters 14 and 15.]

1. What semiconductor materials are used for rectifiers?

2. Describe the operation of a voltage doubler.

3. What is the difference between the terms "heater" and "filament"?

4. Why is a resistive divider used in the low-voltage supply?

5. What is an interlock? Why is it used? What is a cheater cord?

6. What are two advantages of the voltage-doubler power supply?

7. What is an energy cell? What type of TV set uses it?

8. What is MADT?

9. Why are both forward and reverse agc used in transistor TV receivers?

10. What are the elements of a transistor? What are the comparable elements in a tube?

11. How do the waveforms in a transistor TV receiver compare with those in a tube-type TV set?

12. Describe the direction of current flow through a semiconductor diode.

13. What is the difference between a transformerless supply and an ac-dc supply?

14. What technique is used for eliminating adjacent-channel picture and sound interference in a transistor TV receiver?

INDEX

221

222