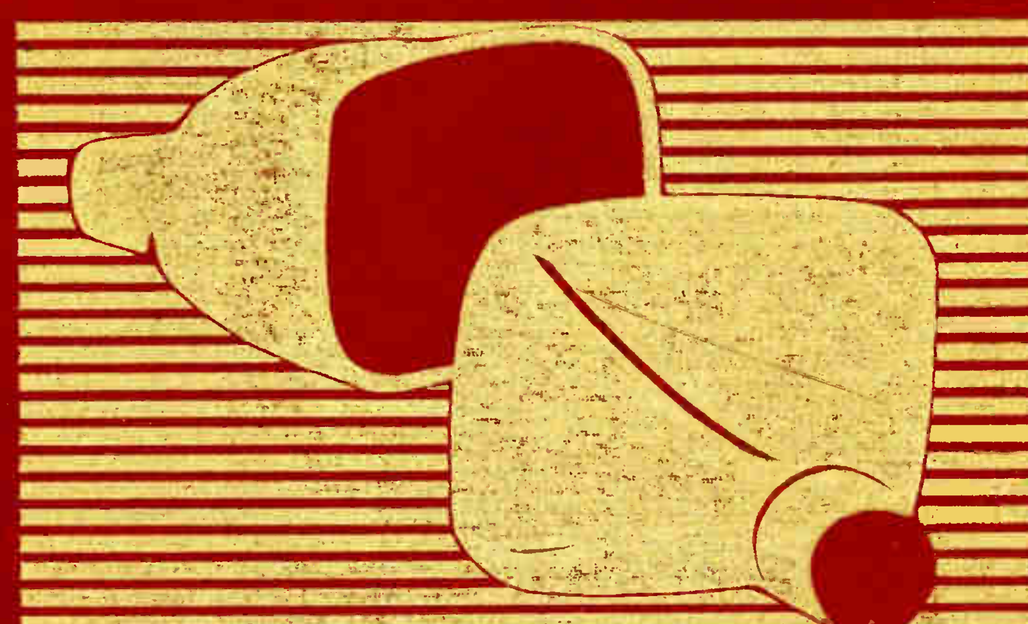
horizontal sweep servicing handbook

Jack Darr

horizontal sweep servicing handbook

Jack Darr



$5.75
(in the U.S.)

Horizontal Sweep Servicing Handbook

Jack Darr

Gernsback Library, Inc., New York

Library of Congress Catalog Card No. 63-23035

contents

Introduction

THE HORIZONTAL SWEEP STAGE IS A VERY IMPORTANT PART OF ALL TV receivers. Because of the high voltages and currents it handles, it is also the location of some extremely interesting causes of trouble. In the horizontal sweep stage we include the horizontal oscillator with its automatic frequency control, the horizontal output tube, flyback transformer, yoke, damper tube, boost circuit and high-voltage supply circuits. These sections are all necessary: they all work together. Trouble originating in any one can show up as trouble in another, they're so closely interlocked. This interweaving of functions has caused much bewilderment.

It needn't be this way. If you understand the purpose of each part, why it is there, and how it acts when it breaks down, you shouldn't have any trouble. I have long felt that there was a need for a book, written, as a famous magazine slogan used to say, "so you can understand it." This book is written by a working TV technician *for* working TV technicians. It is a book neither for beginners nor for old-timers, exclusively. It is a help for *anyone* who has trouble working with TV horizontal sweep circuits.

If you understand the purpose of each part in the horizontal sweep circuits you'll have less difficulty in spotting troubles and fixing them. All horizontal sweep systems can be broken down into their *basic components* and tested a piece at a time, using only very simple test equipment. In fact, you can't check them any other way! (Not reliably, that is.) That's what I'm trying to show here; to give you, the working type TV technicians, fast, simple methods of locating and repairing troubles in the sweep system. I'll show you lots of practical shortcuts, developed on the bench, for rapid isolation of trouble. This can be almost as simple as finding a dead bulb in a parallel string of Christmas-tree lights!

Each fault has a typical symptom. Some have "double symptoms" showing up in other circuits. I'll show you how to take these circuits apart and pin down the bug. It's actually pretty easy, once you get the idea.

You'll get the practical application of test equipment for use in checking out this stage. You'll learn how to use your scope to measure voltages, etc. You won't find a lot of mysterious waveforms taken with $1,500 laboratory scopes, with which you're expected to compare your results from your $150 service-bench scope! I *will* show how to get the *necessary* waveforms, using service type equipment, and how to interpret these. The scope is essential for certain tests, but it can be confusing if used incorrectly. (Ask me how I found *that* out.)

You have an advantage over the design engineer. When he builds a circuit, he doesn't *really* know whether it's going to work until he tries it out. *You* know that this circuit worked, at one time. Now, it isn't working; so, what do you do? Find the defective part and replace it. That's all that any service job is. There are your two requirements. Many people seem to think that the technician must know how to *design* the circuit; nay, not so. He has to know *how* it works *in practice*, and know how to recognize signs of trouble. This is a far different thing from design work and, in my opinion, just as complicated! The two requirements aren't at all alike. In fact, many design engineers, despite their knowledge of theory, can't *repair* a defective circuit as fast as a trained technician! The engineer is handicapped by his reliance on theory: the technician knows that "impossible" things can happen, because he's *seen* 'em happen! So, he approaches the problem with an open mind, is able to find the trouble and repair it while the "pure engineer" is still hunting for his slide rule! This kind of *practical* applied theory (actual examples of troubles that have come to service benches) is what you are going to get in this book. I will give the cures, but I will also give the basic theory behind the cure, and how to use it. Armed with this knowledge, you can deal with any kind of defect encountered in horizontal sweep systems more easily.

JACK DARR

Chapter 1

Basic Parts of the Horizontal Sweep Circuit

THE HORIZONTAL SWEEP CIRCUIT IN ALL TV RECEIVERS IS ABOUT the same. The same types of parts are used, for the same purpose. Different tubes, flyback transformers, etc., are used, of course, but *basically* they're alike—they have to be: they all do the same things!

This circuit has three functions: it provides the horizontal sweep currents to sweep the beam across the face of the CRT screen; it is the source of the 10- to 25,000-volt dc supply for the *ultor* (high-voltage) anode of the picture tube, and it is the source of the boost voltage. It also provides pulses for various keyed and gated circuits in the receiver. Now, let's see what we need in this circuit to do all of these jobs at the same time.

The *horizontal oscillator* furnishes the driving signal for the system. Its frequency is controlled by the automatic frequency control (afc) circuit, and its output is a 15,750 cycles per second* trapezoidal waveform. This is the drive signal for the horizontal-output

---

*While the horizontal sweep frequency is considered to be precisely 15,750 cycles, this is often only a nominal value. The main point is that the horizontal oscillator in the receiver stays locked to that from the TV transmitting station. The transmitting station may get its sync signals from any one of four sources: a crystal oscillator, a station network signal, a multiple of the 60-cycle line frequency or that frequency recorded on a tape along with the program material.

The 60-cycle power line is a commonly used stabilization method, which is precise only during a 24-hour period. At any instant, it is possible to be off by several cycles. Its use eliminates or reduces some types of ac hum effects in the picture.

The crystal oscillator will also vary over a period of time as well as from TV

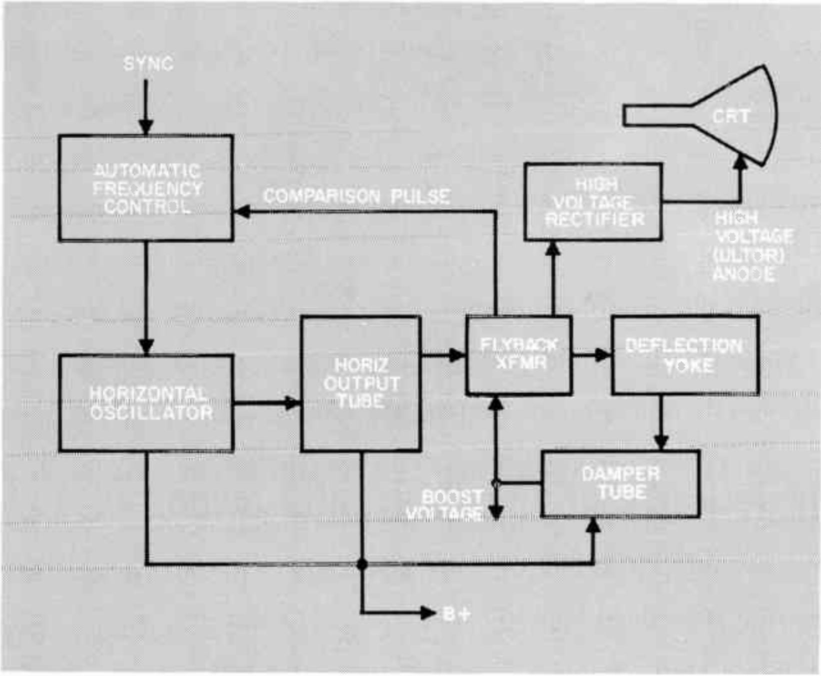


Fig. 101. *Block diagram shows basic connections between stages in TV horizontal sweep circuits.*

tube, a power amplifier which has the flyback transformer as an output load. This is a specially designed transformer with a dual purpose. One winding steps up the pulses to a high voltage; these are applied to the plate of a special high-voltage rectifier tube, to supply

---

broadcast station to broadcast station. It is this frequency variation that causes the windshield-wiper effect seen when two stations are received on the same channel at the same time. For color TV, the sweep frequency is lowered to 15,734.264 cycles.

Network stations and co-channel stations that interfere with one another in certain service areas use a common sync source to eliminate the windshield-wiper effect. The common sync source keeps the blanking bars locked so that they are superimposed one on the other—preventing the sync of one broadcasting station from affecting the received picture stability of the other. The faint picture in the background is less objectional to watch than the constant wiping effect of the equally faint blanking bar.

Programs recorded on tape are complete with synchronizing signals. The frequency can be affected by the tape drive speed (from the 60-cycle power line) as well as by the "stretch" inherent in the tape because of temperature and humidity effects, among other things.

Switching from one program to another may switch the sync source as well. This is common when switching from a "live" program to a recorded commercial announcement. This often causes picture jitter or jumping or (in the case of a color commercial) a complete loss of horizontal sync. Such effects may be quite normal in the design of the receiver.

the high-voltage (HV) for the CRT. Follow these through on the block diagram of Fig. 101.

The flyback is connected to the deflection yoke. What we are looking for is a sawtooth *current* waveform in the yoke windings

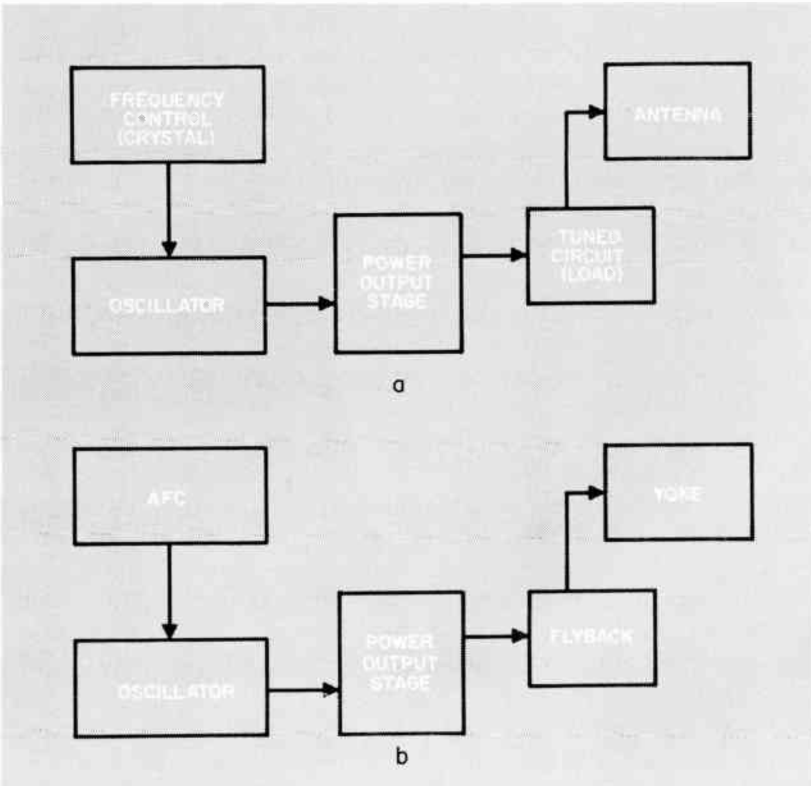


Fig. 102. *Comparison between low-power transmitter (a) and horizontal sweep stage of TV receiver (b) shows areas of similarity.*

for linear deflection of the electron beam in the CRT. To make this possible, another rectifier tube (called the damper) is connected so that it "straightens out" (makes more linear) the sweep waveform. As a bonus, we get an additional dc voltage from this tube. Added on top of the normal B-plus voltage, this is called *boost*. We use it for supplying other stages in the receiver—even the horizontal output tube itself. We'll go through a detailed analysis of the whole circuit later.

The horizontal sweep circuits are a lot like a radio transmitter.

In fact, you'll hear us referring to *rf* later on, meaning the 15,750-cycle ac in the HV rectifier circuit. While this is not, strictly speaking, rf, if you get an unwary fingertip into some of it, you'll know what we mean!

Fig. 102 shows the comparison between a radio transmitter and the sweep stage. In the transmitter, we have an oscillator (the source of the signal) with its frequency control (a crystal). The power amplifier stage builds this signal to the level we want, and feeds it to a tuned load, the antenna coupling circuit. If this circuit is not tuned, resonant at the right frequency, we lose efficiency. From this, we go to the actual output, the antenna itself.

Note the almost exact duplication of functions in the horizontal sweep stage. The main object in all work like this is to get the most out for the least in: in other words, the highest efficiency. In the transmitter, if the load is properly tuned, we take advantage of the resonance of this circuit to build a very large circulating current, and get a high rf output for a minimum expenditure of energy. In the horizontal-sweep circuit, the same basic principle is used. The load of the yoke/damper circuit is actually tuned, so that we can get maximum efficiency. Remember this basic fact, for we're going to refer to it several times in the future. By resonating this circuit, we can make it very efficient. In fact, as they used to say about the old packing houses, we're going to use everything but the squeal before we get through! You'll see how this works; we can pump energy into the circuit, use it, then take the same energy back again and use it for something else! (This is the boost circuit.)

So there you have it. That's all there is to this stage: four tubes, the oscillator coil, flyback and yoke. They work together in such a way as to do all of their many jobs at the same time. Naturally, any trouble in one part is going to be reflected into other parts of the circuit. So, we must learn to recognize the symptoms of different defects, and be able to isolate them to the circuit which is actually the cause.

There is only one way to do this: sectionalizing the circuit and checking parts one at a time. If you try to test the circuit as a whole, the interlocking of reactions sometimes makes it almost·impossible to pin down the defective part. This is something like passing a signal through a four-stage audio amplifier and, by this one test, trying to decide *which* stage has low gain! It can't be done. You'll have to check each stage by itself. So, learn to start sectionalizing *at once* when you have horizontal sweep trouble.

Just as in all other circuits, there are a lot of short-cut tests you can use; observations, which, if properly interpreted, will eliminate one whole stage or another as a possible cause of the trouble. For example, if you connect a scope to the grid of the horizontal-output tube, and find a trapezoidal waveform of about the right frequency at some 75 to 100 volts peak-to-peak amplitude, you can go on from there without further testing of the horizontal oscillator or afc. They must be OK or you wouldn't have that kind of signal at the output tube grid. Many other short-cut tests can be made in the same way, and we'll show you all of them.

The main thing about any testing is to use a definite *order*, a method of testing. You must learn to begin at the beginning and make the right tests in the right order, so you won't overlook some defect in the early stages. For example, if you checked the output tube's grid and found no signal there, it would be useless to go farther, testing the flyback, for example. We must have signal on this grid before we can get *anything* out of the flyback! As we have said, and will say again, you have one definite advantage: you know that the circuit did work *at one time*. All you have to do is locate the part which has failed, replace it and readjust the circuit for best operation. It isn't half as complicated as it seems!

Chapter 2

The Horizontal Oscillator

To BEGIN AT THE BEGINNING, AS WE OUGHT TO, LET'S LOOK AT THE horizontal oscillator. After all, this is the source of the driving signal for the whole circuit. If it isn't working as it should, we're not going to get anything at all from the rest! The oscillator stage must furnish signals of the right frequency, amplitude and waveform, so that the horizontal-output stage can do its job. So, there you have the first requirement for servicing these circuits: the oscillator must be working, and working right.

Many technicians are somewhat afraid of this circuit. Actually, it's a pretty friendly sort of stage. Remember, it did work, once, and all it wants now is a little help from you to work again. If you could lift the oscillator circuit out of a set and put it on the bench, you'd have more trouble keeping it from oscillating then you would getting it to oscillate. It *likes* to oscillate! Why? Let's see.

Basic characteristics of oscillator circuits

What *is* an oscillator circuit? First, what's an amplifier? An amplifier is an electronic circuit which can accept a small signal, and make it into a larger one (Fig. 201). Sometimes we use negative feedback, in which a percentage of the output is connected back to the input, in the proper phase to correct the frequency response (Fig. 202). If this feedback is not in the right phase (out of phase), the amplifier will oscillate. Again, what's an oscillator? An amplifier which has enough of its output fed back to its input (Fig. 203), so the circuit overcomes its own losses. It can't help but oscillate.

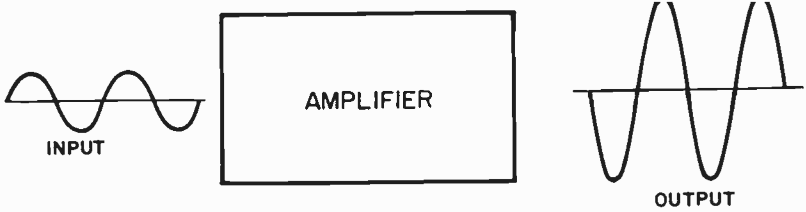


Fig. 201. *An amplifier increases the amplitude of signals passing through it.*

So, now you see the one condition necessary for a circuit to generate oscillations; it must be capable of *amplifying* a signal. This means that the tube or transistor must be good, and that the correct operating voltages must be applied to it. Simple enough. Now, if we connect the output of this amplifier (in phase) to its input, it oscil-

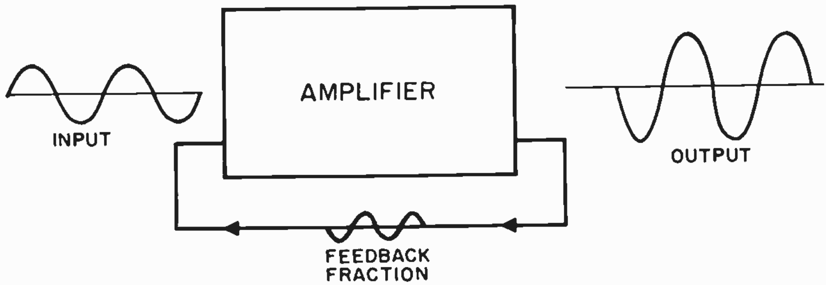


Fig. 202. *Feedback circuit added to amplifier can cause many different effects depending on the phase and amplitude of feedback. Oscillations will generally occur at one frequency only. This depends on circuit constants that are most favorable to that frequency.*

lates. What if it oscillates at the wrong frequency? One of the frequency-determining parts of the circuit is off value. As you'll see very soon when we get into practical oscillator circuits used in TV receivers, this amounts to only *two or three parts*. If necessary, we can replace all of them at once, to be sure of getting the defective one, without going to too much trouble. We will indicate these parts in each diagram.

Each oscillator circuit used in TV circuitry must have three basic characteristics. It must be capable of free-running: that is, of sustaining oscillations all the time, without having to have external excitation (from the sync, for example). This is needed to keep the electron beam moving and make a raster on the CRT when no signal is being received. That's one. Two, it must make waveforms of the proper *shape* and frequency for the circuit in which it is used. (We'll show you how this gets done in just a minute.) Three, it must be capable of being *controlled* by the incoming sync signals, so that it will remain locked in step with the transmitted video signals at all times. An oscillator which is *too* stable won't do for this kind of service; for example, a crystal-controlled type. This would be too stiff, as the phrase goes. The sync wouldn't be able to pull it into frequency and hold it, as it must. The oscillator circuit used must basically be capable of holding somewhere *near* the right frequency, yet be easily controllable

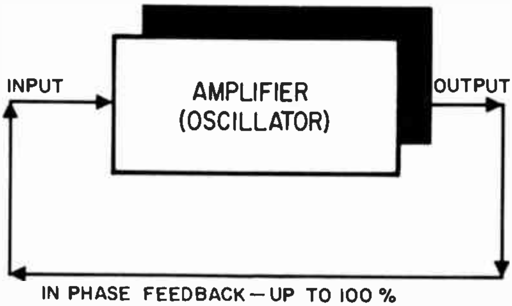


Fig. 203. *Amount of feedback needed depends on the gain of the amplifier.*

over the right range of frequencies. The horizontal oscillators and control circuits used in modern TV receivers do a wonderful job of holding the horizontal-sweep frequency constant, without too much jittering or falling out of sync during interruptions or noise interference. We'll show how this is done when we get to the automatic frequency control circuits.

The isolation method of servicing

Because of the interaction in these circuits, there is only one practical way to service them. They must be broken down into sections, and checked out one at a time. This isn't as hard as it sounds. The horizontal stage has two basic parts: the oscillator, which includes the afc and stabilizer circuits, and the output, which includes the output tube, flyback transformer, yoke, damper and HV rectifier tubes. It is possible to take these circuits apart and check them out a piece at a time. More details will be given as we go through the circuit of each type used in TV receivers.

Since the horizontal oscillator is the source of the driving signal for the output stage, it must be checked first. Unless the oscillator is working properly, any tests that we make on the output stage will be meaningless.

Basic method of isolating the cause of oscillator trouble

Each oscillator stage has three parts: the oscillator circuit itself, the "stabilizer" circuit and the afc. To pin down the cause of any defect in the circuit, we must check these three parts one at a time. Since the oscillator circuit is the prime mover here, we disable the two control circuits and make the oscillator stand on its own two feet and work all alone. Only in this way can we be sure that it is capable of doing the job. The actual methods used will vary, but this is the general outline. We disable the stabilizer circuit by shunting it out, sometimes actually shorting out whatever part is used (coil, etc.).

Next, we disable the afc, so that the horizontal sync cannot affect the oscillator frequency. Reason: we must have an oscillator circuit capable of running by itself, very near to the correct frequency. If the oscillator is slightly off frequency, the afc may be able to pull it back and hold it fairly well, but the set will be very unstable, like a car with a soft front tire: the driver must hold a constant pull on one side of the wheel to keep it on the road. For the best results, we want our oscillator to run on frequency with only a gentle nudge now and then from the afc to keep it there. So, we make sure that it will by taking away the action of the afc and making the oscillator run alone. As to "how", we will give detailed instructions for doing this, as we go through the circuit description and servicing techniques for each oscillator circuit.

To sum up this process for now, we disable both the stabilizer circuit and the afc, and see if the oscillator will run and make a single picture on the TV screen. Under these conditions, with no control of any kind, this picture will float back and forth across the screen. But, the fact that it is possible to get a *single* picture tells you that the oscillator *is* running at 15,750 cycles per second.

After this, we reconnect the afc and stabilizer, one at a time, and watch the results. If one of these circuits causes a normally operating oscillator to suddenly take off, then we have discovered one fact: the oscillator circuit is OK, but one of the *control* circuits has a bug in it!

Horizontal blocking oscillators

First, let's take some of the popular circuits used in horizontal-oscillator stages, then we'll go into the matter of waveform shaping. Let's start with one of the older oscillator circuits in use: the blocking oscillator.

Fig. 204 shows the basic circuit of a blocking oscillator. Note that both plate and grid circuits are connected to the same transformer. Now, if we turn this circuit on (apply proper voltages), what happens? Plate current starts flowing through the load resistor (R_p) and the primary of the transformer. This induces a voltage in the secondary. If the transformer is connected right, this causes the

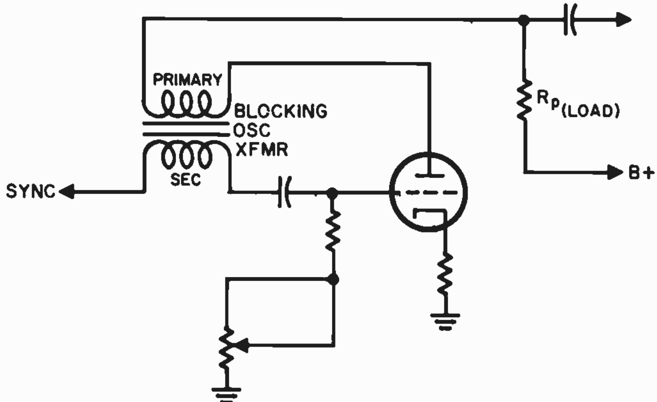


Fig. 204. *The basic blocking oscillator circuit. The load (Rp) is needed to transfer signals to the following stage. The transformer is used to couple feedback voltages to the input.*

grid voltage to go positive. This bias increases the plate current, which in turn causes more positive bias to show up on the grid. This keeps on until the tube reaches its saturation point. It is drawing all of the plate current it possibly can, with the amount of plate voltage that is applied.

At this point, the plate current becomes steady. So, since it takes a *changing* current in one winding of a transformer to cause any induced voltage in the other, our grid voltage stops increasing. Now, the magnetic field which was created by the rising plate current stops moving out, and begins to "fall back" into the transformer. As it does, it cuts the turns of the windings in such a way as to induce a voltage in the secondary of *opposite* polarity from the initial surge. This places a negative voltage on the control grid. Negative grid voltage means a *decrease* in plate current; this reduction in plate current means still more negative grid voltage, which reduces plate current again, and on and on.

The finish, of course, is the point where the negative grid voltage is so high that the tube is blocked, or cut off; so, we call this circuit a *blocking oscillator*. It runs alternatively from a "plate block": full-saturation plate current, to a grid block, or cutoff; full negative grid voltage stopping all plate current from flowing. The alternations in plate current created by this process appear across the load

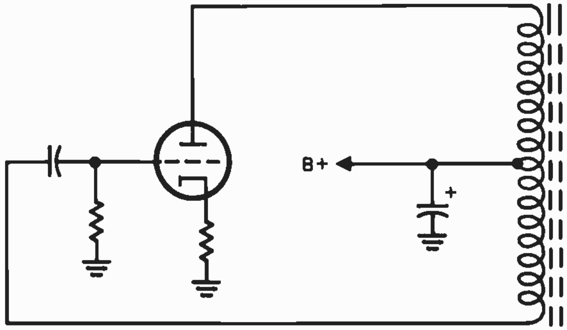


Fig. 205. *Tapped winding of Hartley oscillator circuit is used for feedback. Amount of feedback is controlled by the turns ratio of the two portions of the winding. A secondary can be added to provide an output or a load resistor can be inserted between the tap and the electrolytic capacitor.*

resistor R_p in the plate circuit. Changes in the current through this resistor create a varying voltage drop. This can be taken off through a suitable capacitor and used as the oscillator's output signal.

Now, let's look at another version of this circuit, one found in many of the older TV receivers, and still used today in one form or another. Fig. 205 look familiar? Not yet. This is a genuine blocking oscillator, though; look at the plate and grid connected to opposite ends of the *same coil*. This satisfies our feedback requirement, since this has 100% feedback. The ends of the coil are out of phase by 180°, so our feedback is regenerative (tending to *cause* oscillation). The center tap of the coil is actually ground, as far as ac is concerned, since it is connected to a presumably very well bypassed B-plus point.

All right, now let's add a few parts to this and see if it doesn't look more familiar to you (Fig. 206). Now. What's that? Yep. This is the old faithful *Synchroguide* circuit. You'll find small variations of the basic circuit, but as long as it has a tapped blocking-oscillator coil, with a *waveform coil* in series with the tap to the output, it's still a Synchroguide, and can be serviced as such.

The working part of this circuit is the blocking oscillator. This consists of the tapped coil, the tube (to keep oscillations going) and the various coupling units and voltage-supply parts. Here, these consist of a small (usually about 300-350 pf (μμf) mica capacitor (C4) to couple the grid to the coil and isolate the B-plus voltage; a damping resistor (R6) across the coil to help shape the waveform, and the resistors which supply the B-plus voltage to the oscillator plate and the grid resistor. (More about this last in just a minute;

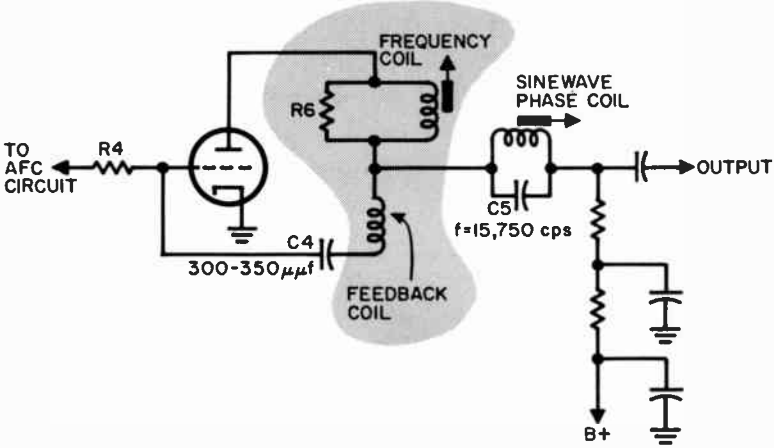


Fig. 206. *Compare this circuit with that in Fig. 205. Feedback coil appears in shaded portion.*

we've got other uses for it.) That's all the parts that are used in the *oscillator* circuit. The rest, like the waveform coil (often called the *sine-wave coil*) and the afc circuit, are merely controls for the basic oscillator.

The sine-wave coil is so called because it generates a sine waveform every time a sawtooth pulse arrives from the oscillator. (Or, from shock excitation, if you'd rather.) It's a parallel-resonant circuit, as you can see from Fig. 206, made resonant to 15,750 cycles. An adjustable iron core in the coil allows adjustment of this resonant frequency. Because this also means that the resonant frequency can be changed in phase (we'll see how this is done in a short time), comparing it to the sawtooth oscillator frequency, this is sometimes called the "phase" coil.

The basic purpose of this coil is to stabilize the oscillator frequency. The resultant waveform is a combination of the sawtooth and sine wave, as you can see in Fig. 207. Remember this funny-looking wave; you're going to see a lot of it in the future!

We have drawn this as a pure sawtooth. Actually, the output of the oscillator circuit would look more like Fig. 208-a, if we disconnected all of the shaping components—a sort of humpbacked sawtooth. The big disadvantage to this is its very gradual approach to the *firing point* of the oscillator. In all oscillator circuits, the waveforms raise the grid (usually) or plate voltage to the point where the tube starts to conduct very suddenly. By doing this, we get the desired sawtooth waveform shape. Circuit conditions often cause this to come out as a sort of rectangular waveform, but we can always make this into the shape we need. Later, we will go into the actual process of making sawtooth waves and show just how it's done.

In such circuits, we need a couple of things. One is constant control of the firing point of the oscillator, so that it will be stable—stay

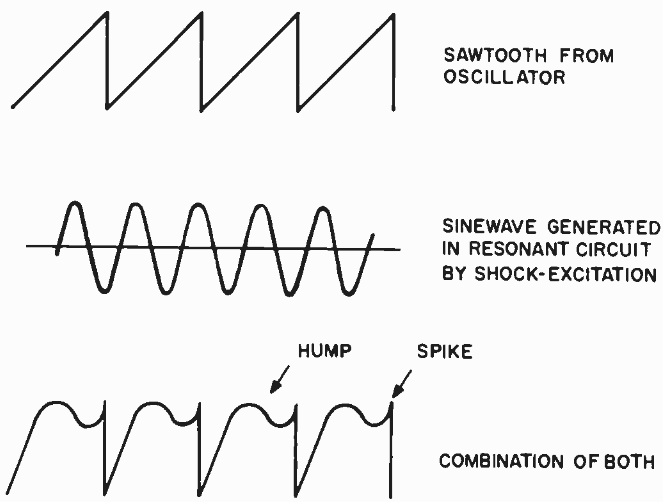


Fig. 207. *The sawtooth and sine waveforms are combined to produce the waveform shown at the bottom of the drawing.*

on frequency. The other, the maximum immunity to disturbance by noise. If a random noise burst causes the oscillator to fire at the wrong time, it will be off frequency. In the dashed waveform of Fig. 208-a, we can see what would happen if a small noise pulse got into the circuit; the oscillator fires a fraction of a cycle ahead of time. This would cause that line in the raster to be displaced to the left by a certain amount. Of course, the picture information it carried would go with it. Several of these interfering pulses, and we get a jagged picture, with groups of lines displaced sidewise with respect to the rest. Vertical lines in the picture look like sawteeth.

So, if we add a sine wave to the humped sawtooth, we get the Synchroguide waveform of Fig. 208-b, with the hump and spike. By adding the sine wave, we have made the waveform approach the firing level much more steeply than it did before. So, only the very high-amplitude noise bursts cause the oscillator to fire too soon.

Another benefit of this is the added stabilization given by the presence of the sine wave. Since this waveform section is a "passive" circuit, one in which there are no active elements like tubes, it tends

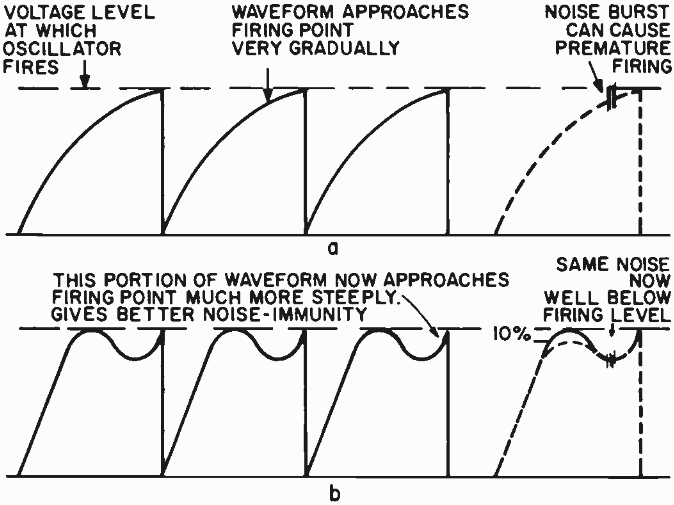


Fig. 208. *Noise pulse at oscillator grid can cause tube to conduct earlier than it should (a). Addition of sine wave pulls noise pulse below firing level of tube (b).*

to be pretty stable. This holds the oscillator frequency more constant. As we said, we can shift the relative phase of the sine wave with respect to the sawtooth, making the resonant frequency higher or lower than the oscillator, and change the position of the hump with relation to the spike as well as change the shape of the waveform.

Fig. 209 shows the complete circuit of a Synchroguide horizontal oscillator. The left triode, V1, is the afc tube. The right triode, V2, is the oscillator. Parts values are taken from an actual circuit. Note that we have indicated the parts which determine the *operating frequency* of the oscillator. We'll do this in all succeeding schematics, so that you'll know where to look first when you get off-frequency troubles.

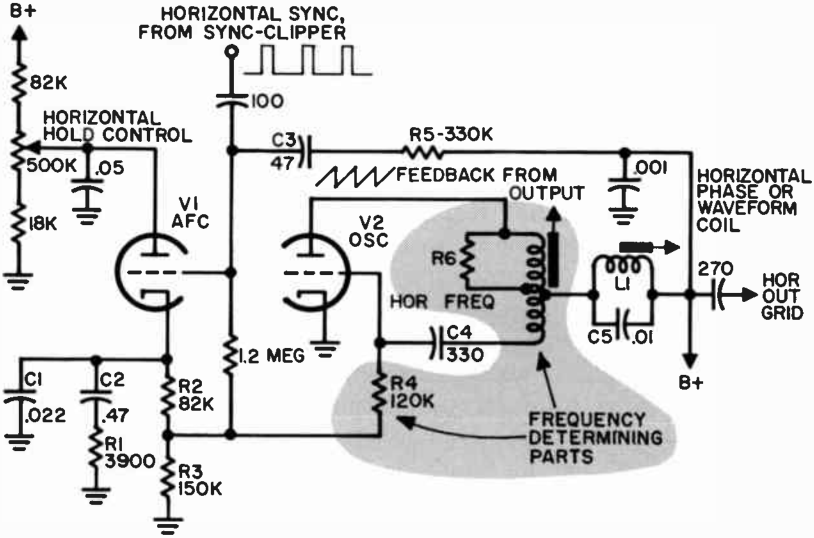


Fig. 209. *Frequency determining components not in the afc circuit are shaded. Any change in voltage to the grid of V2 (through R4) will cause the frequency to vary.*

Now, we have the oscillator circuit and its stabilizing coil. We must have some way to synchronize the waveforms from this circuit with the horizontal sweep sync pulses in the incoming video signals. So, we add an afc (automatic frequency control) circuit. Let's take a look at this part of it.

The pulse-width afc circuit

Because we make the *effective width* of the horizontal sync pulse control the amount of dc voltage this stage develops, this is called a pulse-width afc circuit. We do *not* change the width of the sync pulse, just the amount of it that is *used*. Let's see how.

As you can see from Fig. 209, two pulses are fed into the grid of the afc triode at the same time. One is a regulated-amplitude horizontal-sync pulse from the sync-clipper stage, which maintains the same amplitude at all times. The other is a shaped sawtooth fed back from the output of the oscillator through the 330K resistor (R5) and 47-pf capacitor (C3). Incidentally, this network also helps reshape the hump–spike waveform into a slightly better sawtooth pulse.

In Fig. 210 you see the two pulses and their combination waveform. Note that the sync pulses are riding on top of the sawtooth.

They are not riding exactly on the peaks, but halfway, so that part of the horizontal sync pulse falls into the steep valley caused by the return trace or "flyback" part of the sawtooth waveform. This is the "on-frequency" condition, where approximately half of the sync pulse is effective above the peak of the sawtooth.

Now, let's see how we can make this control the oscillator frequency without going too deeply into the very complicated mathematics of this circuit. If we can change the steady dc bias on the control grid of the oscillator tube, we can change the frequency of operation. Why? Because we're changing the grid *operating point,* we change the amount of time which the tube conducts during each cycle of oscillation. If we make this nearer to zero, that is, more *positive,* the tube conducts sooner and the frequency increases. Making the bias more negative holds the tube cut off longer and the cycles are longer, and the oscillator runs slower.

So, all we need is some kind of circuit which will make a dc voltage that is directly proportional to the *frequency* of the oscillator, a voltage that changes polarity if the oscillator drifts off frequency. If we had a frequency standard, that is, some frequency we could compare the horizontal oscillator with, this would be easy. We've got one in the horizontal sync pulses in the video signal! So, what we do is compare the *phase* (the timing) of this sync with the signal from the horizontal oscillator and we have a *phase detector.*

What's a phase detector? In this case, it is a balanced circuit in which we feed the sync to one input and the oscillator signal to the other. The *amplitude* of the two signals is made the same by using voltage dividers and similar circuits. As long as the two signals arrive at the same time (in phase), we have no dc output. If one of the signals changes frequency, then they get there at different times, the circuit becomes unbalanced and a dc output voltage shows up at a given point. We feed this to the oscillator grid and make it control the oscillator frequency. How? Because the dc voltage output of the phase detector changes in polarity and amplitude according to which *way* the frequency changes and how *far* it changes. (Note: the *change,* here, refers to the *oscillator* signal, always!) Since the sync is our reference frequency, we consider it as fixed, or always accurate, even though it changes. Because the *picture information,* the video, is tied to this frequency, we *must* make *our* local oscillator work at the same frequency. So, any time we speak of frequency change or drift, we mean the oscillator in the TV set. The circuit is designed so that if the oscillator runs faster (higher frequency), the phase detector output goes negative, and the resulting dc voltage slows the oscillator to the right frequency. If the oscillator slows, the dc output of the phase detector becomes positive and makes the oscillator run faster.

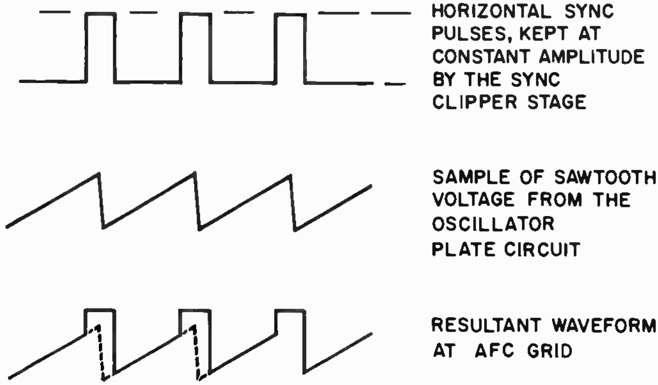


Fig. 210. *Combining the rectangular sync pulse with the oscillator sawtooth forms a trapezoidal waveform. The dashed lines in the trapezoid are included only to show the sawtooth. The actual waveform without these lines is shown in the bottom waveform, at the right.*

Now, let's take a moment to clear a point that has puzzled a lot of technicians. We talk about a change in voltage, as if the control grid were at zero volts. In some circuits, it is. However, in quite a few, it isn't. Don't let this bother you: all that we need in circuits like this is the *change* in grid voltage! For example, if the voltage on the control grid measures −10 volts dc, and our phase detector will shift this from −8 to −12, we have a ±2 volts control voltage shift, and that's usually plenty! We have the same reaction that we would have if the grid were at zero, and the voltage actually shifted from 0 to +2 then back to a −2. As long as the control voltage shifts the right amount, and in the right direction, we don't care if the fixed voltage on the grid is 100 volts. As long as we get our ±2-volt *shift,* it's still operating as it should.

Now, how do we make this voltage shift, and how is it applied to the oscillator? Note in Fig. 209 that the control grid of the oscillator is returned to ground through the 120K grid resistor (R4), and connected to a point on a voltage divider in the cathode circuit of the afc section. So, the dc voltage developed in the cathode circuit of the afc triode determines the dc voltage applied to the control grid of the oscillator. We'll have a little more to say about voltage relations in this circuit very soon; they can be confusing, unless you know exactly what it is doing.

If we change the plate current of the afc tube, the current flowing through the two cathode resistors (R2 and R3) also changes. This gives a dc voltage drop directly proportional to the amount of plate current change. A portion of this change is applied to the control grid of the oscillator tube by the voltage divider. Now, all we need to do is find a way to make this dc voltage change in step with the frequency of the oscillator. We can do this by putting a phase comparing circuit in the grid of the afc tube.

Fig. 211-a shows how we can bias the afc triode by means of the cathode resistors so that only the pulse part of the composite waveform appears above the grid cutoff line. The rest of the waveform has no effect on the afc tube at all, since it represents voltages that are below cutoff, and no plate current is flowing. The *duration* of these pulses is what controls the amount of dc voltage developed. Wide pulses let current flow for a longer time, charging the capacitors (C1 and C2 in Fig. 209) across the resistors in the cathode circuit to a higher voltage. Narrow pulses cause shorter current flow and less voltage is developed. So, by changing the effective *width* of the pulses, we are controlling the amount of dc voltage developed in the cathode circuit. Remember, this is the reason for the name of this circuit: pulse width afc.

Now, we set up the circuit by adjusting resistance values, etc., so that, when the horizontal sync pulse is sitting half on top of the sawtooth and half down in the flyback valley, the horizontal oscillator is on frequency. If the oscillator starts to run slower, it means that the horizontal sync pulses are going to stand still (since they are our reference frequency) and the sawtooth pulses move. Being slower, they are now *longer* than they had been; so, they move to the right (Fig. 211-b). The half of the sync pulse which had been down in the valley moves up to the top of the sawtooth and becomes a wider pulse above the grid cutoff line; the afc tube now conducts for a longer time, and develops a higher positive (+) voltage. This is applied to the oscillator grid and pulls that circuit back to its correct frequency by making it oscillate faster.

When the oscillator runs faster, we get an opposite reaction. The sawtooth waves become shorter, because there are more of them in the same period of time, and move to the left (Fig. 211-c). Now, practically all of the sync pulse has fallen into the valley, leaving only a very thin spike above the cutoff line. This shortens the conduction time of the afc tube, and less voltage develops across the cathode circuit; it goes more negative. This negative voltage slows the oscillator, bringing it back on frequency again.

These shifts in oscillator frequency take place very smoothly and quickly. So quickly, in fact, that you can't see any effect at all in a normally operating circuit. Actually, the afc doesn't wait until the pulses are as far off as we showed them in Fig. 211. The instant the oscillator frequency begins to drift, a correction voltage is developed which very gently nudges the oscillator back into line.

Note that there are two capacitors (C1 and C2 and one resistor R1), in an R-C network in the cathode circuit of the afc in Fig. 209. These have a very definite purpose. The capacitors charge

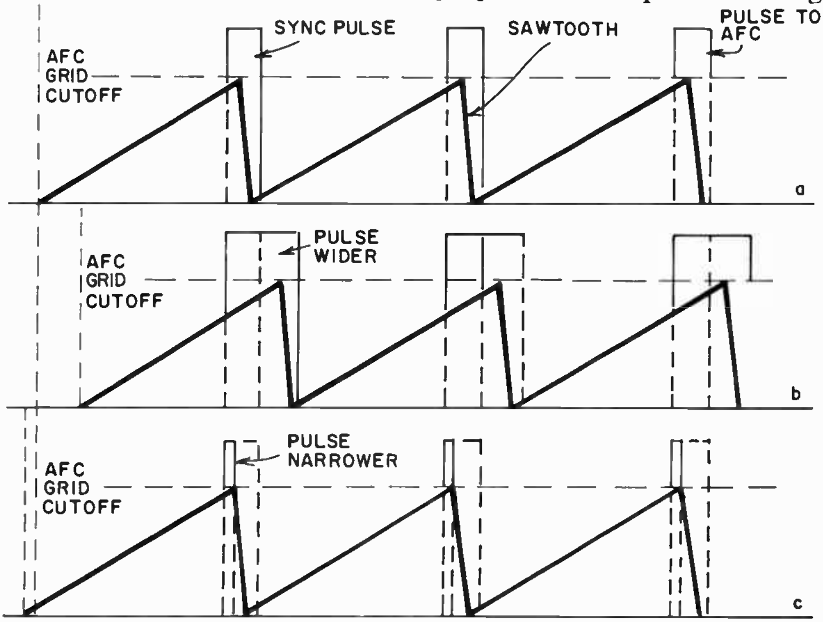


Fig. 211. *Algebraic addition of the sawtooth and rectangular sync pulses during different phase relationships increases or decreases the duration of the pulse fed to the afc control tube grid. A long pulse duration increases the voltage applied to the grid. A short duration pulse decreases the grid voltage.*

during periods of conduction, when there is a voltage drop across resistors R2 and R3. When the voltage changes, they discharge (or charge, depending on which direction it shifts) into the resistive network. This gives a certain amount of delay in the action of the dc control voltage. This is very necessary. If it weren't for this delay action, this control circuit (capable of reacting so rapidly that it can correct a shift in frequency in a fraction of a microsecond) would yank the oscillator frequency violently back. The oscillator frequency will be jerked back and forth past the correct frequency several times, if the *reaction time* is too fast. This *overshoot* is usually called *hunting*. This results in a sidewise displacement of several lines in the picture, part of them to the left and part to the right. This makes vertical lines in the picture seem jagged, and circles in the picture look like gears! For this reason, this effect is called *gear-tooth effect* or *piecrusting* (Fig. 212). It is caused by the horizontal oscillator frequency being jerked rapidly back and forth *across* the correct frequency. The circuit is hunting for the right frequency, but is going too fast to stop there! So, this reaction is called 'hunting', and is always caused by trouble in the horizontal afc.

The resistor (R1) and capacitors (C1 and C2) on the cathode in Fig. 209 are chosen to have a comparatively long time constant —the amount of time needed to charge or discharge the capacitors through the resistor. So, if we use very small value capacitors, we get a short time constant, and the circuit can react rapidly, or hunt. Too large value capacitors would let the circuit react too slowly to frequency changes, and the picture could drift from side to side slowly before the afc could bring it back. So, the values of these parts are chosen to give the best compromise time constant, for the smoothest afc action. For this reason, any defective parts in the anti-hunt circuit must always be replaced with exact duplicate values.

Variations of the Synchroguide circuit: controls

You'll find two common versions of this circuit. One is as we've drawn it in Fig. 209. Note that there is a potentiometer in the plate circuit of V1, which can vary the plate voltage of that tube. This is the horizontal hold control. By changing the plate voltage, we can change the conduction time of the tube. The actual control-grid bias voltage needed to cut plate current off in any tube is dependent on two things: the characteristics of the tube and the dc plate voltage applied to it. Naturally, if a high plate voltage is used, we need more negative grid bias to cut it off, and vice versa. So, we can control the action of the afc tube by varying the plate voltage.

This action takes place through the afc circuit. In other words, we are not controlling the frequency of the oscillator directly, but controlling the control circuit. Since the inductance of the transformer affects the frequency directly, we can also vary the frequency by varying this inductance. So, you'll find this circuit in a lot of TV sets without the potentiometer in the afc plate circuit. The afc plate will be returned to the B-plus line through an appropriate

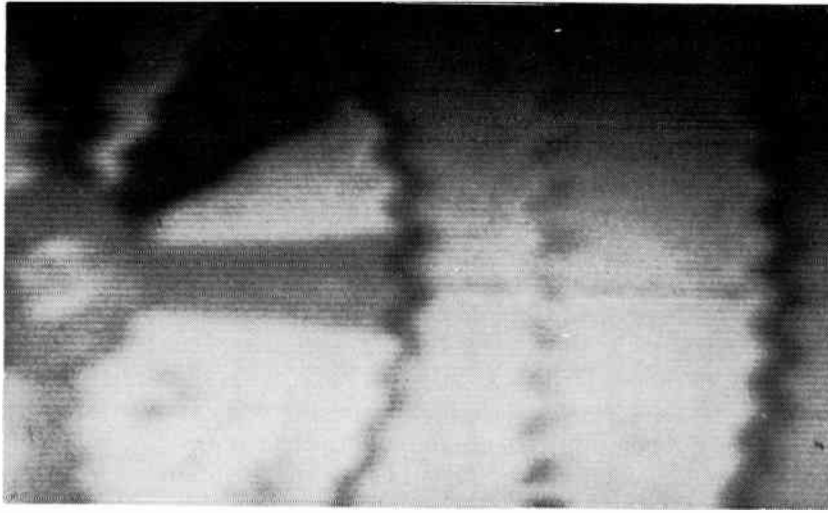


Fig. 212. *Overshoot or hunting results when the afc circuit compensates too rapidly.*

dropping resistor, of course, and the hold control will consist only of the frequency-coil slug of the Synchroguide transformer. The adjustable iron core of this coil, which varies the inductance, will be extended through the front panel of the set and a knob placed on it.

Due to the naturally high degree of stability possible with a correctly designed Synchroguide circuit, this works very well, and saves parts. The resistors and potentiometer can be left out. However, this circuit is always a Synchroguide no matter what parts are missing: as long as you have the center-tapped oscillator coil, plus the sine-wave stabilizer coil connected to the center tap, it will function in the same way. Now, there are other circuits which vaguely resemble a Synchroguide and do have sine-wave stabilization, and we'll get to those in a moment. However, look for the basic structure to be sure.

Horizontal oscillator troubles

Let's stop for a moment and take a look at some general characteristics of all oscillator troubles before we go any farther. Because of the interaction of these circuits, there is absolutely *no way* to tell which section is bad without making the right tests. However, you can pin down oscillator troubles in a very few minutes with the *right* tests. Most of that time which will be spent getting the chassis out of the cabinet. (In some of the vertical-chassis sets, you won't even have to do that.) We're going to give you the *logical* methods of testing such interacting circuits, and you'd better use them! Hit-or-miss testing, without *thinking*, can leave you wandering around in there for a couple of days! If you use these tests in the right order, you can tell in a very short time just which of the three sections of an oscillator circuit is causing the trouble.

What are the characteristic symptoms of oscillator trouble? Slanting bars on the screen, loss of horizontal sync, horizontal instability, horizontal hold control jammed up against the stop at either end of its range, these all indicate troubles somewhere in the horizontal oscillator circuit. There are only two basic types of oscillator trouble—the completely dead oscillator and the one that won't run on frequency. There are also combinations of these, of course, just to make life more interesting! By this, we mean the cases where an oscillator *is* dead, but not from any fault of its own; something else is killing it. This will be covered in due time. For now, let's take an easy one to begin with.

The dead oscillator

This is usually an easy one to find. There are unmistakable symptoms: there will be no raster, no light on the screen at all. The B-plus fuse in the horizontal output feed circuit *should* be blown, if it's the right size (otherwise the horizontal-output tube's plate will be running red hot). This happens because the horizontal output tube draws very heavy plate current if the *drive* (which is part or all of its grid bias) is lost; so, its plate gets red hot, and, of course, it can't make high voltage or sweep without some input signal. Frankly, about 95% of such troubles are due to weak or dead tubes in the horizontal-oscillator socket, or to the loss of B-plus voltage.

The first step here, as in *all* of this servicing, should be to replace the tube. If this doesn't help, measure the operating voltages. Use a test adapter to save taking the set out of the cabinet. If the B-plus is low, check the power supply, replace the low-voltage rectifier, etc., but get those operating voltages up to normal before looking for other more complicated troubles.

Always make the simple tests first. You're going to find in service work that 95% of the troubles *are* simple ones—dead tubes, burned resistors, shorted capacitors or broken wiring, such as cracks or breaks in printed-circuit boards. Replace all tubes that could possibly be associated with the circuit: oscillator, afc, if this is a separate tube, and even the horizontal output and damper tubes. As we'll see later on, these tubes can affect the oscillator stage. If you get in the habit of *always* making all of these simple tests first, as a matter of routine, you'll be spared the embarrassment of working for an hour on a set, only to find that you overlooked some simple little thing. However, don't feel too badly if you do this once in a while; every one of us does it!

The worst troubles are those in which the oscillator refuses to run, although "everything seems OK". There is no apparent cause; yet, there *must* be a cause. Always remember: this circuit worked once! So, it can be made to work again. The most dangerous thing you can do here is unconsciously adopt a defeatist attitude—"Oh, this is so complicated a trouble that I can't fix it!" If you'll excuse the plain speaking, *bunk!* When you do find this trouble it's going to be a shorted capacitor, a bad resistor or even something as simple as a dirty tube-socket contact! Is that complicated?

The trouble is there, and by applying the proper tests in proper sequence, you can dig it out and fix it. However, if you adopt the hopeless attitude I've seen taken by so many technicians, "There's nothing wrong with it, it just won't work!" you're licked before you start. Make that instead, "There's nothing *obviously* wrong with it: no resistors smoking, etc. But, there is one little bad part in there somewhere that is keeping the oscillator from working, and I'll have to find it." Be calm, and keep on checking parts and *keep thinking*, especially the latter. Confidence in your own ability to diagnose trouble is essential. Not overconfidence, just plain confidence. Later on, we'll go a bit deeper into this business of diagnosis and thinking, for it is *very* important.

Servicing the Synchroguide

Now, let's take a typical Synchroguide circuit, and see how to service it. First, let's get one thing straight: if you can see a raster on the screen, or any light at all, the horizontal oscillator is *trying* to work. In fact, it *is* running. It has to be, or there wouldn't be any light on the screen at all. This means that the oscillator is running, even though it may be off frequency.

Now, we're going to make two assumptions, and they will be made in all discussions from this point on. One, you have already replaced *all* tubes in the circuits under test, to be sure that the trouble is not caused by some obscure defect in a tube. Two, you have checked the B-plus (low voltage) supply, and it is up to normal, according to the value given on the schematic. Power supply troubles are very simple, and we'll have no further dealings with them. In this book our only concern is going to be with troubles that actually originate in the horizontal-sweep system. So, make sure that all tubes and the power supply are in good shape first.

All horizontal-oscillator circuits have three parts, like Caesar's Gaul. Fig. 213 shows the block diagram. The trouble which is making the oscillator run off frequency can be located in any one

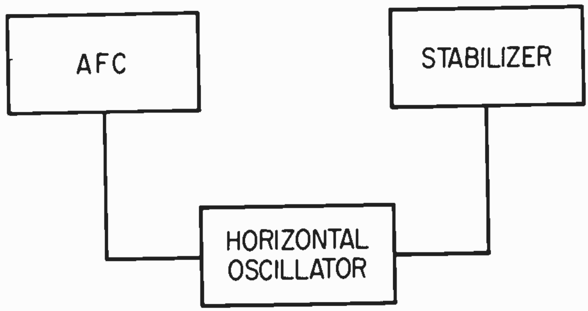


Fig. 213. *The horizontal oscillator and control circuits can be separated into three sections. The oscillator should be able to produce a single picture on the TV screen with the afc and stabilizer disabled.*

of them. The oscillator may have a defective part which is changing the time constant of the frequency-controlling circuit. The afc may have a defective part which is pulling the oscillator off frequency instead of holding it on, or the stabilizer may be bad, or not adjusted properly. Since they are tied together, we can't check any part without untying them.

Let's strip the circuit down to the bare oscillator. Taking the Synchroguide circuit of Fig. 209, we take away the stabilizing action by shorting the waveform coil. Just tie a piece of wire across its terminals, or use a short lead with a clip on each end. Fig. 214 shows the circuit with the parts disabled. To remove the afc action, we open the plate circuit of the afc triode. In most sets, this can be done by unsoldering the lead to the center connection (the slider) of the horizontal hold control.

In a few circuits the afc can be disabled simply by grounding the grid of the afc triode. However, you'll often find a residual dc voltage on this grid which can affect the bias of the oscillator itself. So a safer method is lifting the plate connection. (Later on, we will show you a few other ways to do this.)

Now, what's left? Nothing but the oscillator itself. Will it run this way? Certainly! The circuit has one tube, three resistors (R3, R4 and R5), three capacitors (C1, C3 and C4) and the transformer. A defect in any of these will throw the oscillator off frequency. So we check them out, one at a time.

First step: adjust the core of the frequency coil in the transformer. If the transformer is OK, we should be able to get a single picture on the screen. This will float from side to side, because we've disabled the stabilization and sync. But, if you can see one single picture on the screen, this means that the oscillator is capable of running at 15,750 cps, the correct frequency. If you can't get a single picture, nothing but slanting bars, let's not replace the transformer yet. Check all of the other parts to see if they are good. Measure plate and grid voltages. If these are off, find out why.

For instance, if the plate voltage is low, you should check the .001 μf bypass capacitor (C5) in the B-plus. If this is leaking, it will reduce the plate voltage. This makes the oscillator run far

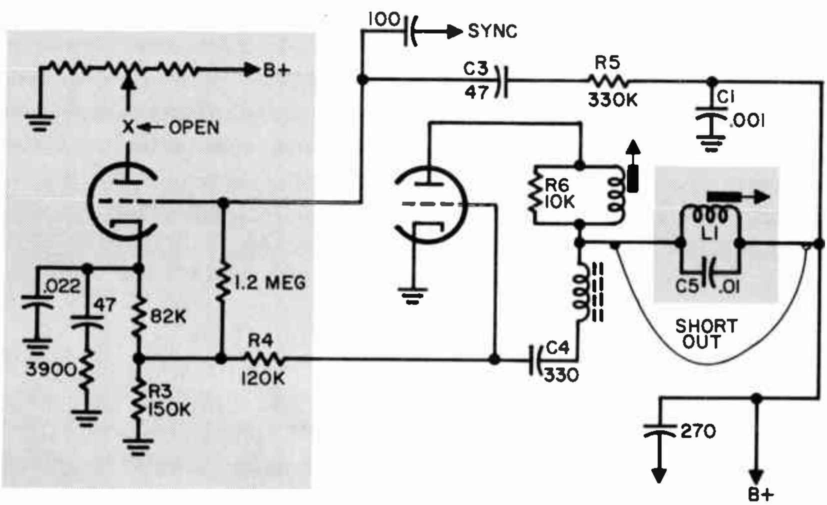


Fig. 214. *Shaded portions of the schematic indicate the afc circuitry (left) and the stabilizer (right). Resistors R3 and R4 form the grid return circuit for the oscillator as well as being considered as part of the afc circuitry.*

below its normal frequency. Measure the dc resistance of the two halves of the oscillator transformer. Check the little 330-pf (μμf) coupling capacitor (C4) for leakage. Measure the dc resistance of the two grid resistors, the 150K and 120K (R3 and R4). Check the 47-pf capacitor (C3) and 330K resistor (R5) in the feedback loop. While these aren't directly connected into the oscillator circuit, they can affect the frequency.

If all these parts check good, *then* you can replace the transformer as it is probably defective. This will sometimes show up in a resistance check as an unbalance in the resistance of the two halves. However, this resistance is a pretty low value, usually, and it takes an extremely sensitive ohmmeter to detect the difference in resistance caused by a few shorted turns in one coil or the other.

After replacing the coil, check to see that you can get a single picture at some setting of the core adjustment; you should. In the average circuit, this will be somewhere near the center of its adjustment range. Incidentally, if an oscillator of this kind suddenly jumps far off frequency but can be brought back by setting the frequency-adjustment core almost all the way to one end of its range or the other, look for other troubles. This means that one of the parts is shifting in value, throwing the circuit out of resonance.

Don't let this set go back without checking all the other parts: in almost all cases this will mean a callback when the bad part goes all the way out. This kind of trouble can be due to small leakages in capacitors, a shift in the ohmic value of resistors, etc. One obscure cause for this has been found in transformers which have a cracked iron core! If only part of the core is still attached to the adjusting screw, you can get some extremely peculiar effects! To check for this, set the oscillator on frequency, then turn the chassis over and jar it with a screwdriver handle, etc., to make the loose part of the core move. If jarring the chassis throws the oscillator off frequency, something like this will be the cause.

Look the whole chassis over very carefully for loose solder joints, bad wiring, loose connections in printed-circuit boards, etc. If the set has been worked on by an inexperienced or careless technician, you can find almost anything!

Incidentally, a word of warning right now: always check the *value* of all parts in these circuits. Check by color coding and by actual measurement, and see that they are the same as those shown on the schematic. You may find parts of the wrong value, wrong connections and other boo-boos put into such circuits! A very common mistake made by incompetent technicians is misreading the final color band on a resistor. So, you find a 12,000-ohm resistor in the circuit in place of a 120,000! (Read orange for yellow!) This can cause some *very* interesting effects, so look out for it.

Checking the oscillator for stability

Now that we've got the oscillator running (and running near the right frequency), we can see one picture sliding back and forth across the screen. It may pause for a split second, then slide away again, but as long as it remains a single picture, not broken up into slanting bars, it's within tolerance. To check the oscillator for stability, let it run this way for a minute or two. If the oscillator is fairly stable, it will hold frequency. If the picture breaks up into bars and keeps gradually drifting farther off frequency, the bars will get thinner and more numerous.

If the bars slant upward at the left side of the screen, this indicates that the oscillator is running too fast, above normal frequency.

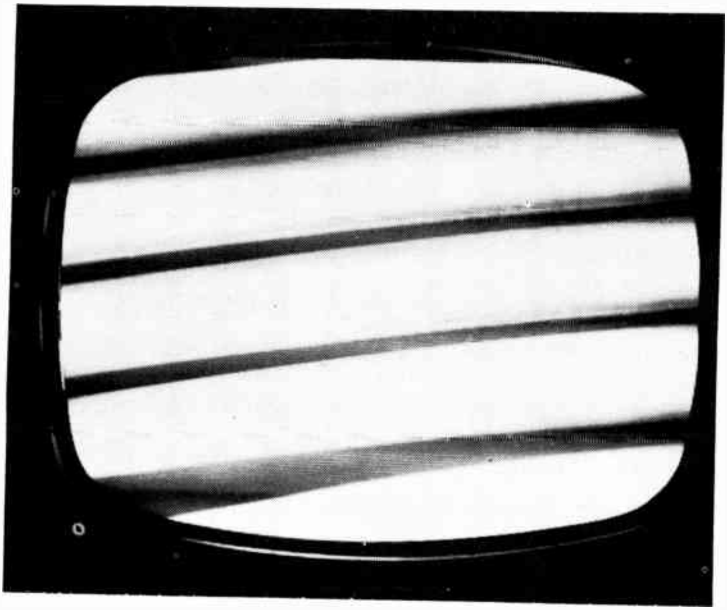


Fig. 215. *Blanking bars slanting downward to the left indicate the oscillator is running slower than normal sweep speed.*

If the bars slant downward at the left, this means that the oscillator is running too slow. If the oscillator is too fast the electron beam in the CRT of the receiver completes one horizontal sweep line before the transmitter has finished sending it. This makes the blanking bar of each line move a little more to the right and we see the blanking bar slant up toward the left.

If the oscillator runs below normal frequency, the transmitter finishes sending a horizontal line before the electron beam in the CRT has completed the line. Thus the blanking interval (bar) between each line is progressively closer to the left and we see a blanking bar slanting up toward the right. Fig. 215 shows what this looks like on the CRT screen.

This can tell us something about conditions in the circuit, if we happen to need it. (Truthfully, most of the time, we don't. It's enough to know that the circuit is *not* running on frequency.) If the oscillator is running too fast, this means that some part in the circuit is *too small*. A capacitor is open, or partly open; a resistor has decreased in value, or an inductor has shorted turns. All of these will decrease the time constant of the circuit, making each cycle shorter and making the oscillator run faster.

The opposite is just as simple. If the oscillator runs too slowly, this means that some part in the circuit has *increased* in value. A resistor has drifted *up* in value; a capacitor is leaking, etc. Ordinarily, a capacitor *cannot* increase in size, nor can a coil get "bigger": this would mean adding more plates to the capacitor, or more turns of wire to the inductor! So we don't find such troubles caused by capacitors or inductances; mostly, we start out hunting for defective resistors. The one case in which an inductor can cause this is an actual misadjustment of the tuning core in a transformer or coil, so that the inductor is "larger". However, we could not call this a fault, in the sense that we are using the word, meaning some part that has actually failed and gone bad. This is simply a wrong setting of an adjustment.

Adding the remaining sections to the circuit

Now we've got the oscillator running. So we can put back the parts we took out a moment ago and see if they affect the operation of the circuit. First, we get the oscillator set as close to on-frequency as we can by adjusting the core in the coil, etc. The best method, in Synchroguides, is to restore the sine-wave stabilizer operation first. So we take off the short. The oscillator will usually fall out of sync immediately. Leave all of the *oscillator* frequency adjustments alone, and turn only the adjusting screw of the sine-wave coil until the picture falls into sync. Keep on turning it until it falls out of sync on the other side. Then back up until it comes into sync once more, and leave the slug at this point. What we are actually doing here, is changing the *phase* of the sine wave generated by this circuit in relation to the phase of the sawtooth wave being generated by the oscillator.

Although this circuit can be adjusted quite well by the method just described, it's better to use a scope. This is one of the places where a scope is invaluable in circuit testing. The actual waveform of the oscillator output can be seen, and the adjustments set for the best results. Fig. 216 shows the combination of sine-wave and

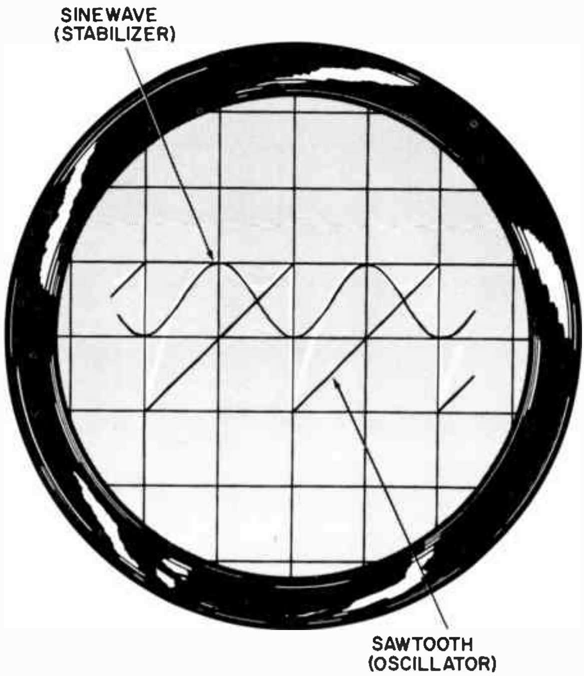


Fig. 216. *Scope trace of typical Synchroguide waveform with sawtooth and sine wave superimposed.*

sawtooth waves, as they are seen on the screen of the scope. To check this waveform, use a low-capacitance probe. Because it is a resonant circuit the connection of any external test equipment to it will have some effect on its operation. So, use very loose coupling to avoid any circuit disturbance.

If you haven't a low-capacitance probe, just put the regular probe of the scope close to the circuit point being tested, but not actually in contact with it! We will get no noticeable disturbance at all and we can still see the waveform. So, to pick up this waveform, simply hook the tip of the scope probe to some insulated object *near* the test terminal, and turn up the vertical gain until you get a pattern of a usable size. Fig. 217 shows how this is done.

Now, leave the frequency coil alone. Don't touch its adjustment at all. It's already set as it should be; all we need to do is adjust the waveform coil for the best stabilization. You'll probably find a waveform looking something like Fig. 218-a when you first test. Adjust the core of the waveform coil until you see the pattern of

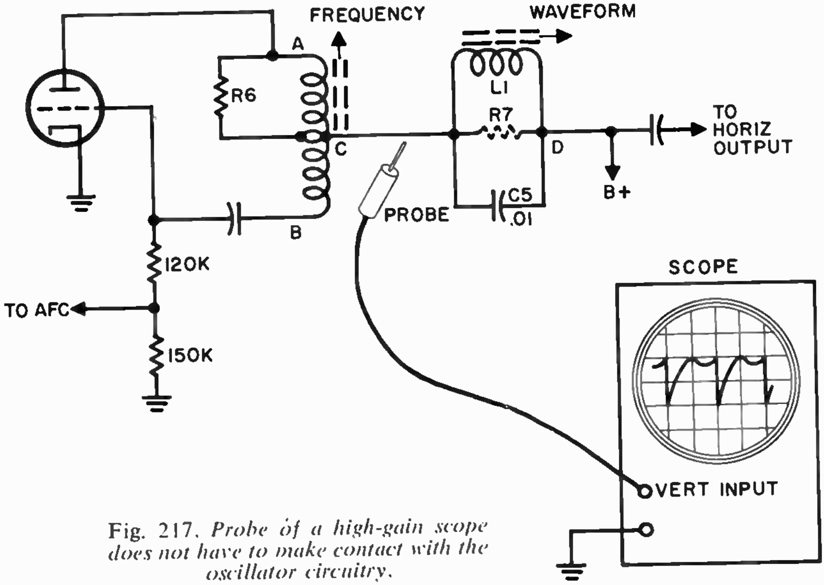


Fig. 217. *Probe of a high-gain scope does not have to make contact with the oscillator circuitry.*

Fig. 218-b. For the best stabilization in some circuits, set the spike portion of the wave to about 10% above the hump of the sine wave. This lets the oscillator approach the firing point at the best angle, and eliminates a lot of noise disturbance. The incorrect waveforms are also shown in Fig. 218-c and 218-d.

There is only one condition that you must look for when you make this adjustment. The picture must be locked in on the screen. It is theoretically possible to get the proper waveform and make the adjustment on the wrong frequency, but for most practical purposes it isn't possible. If the picture is out of sync, you'll generally get so much jitter and drift in the waveform that you won't be able to make any adjustments at all. After all, the purpose of this adjustment is to make the picture stand still on the screen!

So, remember the functions of the two adjustments in the Synchroguide: the frequency coil sets the operating frequency of the oscillator, and it is adjusted only to make a picture stand fairly still on the screen. The waveform coil is used to help lock the picture in place *after* the frequency coil can hold the oscillator to the right frequency. Therefore, adjust the frequency coil *only* while the waveform coil is *shorted out*. If you attempt to make adjustments on the frequency coil while the stabilizer coil is still operating, it will pull against the oscillator and cause the adjustment to be wrong. Follow these instructions *exactly* when setting up Synchroguides, and it'll be much easier. You'll also find this same procedure in practically all service data for TV sets using this type of horizontal oscillator.

Defects in the waveform circuit

If the waveform coil (L1 in Fig. 217) pulls the picture completely out of sync when the short is removed, and no adjustment will bring it back, then the waveform *circuit* is defective. Not necessarily the coil but one of the parts: coil, resonating capacitor (C5) or the shunting resistor (R7) (around 22K ohms) used in

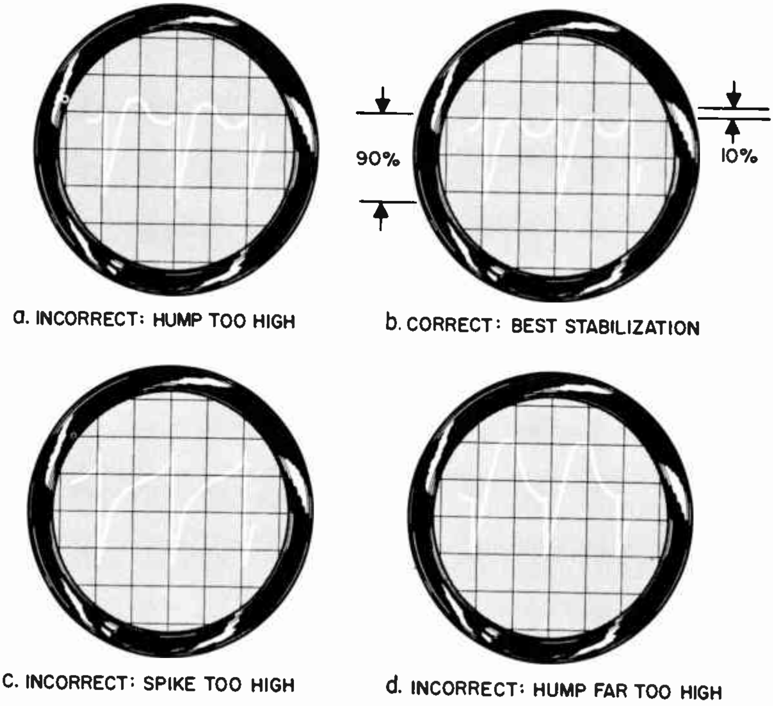


Fig. 218. *Typical Synchroguide waveforms. Only the correct waveform will give a stable TV picture.*

some circuits. The capacitor (C5) seems to be .01 μf in most circuits; however, if a different value is shown *on the schematic*, use that. This is always a special low-drift capacitor to keep the waveform coil's resonant frequency constant during temperature changes. Always replace this with an exact duplicate.

If this capacitor is leaky, you'll be able to see it in the scope waveform at terminal C (Fig. 217). The sine-wave part of the waveform will be very small or missing, and you'll have almost a pure sawtooth. This is because the leaking capacitor acts as a short across the coil, just like the piece of wire we tacked across it to make the first test. You can disconnect the original, check it and replace it *temporarily* with any .01 μf capacitor to see if this brings the circuit back to normal. For permanent replacement, though, use the low-drift type. While you won't need them too often, it's a good idea to have one or two in stock.

A shunting resistor (R7) will be found in some model sets, as we said. This is used to damp the sine-wave circuit slightly to get the right balance between the amount of sine-wave and sawtooth signal. It helps keep the sine-wave circuit from having *too much* effect on the oscillator circuit. If this resistor opens, you'll notice a sort of horizontal bounce in the picture, not exactly a jitter, but a sort of nervousness. It is due to too much sine wave in the output signal. Disconnect one end of the resistor and check it for correct value. If not used originally, this resistor can be added to give slightly better horizontal stability. Use a value somewhere between 10K and 22K. Watch the picture or scope waveform to see which value gives the best results in this particular circuit. The best way, of course, is to hook up the scope as before, and vary the resistor value and waveform adjustments for the most symmetrical pattern, as in Fig. 216.

Shorted turns in waveform coils

Since nothing is impossible, now and then you'll find a set with shorted turns in the waveform coil. The dc resistance can be measured with an accurate ohmmeter; disconnect the shunt resistor to be sure that it is not affecting the reading. Another test which can be used: disconnect the original waveform coil completely by taking off all wires on terminal D (Fig. 217). Substitute a standard *ringing coil* of the type used in multivibrator oscillators (we'll cover this in the next section). This is a coil-capacitor combination which is resonant at 15,750 cycles, like the waveform coil. The major difference here is that most of these coils are wound to resonate with a .0039-μf capacitor instead of the .01-μf. For this test, however, it can be used as-is; all we need is a circuit which will resonate at 15,750 cycles. For a quick check, it will tell if the original coil is bad, by bringing back the sine-wave part of the output waveform.

Variations of the basic Synchroguide circuit

In some models this circuit is used in slightly different forms. These differences are mostly physical, but now and then you'll find a slight electrical variation. They are still Synchroguides, however, and are serviced and adjusted in the same way.

The most common variation is the separation of the two coils of the Synchroguide transformer. You may find them unshielded,

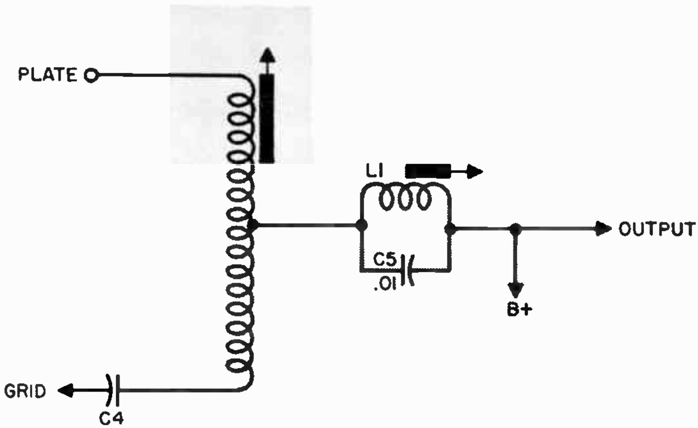


Fig. 219. *The Synchroguide circuit is always in the form (or can be redrawn) of a T on its side, hence the name Lazy-T.*

with one mounted on the front apron of the chassis and the other on the back. Another variation with unshielded coils has one mounted on the back apron and the other on the top of the chassis, and so on. Check the *schematic*. If you can see that the oscillator coils have the basic Lazy-T (|—) shape of the Synchroguide, that's what it is. Look for the center tap of the oscillator coil with the waveform coil connected to this tap, as in Fig. 219.

Identifying coils and adjustment screws on the Synchroguide transformer

One of the biggest headaches in any service work is identification. Which adjustment is which? It's often hard to tell, so here

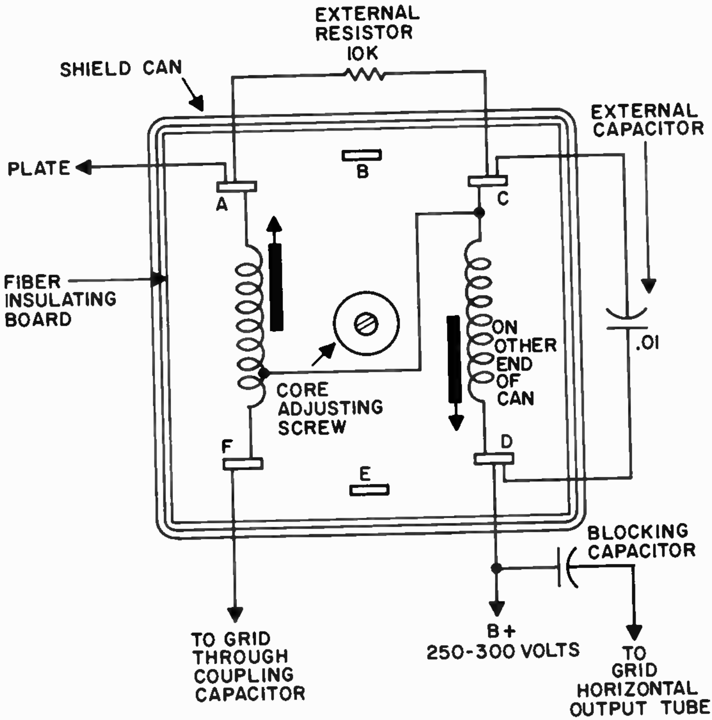


Fig. 220. *Typical connections at the base of a Synchroguide transformer.*

are some clues you can use to locate each adjustment *positively*. Fortunately, most Synchroguide transformers have been standardized: they use the same terminal arrangement and circuitry. The identification lettering is always the same, as shown in Fig. 220. The bottom insulating plate of the transformer has spaces for six terminals, lettered from A through F. Of these, only A, C, D and F are used. Fig. 220 shows the bottom view—what the technician sees.

The stamped letters on the insulating board are sometimes hard to see. The plate or frequency coil is connected between A and F: A is the plate, F the grid end. The tap is on C, as is one end of the waveform coil. *Clue:* look for the terminal which has one end of the 10K resistor and one end of the .01-μf capacitor and no external wiring at all; this will always be terminal C.

Now, the problem is to identify the adjustment screws. We have two of these, one for the core in the frequency coil and the other for the core in the waveform coil. Which one comes out the top and which out the bottom? This varies between sets, and you have to be sure which is which before you can adjust the circuit. In most cases, this information is in the service data. However, if the transformer has been replaced, or you don't happen to have

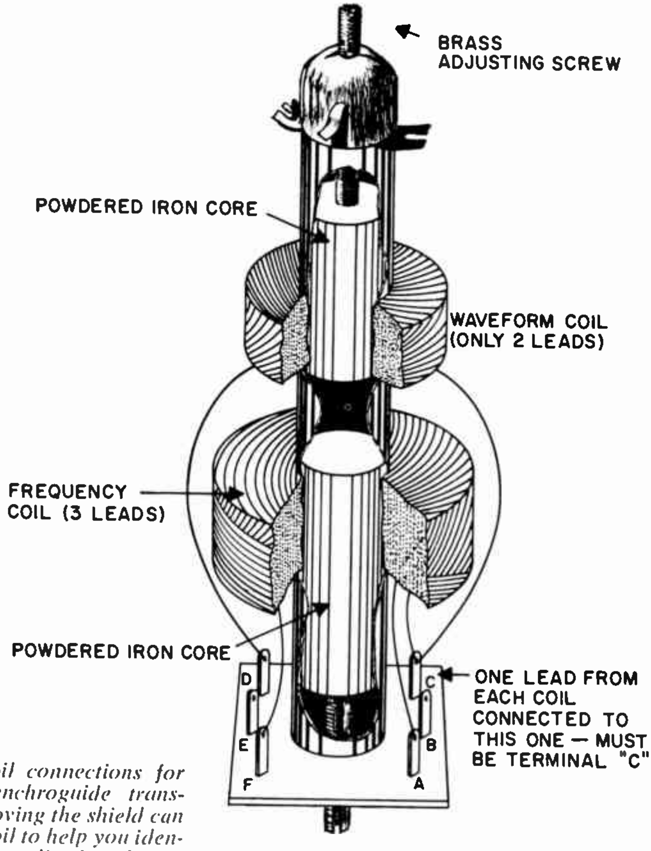


Fig. 221. *Coil connections for a typical Synchroguide transformer. Removing the shield can exposes the coil to help you identify unknown adjusting slugs.*

the service information, you'll have to identify them. This isn't too hard to do.

One of the quickest ways is checking the waveforms while you have the jumper connected across the waveform coil, as we just described. Obviously, the core of this coil isn't going to have much effect on the picture! So, the coil adjustment which affects the frequency of the signal *now* is the frequency coil. The waveform coil adjustment will have no effect at all on the picture.

Most replacement transformers will be standardized, with all terminals identified. However, if you should ever have to do it, there is an easy way to identify the coils. Take the transformer out of the shield can. It will look like that in Fig. 221. You'll see the two coils, and you can trace their connections to the plate and terminals. The frequency coil is tapped, so that you'll have three leads from it; the waveform coil has only two. To identify terminal C for measuring waveforms, look for the base terminal which has one wire from the frequency coil and one from the waveform coil connected to it. You can also identify the adjustment screws at this time. In Fig. 221, the waveform coil adjustment is at the top of the transformer, and frequency through the base. It is quite possible to build this transformer so that these adjustments are exactly opposite. With the shield can off, you can always tell, if it is necessary.

Now and then, you'll find a transformer with a coil winding open. Take the shield can off carefully and check the leads between the coils and terminals. These are very fine wires, and sometimes corrode and open. They can be repaired by resoldering the leads. *Hint:* If the lead is too short, carefully tack a short piece of solid wire (like the scrap ends clipped off bypass capacitors or resistors) to the terminal. Let this wire extend upward toward the coil. Now wrap the open end of the fine-wire lead around this, and solder. Touch the resulting joint with a dab of coil dope or some kind of insulating spray to prevent corrosion in the future. Check for resistance to be sure that there are no other corroded joints in the windings.

Commercial variations of the Synchroguide

Another variation of the basic Synchroguide circuit is almost automatically associated with the pulse-width afc circuit described earlier. However, it doesn't have to use this type of control. The circuit of this version is shown in Fig. 222. Cover the left side of the dual triode tube used, and you'll see the characteristic "T" shape of the coils. There is a small difference: note the 68K resistor shunting the lower half of the frequency coil, instead of the plate end. This is still the same old Synchroguide, though, and is adjusted in exactly the same way as the first circuit.

The afc circuit used here is called a phase-detector dual-diode type. It is most often found in circuits using multivibrator oscillators. It will be completely covered in the next section. However, it will work with almost any type of horizontal oscillator circuit, since it works on the same basic principle as the pulse-width circuit

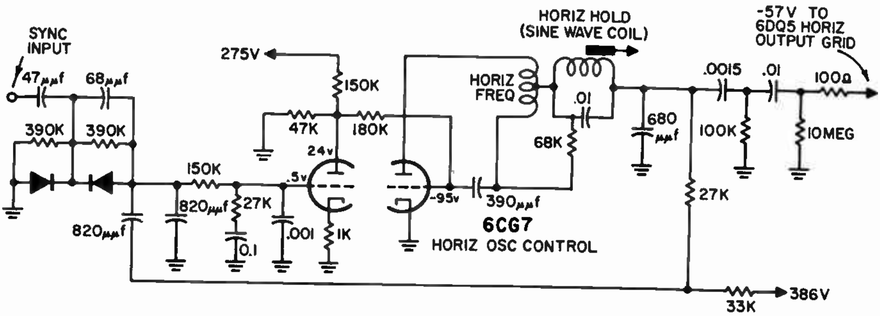


Fig. 222. *Variation of the Synchroguide horizontal oscillator. The main difference is in the type of afc circuit.*

we talked about a while ago. It produces a dc control voltage when the oscillator goes off frequency: negative if it is running fast, positive if it's too slow.

Now, take a deep breath and let's move on to the next chapter.

Chapter 3

The Horizontal Multivibrator

A MULTIVIBRATOR IS A FAIRLY SIMPLE OSCILLATOR. THE STEP-BY-step explanation of how it works can get pretty complicated, but the oscillator circuit itself *is* simple. You'll remember we connected the output of an amplifier back to its input, a while ago, to make an oscillator. Now let's do it again; this time, we'll use a simple two-stage resistance–capacitance-coupled amplifier (Fig. 301-a). If we swing the output around and connect it to the input, we get a circuit that looks like Fig. 301-b. This is exactly the same circuit, redrawn in the form you'll see from now on in multivibrators.

We have a 180° phase shift in each tube of this two-stage amplifier—the input signal is our reference point. This means that the signal at C2 (the output), is 360° out of phase, or *in-phase* with the next cycle of the signal at the input grid. This fulfills all conditions for oscillation. The feedback in Fig. 301-b is 100%, and you can't stop the thing from oscillating! (This can be verified by many builders of audio amplifiers!) This particular circuit is called a *plate-coupled multivibrator* because the basic coupling is from each plate to the other grid.

All right, let's go through a quick analysis of this circuit now to see how it works. If we make R1 = the same value as R2, R3 = the same value as R4 and C1 = the same value as C2, you might think that the circuit would be balanced so this particular circuit is also called a *symmetrical multivibrator* for that reason. Since there is very little, if any, phase shift through the coupling capacitors, the signal from each plate is fed to the other grid in exactly the right phase to sustain oscillation. But, how does the thing oscillate?

Let's take a condition that is theoretically possible, actually impossible. To explain some circuit actions, we often have to assume certain conditions that could never exist in a real circuit. We're assuming that this circuit is turned on, power applied, and both halves perfectly balanced. This is the impossible part. Plate

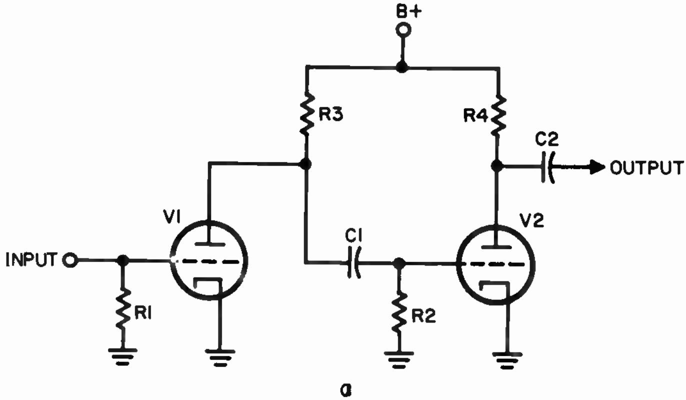
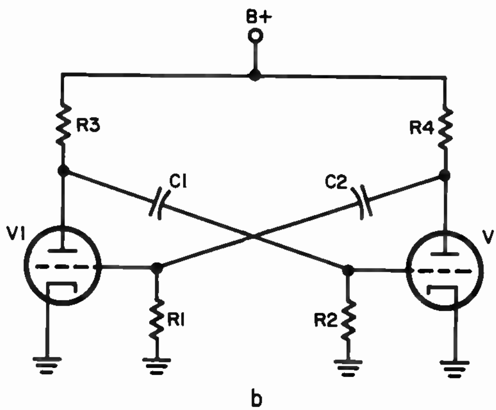


Fig. 301. *The common R-C amplifier circuit (a) becomes a multivibrator when the output is connected back to the input. Redrawn circuit (b) is the more familiar form.*



currents flowing through R3 and R4 are exactly equal. Since R3 = R4, their voltage drops are equal. C1 and C2 are charged to exactly the same voltage, plate voltage on the upper plates and zero voltage (ground) on the lower, since this charge is assumed to have been drained away to ground through the equal-value grid-leak resistors R1 and R2. Now the circuit is in that impossible condition of "exact balance".

How long will it stay that way? Not for long! Let's allow just a few extra electrons to leave the cathode of V1. This makes an increase in its plate current, which lowers the plate voltage. Since one end of C1 is connected to the "negative-going" plate of tube

V1*, its charge becomes more negative, or less positive, which is another way of saying the same thing. The other end of C1 being connected to the grid of V2 makes the grid bias increase, go more negative, which reduces V2's plate current. As the plate current drops through V2, its plate voltage goes up. This increases the positive charge across C2, and the grid of V1 also becomes more positive, which increases its plate current.

Now, we've gone all the way around the circle. Beginning with a few extra electrons in V1's plate circuit, all of these actions have taken place. Notice that each circuit action causes an *opposite* action in the other tube: If V1's plate current goes down, V2's is forced up, and every action that takes place helps this. Grid voltage changes also help. This action continues until the grid of V2 has reached a negative potential high enough to cut off the current flow through V2 completely. V1's plate current at the same time has reached maximum: saturation. That, in a condensed form, is the key to the whole process. From our theoretical state of complete balance, the circuit has very suddenly changed *itself* to a state of complete *unbalance*. One tube is cut off, the other is conducting maximum plate current; one plate voltage is minimum, the other maximum, and so on. You might think that this is the equivalent of the balanced condition, since there aren't any changes taking place. But will the circuit *hold* this condition? No. (By careful choice of components, we can make such a circuit balance. It is then called a monostable multivibrator and will unbalance and hold that state until turned off again. But let's not go into that at this time; that's strictly for computers and stuff.)

The circuit in Fig. 301-b will not remain in the full-unbalance condition, because the grid capacitors are returned to ground through the grid resistors. When the plate voltages stop changing, the capacitors immediately begin to lose electrons through the grid resistor to ground and try to reach a state of equilibrium (no charge difference at all) with respect to ground. This starts the whole process over again but in the opposite direction.

---

* Terms such as negative and negative going, positive and positive going can be confusing. A positive-going voltage is one that is changing and becoming more positive. If we move from +3 volts to +4 volts, we have a positive-going voltage. The mental alarm arises when we apply this thinking to negative voltages. If we move from −4 volts to −3 volts, we have a positive-going voltage. It is true we are talking about minus or negative voltages, but that isn't the point. We're just discussing the *direction* in which the voltage is going. Similarly, if you decrease a voltage from +4 to +3 volts, you are decreasing that voltage or you are moving it in a negative direction. Plus 4 volts is positive—no argument about that. But decrease it, and you are moving in a negative direction.

V2 is cut off. As C1 begins to leak off the negative charge, its grid goes back toward zero, and plate current starts to flow again. As C2 loses its positive charge, V1's plate current begins to drop. So, our opposite actions start. When one plate does something, the other immediately starts to do the opposite. It is now the other plate voltage which is going *up;* this action keeps going until an "equal but opposite" condition is reached. V1 is cut off and V2 saturated and, from now on, this will continue as long as the voltages are applied to the circuit. This is called a *free-running* multivibrator.

Before we go on, let's review a few simple facts about electronic circuits in general. We'll need them after a while, and they're of the type that are easily forgotten after you've been out of school for a while! (The principles are used, but the basic applications and theory are forgotten!)

1. The voltage across a capacitor never changes instantaneously. It always requires a certain amount of time to charge or discharge. This is determined by the size (value) of the capacitor and the resistance present in the circuit (the time constant).
2. When a voltage *change* appears in an R-C circuit, the whole voltage change appears across the *resistor* instantaneously.
3. When the plate current of a tube increases, the plate voltage decreases, and vice versa.
4. If the grid voltage of a tube is made more positive, more grid current flows, and the plate current becomes larger. The tube offers a very low resistance to the current.
5. When a high negative voltage is applied to the grid, plate current is stopped completely (cut off) and the tube becomes a very high resistance. In either case, the tube could be replaced with a low- or high-value resistor, to represent the action in the circuit at that instant.

You'd be surprised how many of us forget to *apply* these fundamentals of vacuum-tube circuitry while we're servicing. Brush up on them, for we're going to be using them quite often for the next few chapters.

The cathode-coupled multivibrator

Now let's take a look at a slightly different version of the multivibrator. This one is quite commonly used in TV circuits, because of its simplicity, ease of control and so on. (Yes, you *will* find plate-coupled multivibrators used in TV circuits, too. They are very common in vertical oscillator circuits, but we're not interested in those; we've got our hands full with the horizontal circuits!)

In Fig. 302 we see the circuit of the cathode-coupled multivibrator. There are a few minor differences between this and the plate-coupled circuit, but the basic circuit action is much the same. Let's run through it quickly.

This is also called an *asymmetrical multivibrator,* a long word meaning that the two "halves" of the circuit are not exactly alike, as they were in the circuit of Fig. 301. V2 in this circuit remains cut off for a longer time than it conducts. Its plate waveform is a series of rectangular pulses. These are shaped into trapezoidal waveforms by an R-C network shunted from plate to ground (this process will be taken up in detail, in a moment). Now let's trace the series of events that make this thing oscillate.

When voltage is applied, capacitor C1 charges through R1. V1 and V2 are both conducting. The grid of V1 is at zero, since it returns to ground through the .27 megohm resistor, R2. The initial charging current flow through C1 makes the grid of V2 more positive, so it conducts heavily. This causes the current flow through the common cathode resistor R5 (1K) to be high, and a high voltage drop appears across it. Since this is common to both tubes, the positive voltage appears on each grid, as a negative bias. Because V1 started at zero, this causes it to cut off. V2, on the other hand, still has some positive voltage left on its grid, so it conducts heavily. Now, we've got the same unbalanced condition we had in the plate-coupled multivibrator. One tube is cut off, the other is conducting very heavily.

When we get to this condition, V2's plate current stops changing, because the tube is saturated, drawing maximum plate current. C1 now discharges through R4 and R5. This drives the grid of V2 negative, reducing the plate current of V2. The bias developed across the cathode resistor falls because the voltage drop is caused entirely by V2's plate current, since V1 is cut off. When the bias falls, V1 begins to draw plate current. Its plate voltage decreases as the plate current increases. This *negative change* is applied (through C1) to the grid of V2, and finally causes V2 to be cut off. (Note: Even though the plate is still positive, the voltage is changing in a *negative direction.*) Now, we've completed one full cycle: each tube has been cut off in turn.

For the first time, we get into the idea of time constants in such circuits. The time constant of an R-C circuit, as briefly as we can state it, is the amount of time needed for a given capacitor to charge to 63.2% of the maximum possible charge, through a re-

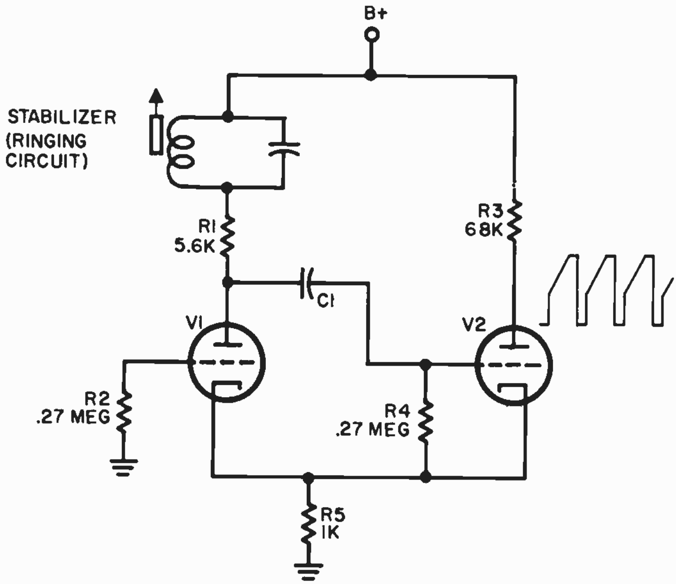


Fig. 302. *The cathode-coupled multivibrator. The circuit gets its name from the common cathode resistor (R5).*

sistor. So, the time constant of this circuit can be figured by multiplying the value of the capacitor by the value of the resistor. This is generally stated as T = RC and comes out in seconds. Since we work with microfarads and megohms, a more useful statement of this formula is T (in seconds) = R (in megohms) × C (in μf), which is the same thing. The "maximum possible charge" here means the dc voltage applied to the circuit. Actually, it doesn't matter at all how much voltage is applied; the capacitor will still charge to 63.2% of maximum voltage in the same length of time! Speaking practically, we would consider the capacitor fully charged.

The reason why this is important in these circuits can be readily seen by checking back over the circuit action description. Notice that the time of each cycle is determined by the length of time it takes to charge a capacitor; for example, the coupling capacitors in Figs. 301 and 302. We can make the circuit oscillate faster by changing the time constant. If we reduce the size of either the resistor or the capacitor in the R-C network, the frequency goes up; if we increase them, it goes down.

We can use this effect to advantage. The operating frequency of these circuits must be controllable. So we make one grid resistor variable. This is simpler and cheaper than putting in a large vari-able capacitor, and just as good. By changing the value of this resistor, we change the time constant of the circuit and the operating frequency. You'll find some circuits which have both of these variable. However, the variable resistor will always be the front-panel hold control, while the variable capacitor is used as a technician's adjustment for setting up the circuit. It will be located on the chassis so that the customer can't get at it and is adjustable with a small screwdriver.

You will find time constants mentioned and used in several ways as we go along through the rest of the horizontal sweep circuits. Some of the applications might look just a wee bit complicated, but always remember that each one is based on a simple action: charging of a capacitor. The larger the capacitor or the resistor, the longer the time constant, and that's all there is to it.

Why choose the cathode-coupled multivibrator?

Why do we use the cathode-coupled type of multivibrator in horizontal oscillator circuits? For several reasons. This circuit has quite a few useful characteristics. First, an oscillator circuit is no good to us unless we can get useful signal output easily. This circuit has a "free plate" on V2 which can be used for signal output without disturbing the circuit action, which takes place mostly between the grid of V2 and the plate of V1. (This is an oversimplification, but it helps in understanding the circuit action to think of it in that way.) So, we can connect a coupling capacitor to V2's plate and take off our signal waveform with no trouble.

Two, we need a way of controlling the frequency of the oscillator with the horizontal sync pulses in the video signal. This circuit also has a "free grid"—in V1—which doesn't have anything to do. So we put it to work as a control element by feeding our control voltage from the afc to it. Look at the circuit in Fig. 302 and you can see what we mean.

Stabilization and frequency control of the multivibrator

A multivibrator all by itself is a handy little oscillator. However, for our purpose, we need to dress it up a little. For one thing, it lacks stabilization. It would tend to follow the sync too rapidly, and hunt; so we need a circuit which will gently hold it in line. Due to the very steep waveforms generated, this circuit is prone to disturbance by random noise. So, we add the same type of stabilization used in the Synchroguide oscillator—a sine-wave coil.

This is known by several names: *stabilizer coil, ringing coil,* and so on. You'll even find it called *horizontal lock* in some schematics. We'll call it ringing coil, because this is the most common name among technicians. Fig. 303 shows the typical waveforms found in this circuit, with and without the addition of the ringing coil. We

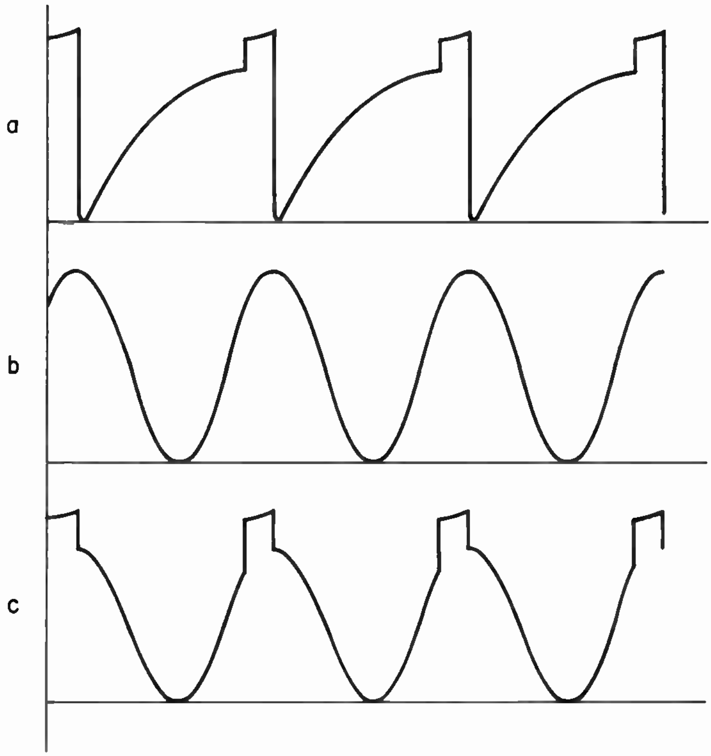


Fig. 303. *Typical output waveform of a multivibrator (a); sine wave (b) from ringing coil and combined waveform (c). There will be differences in circuits, component values and the waveforms but the spike or pulse should always be at or quite near the top (positive peak) of the sine wave. Variations will be due to slight phase shift and control settings.*

have slightly different waveforms here, compared to the previous oscillator circuit, due to the different shape of the output waveform of the oscillator. You'll find quite a bit of variation between these waveforms in commercial circuits, because of the difference in design practices, size of components, and so on. However, they will all have the same basic shape. With a little experience, you'll learn to recognize them without any trouble.

Fig. 304 shows a cathode-coupled multivibrator circuit with the actual parts values and operating voltages shown. A few of the key waveforms are shown around the circuit. Actually, the sine-wave stabilization should show up more plainly in the cathode than it does on V2's grid waveform. This is due to the difference in time constant in the two circuits, plus the added shaping components in the grid. At the output, the waveform has been shaped into a very good trapezoidal wave, which is what we need for driving the horizontal output stage. This is an important subject, and we're going to go into it in much detail a little later on. For now, we'll just say that the wave *is* shaped and let it go at that; we've got a few more things to cover before we get into that section.

If you'll trace the circuit of Fig. 304, you'll see the circuit of Fig. 302 with a few parts added. The 910-pf ($\mu\mu$f) coupling capacitor is C1, R3 is 82K instead of the 68K of Fig. 302, the cathode resistor (R5) is 820 ohms instead of 1,000, and so on. We did this deliberately to show you that the circuit can be practically the same and work the same, with different sizes of parts.

You will notice a change in the waveshape at the output, and in different sets in some places through the oscillator circuit. However, if you'll learn to look for the *basic* waveform, you'll always know what's going on. Incidentally, to clear up one point which has puzzled quite a few technicians, the spike you see sitting on top of the sine wave in the combined waveform is *not* the *horizontal sync pulse*. This is the *spike portion* of the output waveform from the horizontal multivibrator! The horizontal sync pulses never get anywhere near the multivibrator circuit in this one. We make a varying dc voltage out of them and use that to control the frequency, just as we did in the previous circuit. We'll get to the afc in a moment.

The decoupling resistor in the ringing-coil circuit

Note that there is a resistor (R6) between the ringing coil and the plate of V1. It is there for a purpose, just as all the parts are. This resistor helps to isolate the ringing coil from the actual oscillator circuit. If we make this resistor value small enough, our sine wave will have a tendency to get bossy with the oscillator frequency. This distorts the waveform and makes the oscillator just a little too stiff; it won't respond to the control action of the afc as easily. So we isolate it with a resistor. The value of this resistor varies between 3,000 and 15,000 ohms, according to the designer's idea of how much stabilization he wants. We'll say more about this resistor in a minute or two.

Part values are fairly critical in this circuit. We choose the value

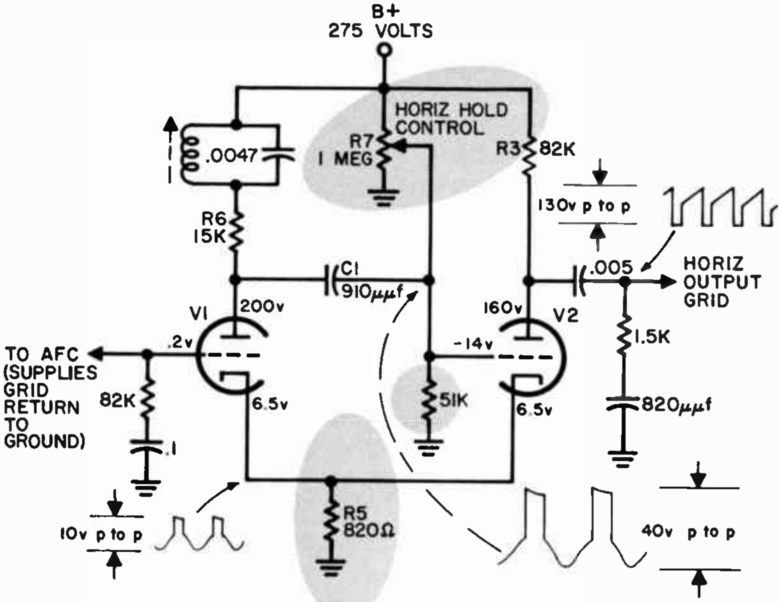


Fig. 304. *Schematic of a version of the cathode-coupled multivibrator used in one model of a TV receiver. The frequency determining components circled also vary the dc voltages applied to the V2 half of the dual triode. Any change in component values in this circuit is going to cause trouble. In the case of R7, the end result will be the hold control jammed up against its stop and tricky hold action. Changing stations causes set to jump hold, lose sync. This is a very common symptom.*

of each to make our time constant come out right and to give us the peak-to-peak voltage at the output that we need for driving the horizontal output grid. Also, some of the part values determine the operating frequency of the oscillator. These are the "time-constant" parts circled in Fig. 304. These are the main things to watch out for when we're servicing this circuit; changes in value, if they occur as the set warms up, is what we will call *drift* from now on. In other words, if we have a 1 megohm resistor (R7) in the grid circuit of V2, controlling the frequency of the oscillator together with the capacitance of C1, and this changes to, say, 1.5 megohms, we're in trouble. Our time constant has increased considerably, and the oscillator runs much too slowly. Learn to suspect *all* the components in this circuit when you're working on it.

Variations in circuit connections

Now and then, you'll find different arrangements of parts in this circuit. The ringing coil may be connected in series with the plate of V2 instead of V1. The horizontal hold control may be in the plate circuit of the first triode, V1. An extra capacitor may be used across the coupling capacitor C1 as a frequency control, and so on. Don't let this bother you. The circuit will work in exactly the same way as long as all of the parts are there, no matter how they are connected. And, always remember this: *it did work,* at least when the set was new! You'd be surprised how many technicians find themselves unconsciously forgetting that indisputable fact, that it *must* have worked at one time or they could never have *sold* the set!

Another variation that you'll find is in the design of the ringing coil. The most common ringing coil will be one which has the right

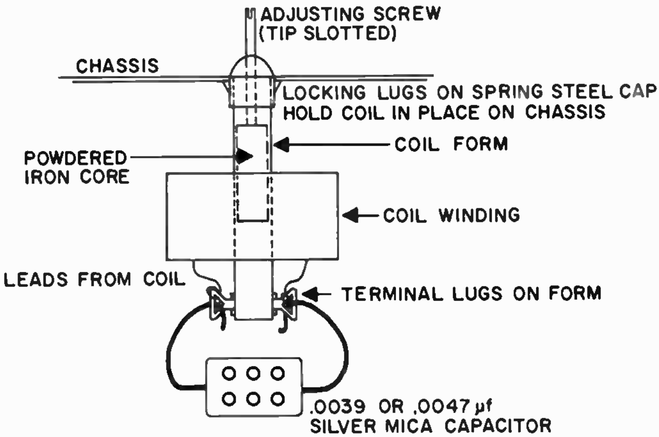


Fig. 305. *Typical ringing coil and its mounting.*

inductance to resonate at 15,750 cycles with a .0039-μf (3,900-pf) capacitor. Others resonate with a .0047-μf capacitor, as in the circuit shown in Fig. 304. In one variation, the ringing coil resonates at 31,500 cycles (the second harmonic of 15,750 cycles). The designer did this to get the output waveform shaped the way he wanted it and give the oscillator a steeper approach to the firing point. These are some individual variations: the circuit as a whole *still* works in exactly the same way as all the other multivibrators, and can be serviced exactly the same way.

Physical construction of the ringing coil

These coils are wound on a hollow fiber form, with an adjustable powdered-iron slug on the inside. This is moved in or out to adjust the inductance so that the coil–capacitor combination will resonate at 15,750 cycles. Fig. 305 is a drawing of the coil. You'll usually find the resonating capacitor mounted on the end of the coil form, to the two terminal lugs provided there. These lugs may be on the end of the coil nearest the chassis; this makes no difference. The capacitors used are generally silver-mica types, which are more expensive than the paper but far more stable in value. By using low-drift capacitors, the operating frequency of the coil is held as closely as possible to the right value and there is little drift in inductance values of the coils. (Just as a curiosity, since it has no real value to us in this connection, the inductance of these coils would be about 27 mh to resonate with a .0039-μf capacitor, and 20 mh with a .0047-μf.)

These coils are wound with fairly fine wire. The ohmic resistance will vary according to wire size: the finer the wire, the higher dc resistance it will have. This resistance value is generally given on the schematic. It's a useful check if you suspect the ringing coil of

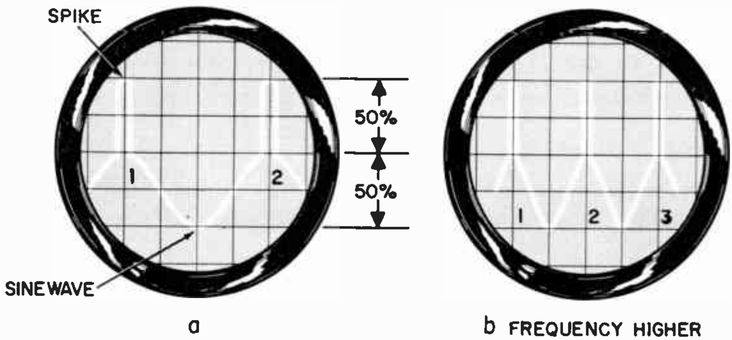


Fig. 306. *Normal waveform produced by the ringing coil (a) and that produced when the frequency is made higher by lowered inductance of shorted coil (b).*

having more than a few shorted turns in it. If the resistance is off value by more than about 10%, suspect the coil. This resistance will be below normal, of course, because of the shorted turns.

A better clue is the action of the adjustment slug in the coil. The oscillator will be pulled far off frequency, of course, if such a short happens, and you usually won't be able to get it back to normal by turning the adjustment screw in clockwise. In standard construction, this moves the iron core into the coil and increases the inductance. Because some of the turns are shorted, the inductance of the coil has *decreased*. So, the resonant frequency goes higher. In Fig. 306-a, we see the normal waveform, with one spike on top of each hump, at 15,750 cycles. The waveform in Fig. 306-b is what you usually get when enough turns are shorted to increase the frequency to where there are three cycles instead of the normal two (with a scope sweep of 1,875 cps). The waveform is distorted, tall and thin.

Incidentally, if you find such a condition, *don't* try to increase the size of the capacitor to bring the oscillator back on frequency! When the coil is definitely defective, its Q or figure of merit has been lowered by the short. So, even though we can easily bring it to resonance by increasing capacitor size, the whole circuit will not work as well as it should, and you'll have one of those marginal defects which are extremely hard to locate! Make it a habit always to check the size of the capacitor against the value shown on the schematic. If it is different, there has been dirty work at the cross-roads, and you'd better put things back to normal before you go any farther. Always replace a defective coil with an exact duplicate if possible. However, you *can* usually replace a ringing coil which uses the .0039-μf capacitor with the type made for a .0047 if you change the capacitor too. The Q of both coils is about the same. Don't try to use the capacitor from one circuit with the coil of another, though! It won't work!

The phase detector

Horizontal sync pulses can't be used to control the frequency of the horizontal oscillator directly. The vertical sync pulses are used in this way in the vertical oscillator, but we have a different situation here. Because of the higher frequency of the horizontal sweep, or *line scan* as it is also called, direct control of the oscillator is not practical. Because if a random noise pulse can easily throw the oscillator off frequency by making it fire ahead of time, one line of the picture would be displaced to the left. In an effort to recover, the next line would be displaced to the right, by normal overshoot, and this would keep on for several lines. The result of this would be a jagged appearance in the raster and a pretty messy picture.

We use a frequency control circuit which makes use of the horizontal sync pulses, but they do not control the oscillator frequency *directly*. The oscillator circuit is made free-running and as stable as possible. Now, when we apply correction voltages from a circuit which has a long enough time constant, the control effect is slow and gradual and we get rid of the sudden jerking back and forth.

The actual frequency control is done by the horizontal sync. We feed the clipped sync pulses into a phase-detector circuit. This is a circuit which compares the sync pulses against other pulses taken from the horizontal sweep stage. In some circuits, you'll find these taken from the oscillator plate, and in some they come from a special little winding on the flyback transformer. In any case, they are generated by the horizontal oscillator. If the oscillator changes frequency, the pulses for this stage will change *phase* with respect to the horizontal sync pulses from the video signal.

By change in phase, we mean simply that the oscillator pulses will change *time*. The oscillator pulses shown here in Fig. 307-a are arriving *later* than the sync pulses. So we have a 'lagging' phase condition. The oscillator pulses in Fig. 307-b are arriving *before* the sync pulses, so we have a leading phase. By the way, any time you say *phase*, you must specify some reference point. You can't

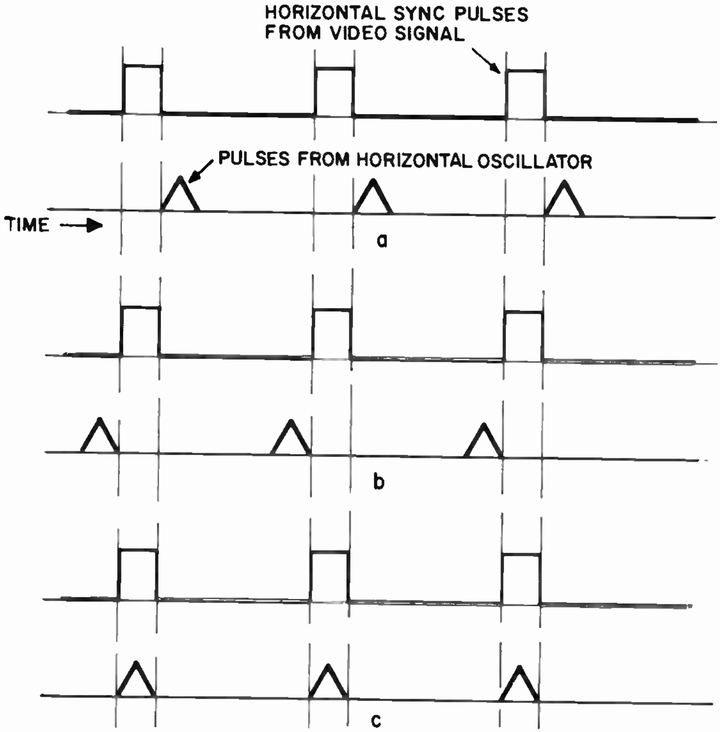


Fig. 307. *Oscillator signal pulses lag sync pulses (a), lead the sync pulses (b) and correct phasing (c).*

have a 90° lead all by itself: you must have something as a beginning—some point which something else is 90° ahead of! In all of the following discussions, we will use the horizontal sync pulses in the video signal as our reference. Since the picture information is always transmitted with its own horizontal sync pulses as a reference point, we must use them in controlling the horizontal oscillator. In Fig. 307-c, you see the oscillator pulses in phase (arriving at the same time) with the sync. Now, for some kind of a circuit that will make use of this action.

If the oscillator leads the sync, this means that the oscillator is running *faster* than it should. Pulses arrive before they should. If the oscillator lags the sync, it's running slower. The sync pulse gets there first, and the oscillator pulse comes lagging along after it. Our control circuit must be something that can detect changes in phase. Just to be different, we call it a *phase detector!* Just as in the Synchroguide circuit, we can apply a small dc voltage to the free grid of the oscillator tube and make it change frequency. We do this by changing the grid bias so that the tube conducts for shorter or longer periods of time. A positive voltage makes the oscillator run faster, a negative voltage makes it run slower. So our phase detector must have a dc output that is related directly to the phase relationships between the two pulses applied to it. This isn't as hard to do as you might think. Let's look at a very practical and widely used circuit.

The duo-diode phase-detector circuit

You'll find this circuit used in television receivers made as far back as 1948. The original circuits used a duo-diode tube, the 6AL5. You may still find this in some later sets. For convenience and economy, most of the more modern sets use a special duo-diode semiconductor (crystal) rectifier unit. For simplicity, we'll use this in the illustrations. Remember, both semiconductor diode and tube act exactly the same way. You may find circuits with triode tubes: if you look closely, you'll see that the triode is being used as a duo diode, with the grid serving as one plate!

How does it work? Simple. We feed the sync pulses to the diodes in such a way that the current through each diode is the same. When both pulses are in phase, the currents from the diodes are equal and opposite in polarity, and the voltages they develop "balance out" in the load, R3. There is no dc voltage output from the circuit.

If the oscillator changes frequency, the oscillator pulses will change their phase relationship to the sync pulses, and the circuit becomes unbalanced. It then produces a dc output. This is applied to the oscillator grid and pushes the oscillator back on frequency. Fig. 308 shows the basic schematic of such a circuit.

Here we have the two diodes, D1 and D2. Each of these is fed horizontal sync pulses from the sync-inverter stage, in opposite polarity. The sync inverter is set up so that it feeds sync pulses of opposite polarity but equal amplitude to the "ends" of the circuit. Neglecting the comparison (or reference) pulses for a moment, the two diodes will conduct equally, causing the rectified currents to flow through the 4.7-megohm load resistor to ground. Since both of these are equal, we'll have equal but opposite voltage drops

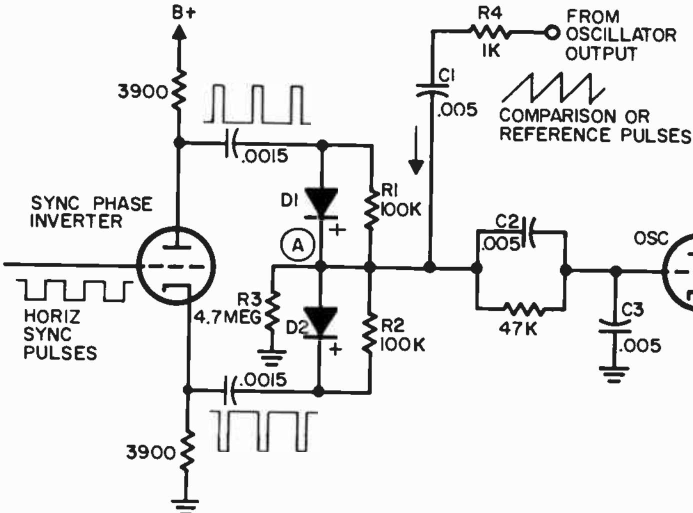


Fig. 308. *Typical circuit of a dual-diode phase detector for an afc stage.*

across the load resistor, R3. For example, if D1's current caused a 5-volt positive voltage to appear at point A, D2's current would cause a 5-volt negative voltage. These two would cancel, or "buck out", and the actual voltage present would be zero.

Now we add another pulse. This time it is a sawtooth voltage taken from the output of the oscillator. This comes through a shaping network, the 1K resistor R4 and .005-μf capacitor C1, and is fed to the centertap, point A, so that it is applied to both diodes at the same time. The current through the load resistor now is a combination of that developed by the sync pulses and that developed by the comparison sawtooth pulses.

The waveforms of the applied voltage might make this a little clearer, so let's look at Fig. 309, the actual waveforms we'd find on the two diodes, under different conditions. Fig. 309-a is the com-

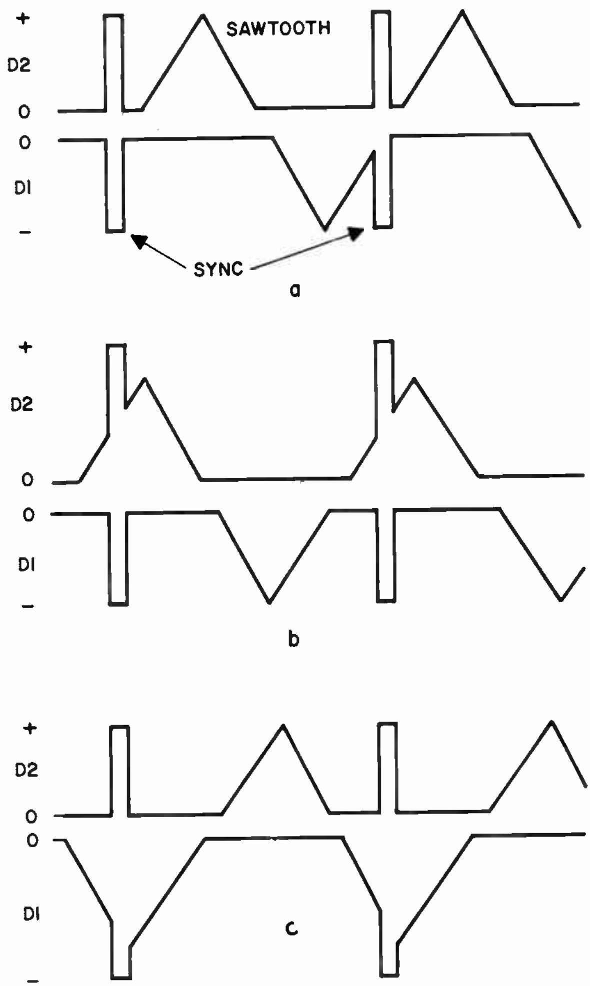


Fig. 309. *On frequency, the waveforms across both diodes are about equal and dc voltages cancel each other (a). When phase between sync and oscillator pulses changes output voltage is increased (b) or (c).*

posite waveform when the oscillator is on frequency. There are the rectangular sync pulses, both with the same height (amplitude) but of opposite polarity: one positive-going, above, on diode D2; the other negative-going on D1.

Notice that through the whole process *neither* of these pulses changes in amplitude! The circuits in the set are designed to hold them that way. All we want here is the change in phase, that is, in the time relationship between the sync and the comparison sawtooth. This action is basically the same as that we found in the pulse-width circuit, but the details are slightly different. Since this is a diode rectifier circuit, it works on the principle of charging a capacitor to the *peak* voltage developed across the load. In a power rectifier circuit, this is the input filter capacitor. In this circuit, it is the two capacitors (C2 and C3) you can see on the oscillator grid, the two .005-μf units. The charge on these capacitors is directly related to the peak voltage developed across the diode load resistor, R3. Note that there is a very-high-resistance path to ground for this charge to leak off. This gives the circuit a fairly long time constant, and prevents hunting by the oscillator.

With the oscillator on frequency, both voltages are equal, as you can see in Fig. 309-a. If the oscillator goes higher in frequency, starts to run faster, the sawtooth pulses will change in phase (time) while the sync pulses stay where they are (Fig. 309-b). So, we see the sync pulses "riding up" on the sawtooth, above the zero line. When this happens, the voltages of the pulses *add,* and the peak voltage on diode D2 becomes larger. So, the voltage across load

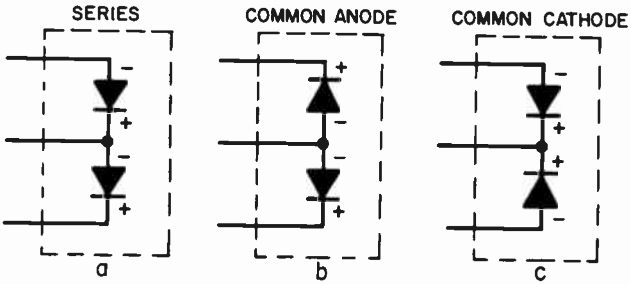


Fig. 310. *Circuits of the three types of semiconductor dual-diodes.*

resistor R3 goes negative. Applying a negative voltage to the oscillator grid causes it to slow down. This brings the sawtooth pulses back to the correct relationship with the sync, and the output goes back to its balanced condition.

If the oscillator slows down, the sawtooth pulses move ahead of the sync, riding up on the negative half of the waveform as you can see in Fig. 309-c. Now, the total of the peak voltages on diode D1 is greater, so the voltage output becomes positive. This is applied to the oscillator grid and the oscillator speeds up to the right frequency again.

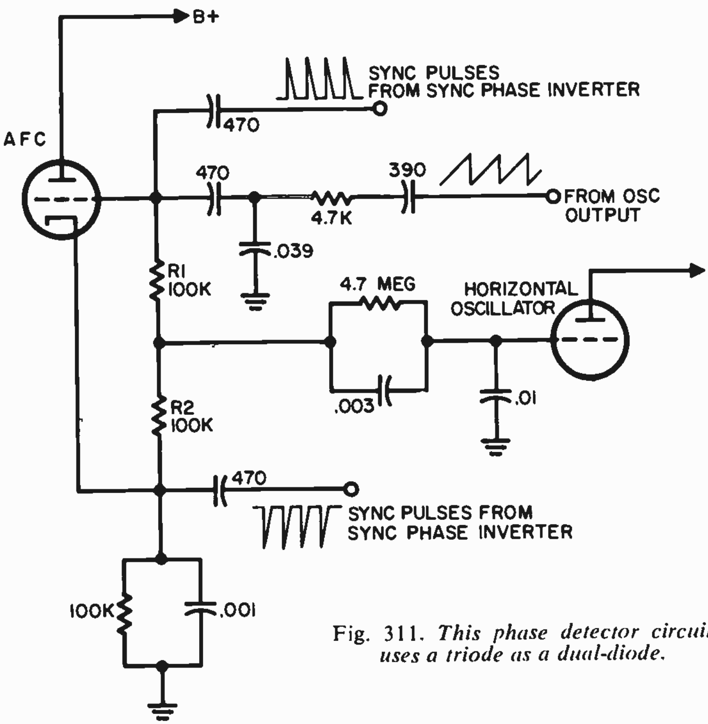


Fig. 311. *This phase detector circuit uses a triode as a dual-diode.*

This might seem to be a slow method of controlling oscillator frequency, with the large time constant of the grid circuit. Actually, while we have shown a change in frequency sufficient to cause 3 or 4 volts of correction voltage to appear at the phase-detector output, this won't happen in actual operation. The correction voltage appears the very instant the oscillator starts to drift off frequency and gently nudges it back to the right frequency. The long time constant in the grid circuit helps to avoid sudden or drastic changes in voltage which would cause jerking of the oscillator back and forth. This would cause jagged lines or jitter in the picture.

Variations of the basic phase-detector circuit

You're going to find several versions of this circuit. There are three types of dual-diodes, for example, as in Fig. 310. We have seen the first (Fig. 310-a), used in the circuit in Fig. 308. This is called a *series* combination, for the anode (plate) of one rectifier is connected to the cathode of the other. The other two are called *common-anode* (Fig. 310-b) and *common-cathode* (Fig. 310-c).

The circuitry used with the other two is slightly different from that in Fig. 308. However, there isn't really enough difference to amount to anything. The basic principles remain the same: the sync pulses are compared with a pulse taken from the output of the oscillator. The phase difference between the two develops a dc control voltage across the balanced load, and this holds the oscillator on frequency. Later on we'll show actual circuits using each of these methods, and some of the waveforms you can expect to find there.

There is one type of circuit, which looks different, but really isn't. This is the triode-tube circuit of Fig. 311. Look at it closely; can you see the "diodes" in there? They're there. The grid of the tube serves as one, with the cathode common, and you can see the balanced load resistors, R1 and R2. The correction voltage is developed across this load and applied to the oscillator grid, just as in the others.

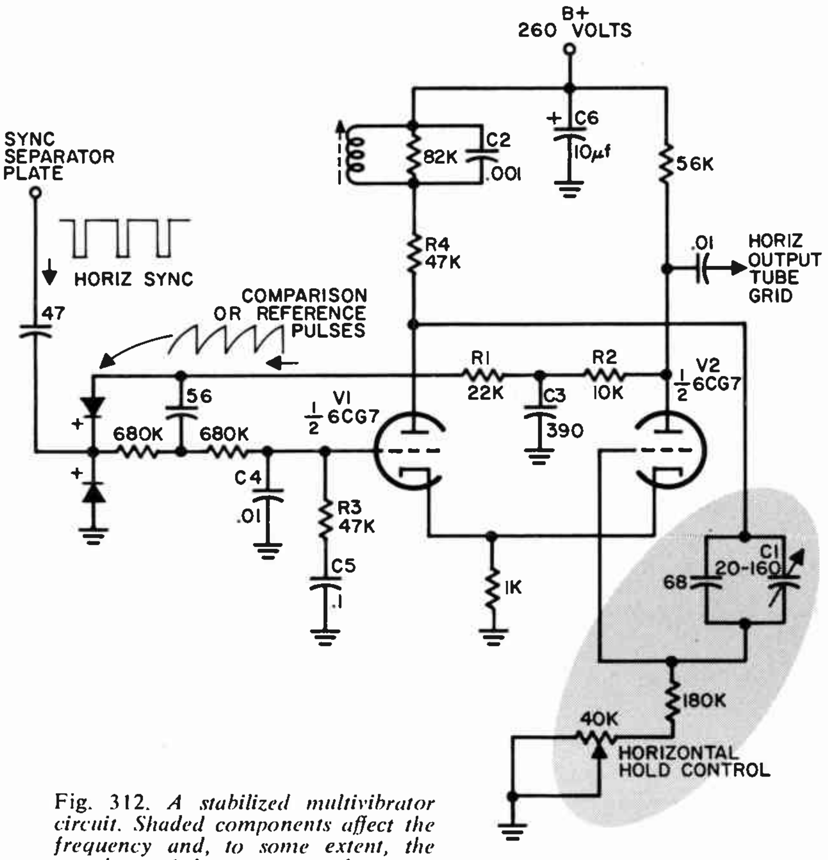


Fig. 312. *A stabilized multivibrator circuit. Shaded components affect the frequency and, to some extent, the shape of the output waveform.*

Complete circuit of stabilized multivibrator with diode afc

Now that we've gone over all of the parts, let's take a look at a complete circuit. Fig. 312 shows a typical example. Now you can see some of the minor variations in part values, etc., which you'll find in the same circuit as used by different manufacturers. The isolating resistor (R4) between the ringing coil and V1 plate is 47K; a variable capacitor (C1) is used across the V1-plate–V2-grid coupling capacitor, and the capacitor (C2) across the ringing coil is .001 μf. However, don't let this bother you at all. From examining the circuit, you can see that it is basically a standard cathode-coupled multivibrator, and that's all that matters. We can treat them all alike.

The dual-diode afc is shown connected into the complete circuit at the left. This version uses a common-cathode setup. The sync pulses are fed to the junction of the two diodes, while shaped comparison or reference pulses from the oscillator output plate are fed to the top. The other end is grounded. Note the 22K-resistor–390-pf-capacitor–10K-resistor network (R1, R2, C3) connected in the plate circuit of V2. This does two things: (1) it shapes the pulses into the sawtooth form shown and (2) serves as a voltage divider to set the amplitude of the comparison pulse fed back into the afc.

Also, note the R-C network (R3, C5) and the .01-μf bypass capacitor (C4) on the grid of V1. This is the anti-hunt circuit for this type of afc. By the size of the capacitors and resistors, you can see that it has a fairly long time constant. It holds the grid voltage steady during changes in control bias and keeps the horizontal oscillator from jerking back and forth across the proper frequency. Remember this whenever you're using a scope in any of these circuits: you should never find any "signal" waveforms on *this grid*—nothing but pure dc.

We check the action of the afc by measuring the amplitude and polarity of this voltage as the frequency of the oscillator is changed. You'll find several voltages here in different receivers. Some sets will have this grid at zero or only 0.1 or 0.2 volt to ground. Others will set up the circuit so that there is always a voltage present, maybe as high as 15 volts positive or negative. Whichever is used, take the actual voltage given on the schematic. Be sure that you are using the right reference point, (ground, B-minus or some other specified connection) and check for the *variation* in voltage around that value when the oscillator frequency is changed.

Servicing the stabilized multivibrator circuit

The symptoms of horizontal oscillator trouble are the same in all circuits. We get the same symptoms here that we would with a Synchroguide or any other. And we'll use the same tests to pin down the trouble. We isolate the oscillator circuit: short out the ringing coil and ground the afc to remove the sync. Now we have the oscillator running all alone. If it will *not run*, then we start checking parts to find out *why*.

Fig. 313 shows the oscillator circuit with the shorting connections made. We connect a jumper across the ringing coil to remove the stabilization. Also, we lift one end of the 6.8K resistor (R4) and replace it with a slightly larger one. This isn't too critical at this

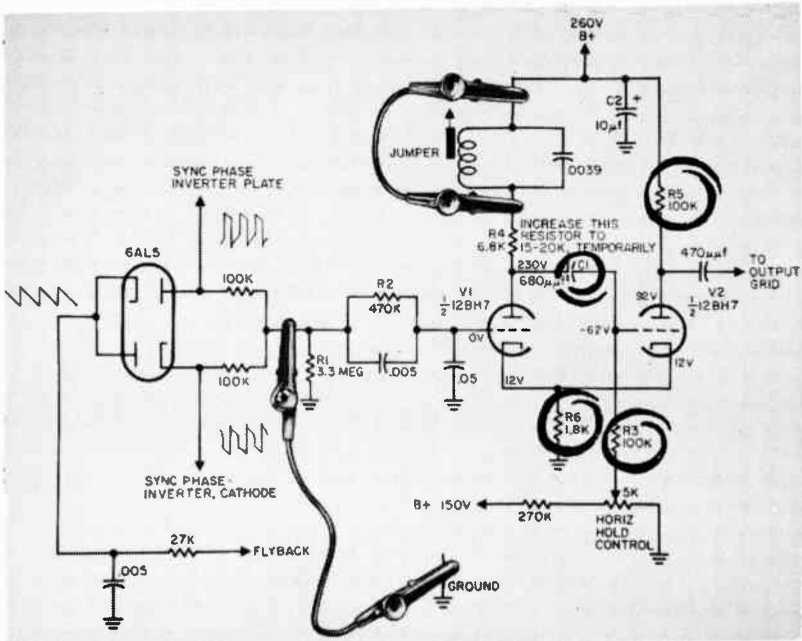


Fig. 313. *Jumper wires on schematic show quick-way connections to disable phase detector and stabilizer to check oscillator.*

time. Use something around 15K. The purpose of this is to increase the plate impedance, so that the oscillator will have enough output to run. If we take out the ringing coil, which is a very high impedance, we'd leave only 6,800 ohms in the plate circuit. The B-plus point is ground for signal frequencies. The V1 triode needs a higher plate load resistor, and we increase it temporarily. Since this circuit does not use any residual afc bias (the grid of V1 normally runs at zero volts, as shown), we can ground it. We connect this ground at the junction of the 470K and 3.3-meg resistors (R1 and R2).

Now, we're ready to check. First we – I beg your pardon? Did someone in the back row have a question? What? Yes, indeed. We did change the circuit constants. This is *not* the same as the circuit of Fig. 312. We did that intentionally! This is the sort of thing you'll find in commercial TV sets: all manufacturers change parts values, etc., even between different models of their own sets! So, we want you to get used to working with this circuit with different values, etc. But, always remember this: this is the *same circuit* as that of Fig. 312, and of *all cathode-coupled multivibrators!* If you'll mentally take away the parts values in these two circuits, you'll see that they are practically alike! So they can be treated alike when you're servicing them.

Now may we get on with the lecture? Thank you. As I was saying, the oscillator *should* run, in this condition. We apply a signal to the set, so that we'll have a picture on the screen. This gives us a simple and easily identified way of knowing when the thing is working as it should. What we must do is find out if this oscillator is capable of running at 15,750 cycles per second. If so, then it is OK. So, we juggle the hold control to see if we can make a single picture float across the screen, just as we did in the first instance. If we can get one picture to slow down enough so that we can positively identify it, then we're OK. The oscillator should be running close enough so that we can keep a single picture on the screen for a little while, anyhow.

Remember, we must have an oscillator that can be controlled. We don't want one that is too stiff, too precise. If it is, it won't respond to the sync and control actions, and it won't work right in a TV circuit. As long as we can make a single picture, the oscillator is in good shape.

If we can't get anything except slanting bars, in either direction, the oscillator is too far off frequency. One of the parts is defective. There aren't too many to check, so take them one at a time and see just which one is faulty. These parts are circled in Fig. 313. Leakage in the 680-pf coupling capacitor (C1), which changes the bias on the grid of V2, a change in value of the 100K resistor (R3) between the horizontal hold control and V2 grid; a change in value of the 100K resistor (R5) in V2's plate, or in the 1,800-ohm common-cathode resistor (R6)–all of these change the natural operating frequency of the oscillator. In general, it is best to lift one end of each part to be tested, to be sure that a parallel path for resistance isn't causing an incorrect reading.

To test capacitors in circuits like this, use one of the capacitor test instruments capable of reading very-high-resistance leakages. Substitution of known good parts is a quick and easy test. An accurate ohmmeter is needed to measure the value of resistors in these stages. Most resistors will be about ±15% tolerance. If they are farther off than that, replace them.

There is one case in which everything's all right but the oscillator won't work (a very common complaint, often unjustified). This happens if the filter capacitor in the B-plus supply line is open. This is the 10-μf electrolytic seen at the top of both Fig. 312 (C6) and Fig. 313 (C2). This point should always be at ac ground potential to prevent feedback, and it is this capacitor that holds it there. At 15,750 cycles, the reactance of this capacitor is only about 1 or 2 ohms. So, all unwanted frequencies go rapidly to ground and are lost. If trouble happens, there are a couple of quick-checks you can use. First, and simplest, of course, is to bridge a good electrolytic capacitor across this point. If the trouble is cured, replace the electrolytic. The other is to pull the horizontal output tube out of its socket.

The actual defect that keeps the oscillator from working is feedback. Oscillators must have feedback to work, but this is feedback in the *wrong phase*. Most of it comes from the horizontal output stage. If we disable this stage by pulling the tube, we remove the cause. The oscillator performance can then be checked by using a scope. But, don't ever forget that electrolytic when you run into a 'mysterious case' of oscillator trouble; it is responsible for many headaches!

Changing parts values to make oscillator run on frequency

As you will see as we go along, we do not recommend making alterations in the circuits. Whenever a part is defective, it should be replaced with an exact duplicate. In the greatest percentage of TV circuits we must work on the basic principle that it worked once (we know, we've told you this before) and can be made to work again, using the part values shown on the schematic. However, once in a blue moon, you will run into a circuit that is not too stable horizontally. When we strap out the ringing coil and afc, it simply will *not* operate as it should. In this case, you *can* juggle part values to bring the oscillator back to the right frequency.

Design procedure in most cases is to set up the oscillator so that it works slightly below standard frequency. Then, the afc can hold it on frequency a little easier. However, in a very few sets, and these are mostly of the cheaper variety, you'll find oscillator circuits that won't work as they should. If the oscillator will *not* make a single picture with the stabilizer and afc out, and all the electrolytics check good, etc., then don't be afraid to try some changes. For example, if the oscillator is running below frequency, it means that some part value is too large, either a resistor or capacitor. You can reduce the size of a part in small jumps. For instance, if there is a 820-pf coupling capacitor in there, cut it down to 680. Reduce the plate or grid resistor to the next size, say, from 100K to 82K, and see what happens. The end result of this process *must* be an oscillator circuit capable of holding a single picture on the screen for a short time.

After you finish your juggling, put the stabilizer and afc back in operation, and see if the oscillator isn't more stable than it was before. If it isn't, then put the circuit back the way you found it! However, if you do have a real case of incorrect parts values in a horizontal oscillator, you *will* be able to improve the performance of the set! (Design engineers don't make *too* many mistakes like this, but they, too, are human.)

Finishing up the multivibrator

After you have the oscillator running on the right frequency, take the short off the stabilizing coil and see what happens. Most of the time, the picture will fall out of sync. Without touching the horizontal hold control, adjust the slug in the coil until the picture locks in again. After it locks in, keep on turning the slug until it falls out once more. Then turn the slug backward until you find a place about in the middle of this range, and leave it there. Now check the stability of the oscillator, by watching the picture. Since we have no sync applied to the circuit, there's nothing but the 'built-in' stability of the oscillator to hold the picture on the screen. We're just using the picture as an *indicator;* as long as we can see only *one* picture, this means that the oscillator is running pretty close to the right speed. Incidentally, this picture can be 'leaning' in either direction, or sliding back and forth across the screen. As long as you can still make out a single picture, it's pretty close.

Now take the short off the afc. The picture should be much more stable. The test procedure for this is the same as that we used before. If the afc throws the picture *out* of sync, check the circuit to see which part is defective; there's one in there somewhere! Changing value in resistors, causing an unbalance in the load; defective tubes or crystal diodes, leaky capacitors—any of these will upset the

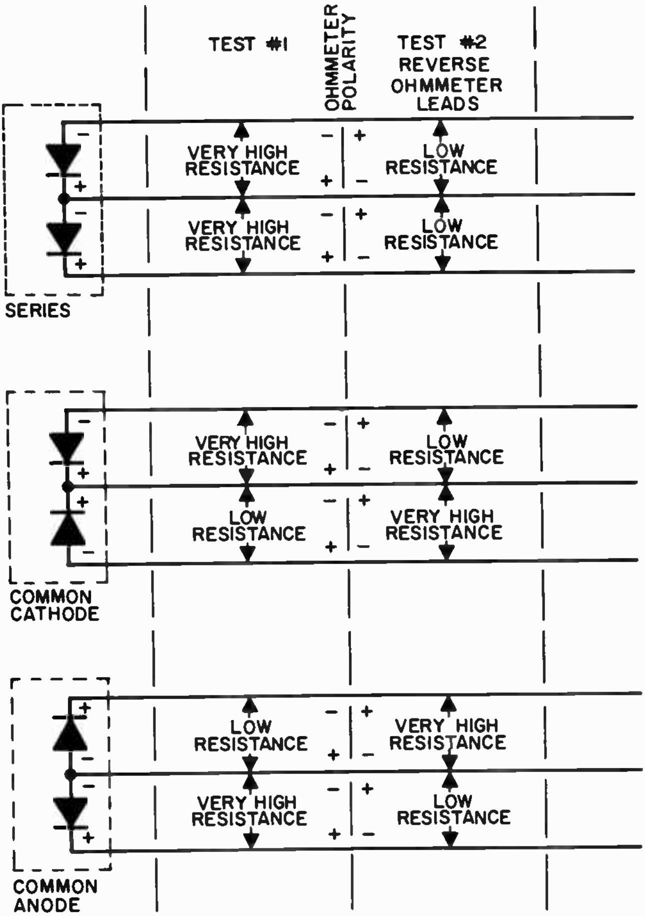


Fig. 314. *Ohmmeter tests for the three dual-diode assemblies available.*

action of the afc. Go through the circuit with ohmmeter and capacitance tester, and the bad part will soon show up.

Check the stability of the picture by turning the tuner off-channel and back again. The picture should come in in-sync; if it appears out of sync, then straightens up after a few seconds, you're close but not right yet. Adjust the horizontal hold control.

Checking crystal diode assemblies

In early versions, some of the duo-diode germanium rectifiers often caused trouble. In fact, many technicians of that time usually changed them first, then looked to see what *else* was the matter! Improvements in manufacturing techniques have cured a great deal of this trouble, but you should still remember it as a possible source of trouble. They are simple to test. In most cases, an ohmmeter will do the job.

The two diodes should balance to do their job properly. If you suspect them, disconnect the diode assembly and check forward and back resistance with an ohmmeter. In measuring resistance of a diode, you'll find a low resistance in the conducting direction and a very high resistance in the other. Fig. 314 shows this. The ohmmeter reading you get will depend on the polarity of the battery in your ohmmeter. This actually makes no difference at all. As long as you get a very small reading in one direction and a very large one in the other, on both diodes, and the two balance (are equal), the diode assembly is probably all right. You will find typical readings to be: Forward (conducting) direction: 1,200 ohms; back (nonconducting) direction, infinity or no reading at all; completely open.

In Fig. 314, you see the three types of dual-diode assemblies used in TV receivers. The results of resistance measurements for each type are shown on the diagram. In this case, low resistance means anything between 1,000 to 5,000 ohms. Very high resistance means anything from about 250,000 ohms to infinity, no reading at all. In some cases, good diodes will read open in one direction. To be sure that the diode is not actually open-circuited, check the low-resistance reading too. A diode which reads the same in both directions, whether it is a low or an open reading is definitely bad.

For best results, the two readings should match. In other words, if one diode reads 1,500 ohms in the low direction, the other should read between 1,400 and 1,600 ohms. If the difference is any more than that, in percentage, replace the diode. The high-resistance readings are not quite so critical. As long as each diode has a back resistance of more than 1 megohm, it will probably work all right. If you have any doubt, replace it and see how the circuit works.

Mismatched diodes can cause some extremely peculiar effects. Always check them whenever you find any mysterious troubles in the sync sections. In one case, a mismatched diode pair caused a severe loss of *vertical* sync, with very little effect on the horizontal stability! This was due to the circuitry used in that particular model. One of the diodes was nearly shorted, and, because of the circuit used, there was a very-low-resistance path to ground for the vertical sync. Since vertical sync depends mainly on amplitude, this caused trouble. Horizontal sync depends mainly upon phase, and can suffer quite a loss in actual amplitude before any severe trouble shows up. This happened in the case mentioned. There was enough horizontal sync getting through the defective diode to hold the oscillator almost stable.

Phase-detector troubles show up as poor horizontal hold action, very little range on hold controls, and misplaced pictures. The horizontal blanking bar which should normally be out of sight at the sides of the screen will lock in the middle (Fig. 315). The bar may be in the center or at either side. As long as it is visible, you have

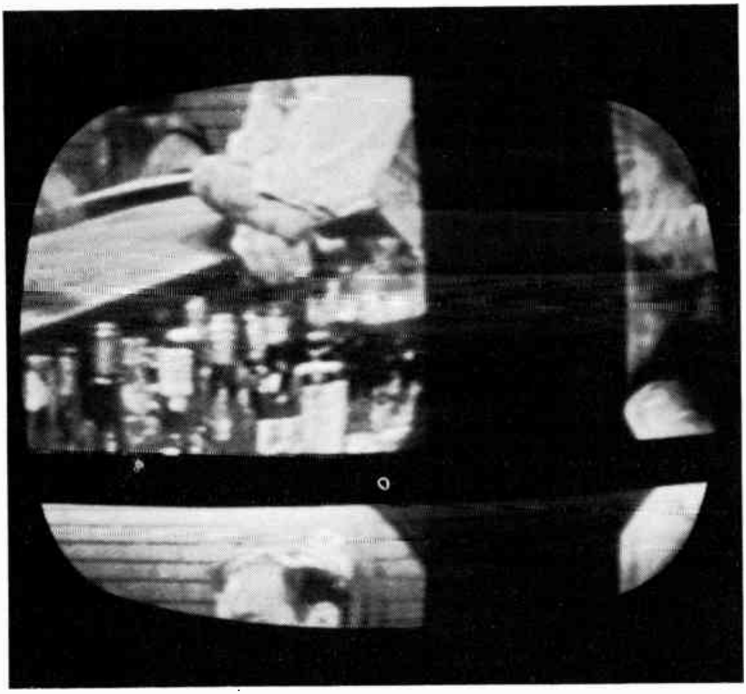


Fig. 315. *Presence of horizontal blanking bar indicates afc trouble.*

horizontal afc troubles. Unequal conduction in the diodes causes an unbalance in the correction voltage developed across the load resistors, and the oscillator is thrown off frequency.

In some sets, you'll find these diodes plugged into a small socket. However, in most sets, especially those using printed circuitry, they will be soldered in place. To test, they must be unsoldered completely, because of the many parallel resistance paths present in the circuit.

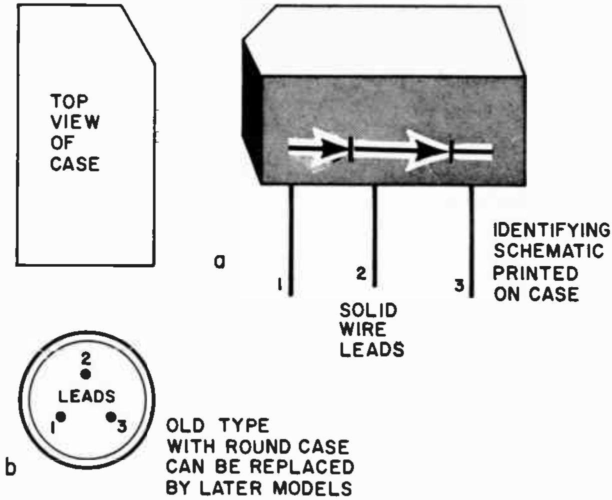


Fig. 316. *Packaging of the semiconductor dual-diodes can vary. The electrical connections are the important factor.*

When you replace one of these, be sure to get it back exactly as it came out. If you are installing a new unit, be sure that it is the right type, exactly the same as the original, and that it is installed with the diode polarity right. Actually, this is not important on the common-anode and common-cathode types, since they are reversible. However, watch out for the series type, since these are very definitely polarized.

Often cases are "polarized"; usually one corner of the case is cut off, so that you can tell which end is which. Fig. 316-a shows a sketch of the cases and leads used. In older sets, you may find a diode assembly in a cylindrical case, as in Fig. 316-b. The diodes will be electrically identical with the later models, and you can use the polarized-case type as replacements, if you get the correct electrical type, series, etc.

Chapter 4

Troubles, Troubles, Troubles

UP TO THIS POINT, WE'VE BEEN TALKING ABOUT TROUBLES THAT originate in the oscillator and afc circuits themselves–shorted ringing coils, leaky capacitors; resistors that have changed in value, and so on. Now, let's take up a very common trouble, one which has caused more headaches than all the others put together. From actual experience, I have found more technicians stuck on this than any other single defect. The symptoms are quite simple: "Everything checks good but it still won't work!" This is true! All of the parts in the oscillator circuit *are* good, all dc voltages are apparently quite normal, but still the picture is unstable, weaving and bending, or in severe cases, the oscillator won't work at all!

What causes such a condition? Feedback. But, someone says in a hurt tone, an oscillator's got to have feedback or it won't work at all! True. However, oscillator circuits are very particular about feedback. It must be of the right shape and size. Feedback in the wrong place causes troubles of all kinds. The basic cause of wrong feedback is a lack of filtering in the supply circuits, mostly in plate voltages, but also in grid or cathode voltages at times. Let's see exactly what's happening.

Fig. 401 shows the oscillator circuit in a slightly different form. Looks quite different, you say? It isn't. If you'll trace the connections, you'll see that it is exactly the same as all of the other Synchroguides we've drawn up to this time. The principle applies to *all* oscillator circuits. We picked the common Synchroguide again.

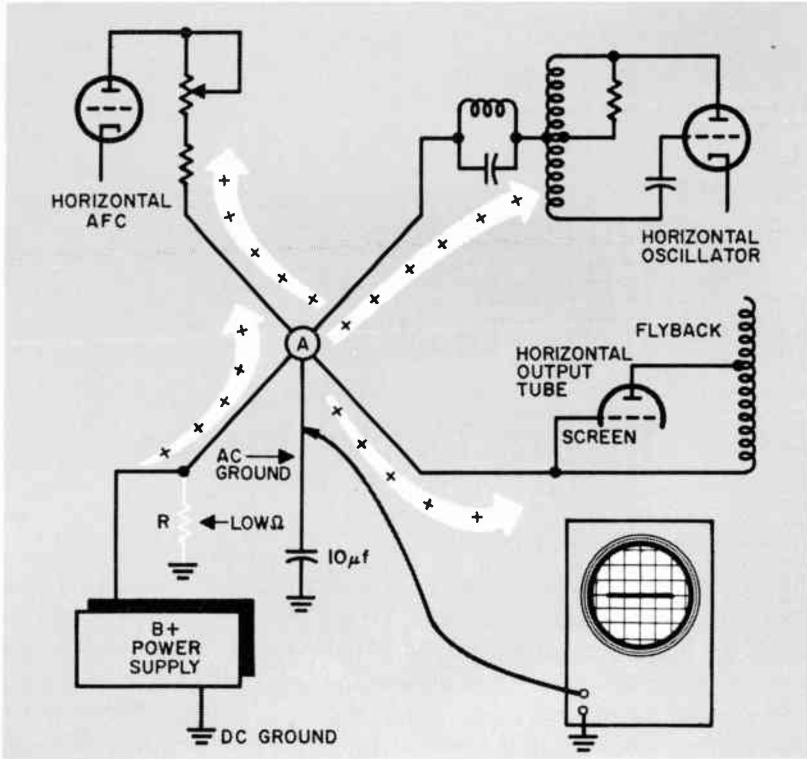


Fig. 401. *A well filtered (low-impedance) power supply will show little trace of signal voltages across its output. A straight line will appear on the scope screen.*

The point we want you to observe is this: all of the plate circuits are connected to the same place, point A (the B-plus supply). Now, what do we have here? Dc? Yes, but we're not interested in that, now. What we're interested in here are the signal voltages, the ac voltages coming to this point from *all* of the stages connected to it. Remember this, as it is the most important part. All of these stages have this *in common*. We have shown some signals along the return leads to the various stages. Notice that we included the horizontal output tube, too, since it plays an important part in this particular discussion.

Ac ground potential

Point A must be at ac ground potential. What's ac ground potential? Simply this: The reactance (ac resistance) of this capacitor must be so low that these signal currents will not have a chance to develop any ac voltage drop across it, as they flow through it to ground. There are signal-frequency (ac) currents in the plate-return circuits of *all* stages. To keep them from getting into *other* stages, or even into the wrong place in their own circuits, we must make the *common return* (A) have the lowest possible reactance to ground. This must be an ac short circuit, even though there may be 200 to 300 volts dc present.

To do this, we connect a large capacitor between the common B-plus point and ground. This may be the chassis, in TV sets with a power transformer, or a floating B-minus in series-string TV sets. The action is the same in both; we bring the unwanted signals back to a common point where they can do no harm.

The 10-μf electrolytic capacitor has a very low reactance. As we

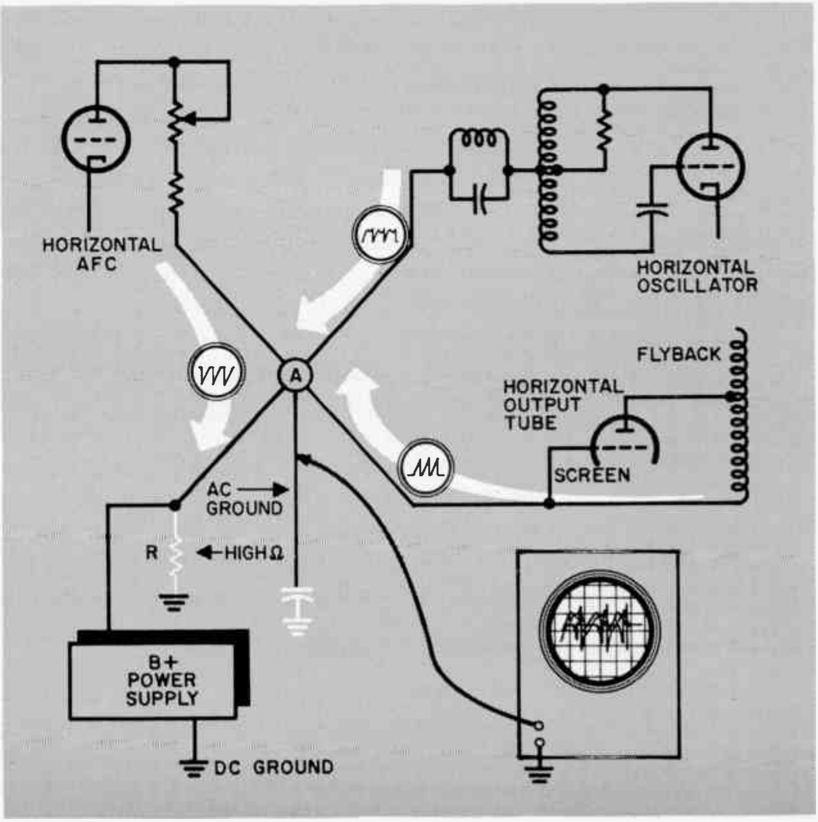


Fig. 402. *With the filter capacitor open all circuits feed back signal voltages which appear across the now high-impedance power supply. (Also see Figs. 417 and 418 on pages 93 and 95.)*

said, this means simply ac resistance. It's an open circuit; very high resistance to dc, but very small to ac. If you want an exact figure, a 10-μf capacitor has less than *1 ohm* of reactance at 15,750 cycles! The higher the applied frequency, the lower the reactance of a capacitor: $X_c = 1/2\pi fC$. You can see from this formula that, if we increase the size of any figure *below the slanted division line* [frequency (f) or capacitance (C)] the fraction is going to get smaller. Helping out in this job are the very large filter capacitors in the B-plus power supply. They're not shown, but they're always there. With these capacitors, running from 40 to more than 100 μf, in parallel with our 10-μf, the total reactance figures out like resistors in parallel. In a well designed power supply, the total parallel reactance will get down to about .001 ohm, which is pretty small!

What happens if we take away this low reactance from this circuit? Note that we drew a resistor R across the capacitor. This represents the ac resistance of the capacitor to signal currents. As long as R stays very small, no trouble; no ac voltage drop at point A. If the capacitor goes bad, opens, etc., then R gets much bigger, and we're in trouble. Fig. 402 shows what happens—pulses, signals and all kinds of ac going in all directions! Not flowing peacefully to ground as they should, but turning around and going into other circuits where they have no business at all! There are so many possible feedback paths that no one could trace them. The only way to describe such a condition is simply, "It's a *mess*!"

What is happening to our oscillator? It has its own feedback path through the coils. All of a sudden these paths are rudely invaded by pulses from the horizontal output stage, of much higher signal voltage and in the wrong phase. The afc too is getting pushed around. Pulses from the horizontal output stage *and* the oscillator are showing up in circuits where nothing but tiny sync pulses from the video signal ought to be. I don't have to describe the result! At any rate, the oscillator and afc simply refuse to work under such conditions; if they are still trying, they can't work as they should.

Picture symptoms of feedback troubles

Of course, the first indication of this kind of trouble is in the picture. (Often the *only* indication! As we said, all voltages, parts and tubes are good!) The most common symptom is a bend or weave in the picture. Vertical lines which should be straight are buckled or writhe back and forth. Sometimes this shows up in the top 20 to 30 lines of the picture; vertical lines in this area bend to right or left, and flutter. This is called *flag waving*. In extreme cases, the oscillator will not run at all, and we will have no raster.

A severe case of this is shown in Fig. 403. This is a bad case of weaving; the 60-cycle bend travels up or down the picture. The trouble here was an open input filter capacitor on the rectifier cathode! In a similar case, a blank raster looked like Fig. 404. A picture on this raster looked very much like Fig. 403, with weaving, and also a pronounced shading from left to right. So don't overlook *any* of the electrolytic capacitors when you are hunting for this

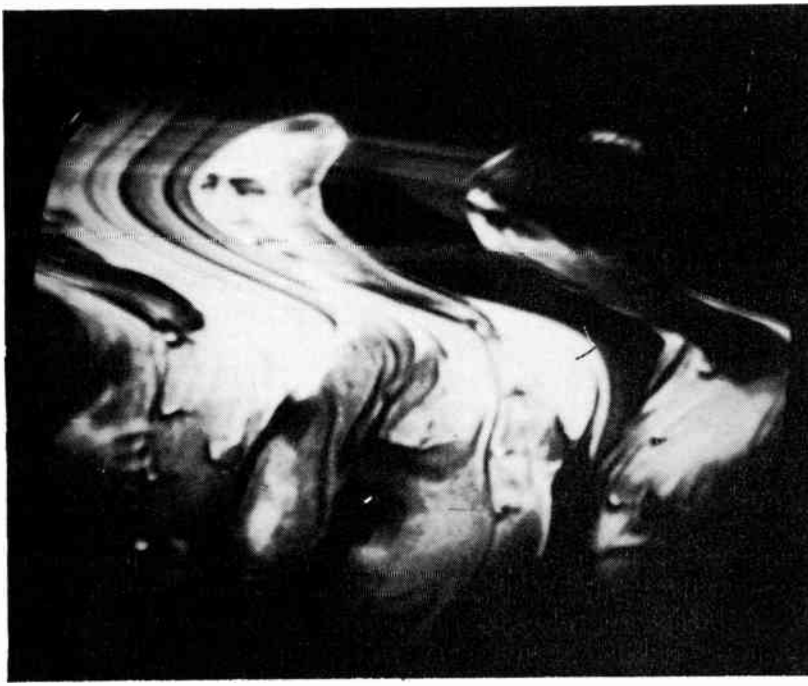


Fig. 403. *Power-line ac can cause many strange effects when it appears where there should be dc only. Look for additional symptoms—hum in the sound, hum in the video as additional helps in locating the defect.*

kind of trouble! No matter how far away they may seem to be in the circuit, they can cause trouble if they go bad.

If the power supply electrolytics are good and the 10-μf electrolytic in the horizontal oscillator–afc circuit opens, you can get some peculiar reactions. The oscillator will usually refuse to work at all. However, if you open the circuit at the horizontal output tube's grid, and feed a substitute drive signal in at that point, the output stage *will* work, make high voltage and light up the screen.

Checking the horizontal oscillator with a scope will show that it, too, is now working beautifully! However, when we put the two together again, neither one will work! This condition is a dead giveaway: there's a filter capacitor open somewhere! Another clue will be a scope waveform looking somewhat like Fig. 405. Note the small squiggles in the middle of the sweep stroke? These shouldn't be there at all, and they mean trouble.

The reason for the inoperative stage is the severely distorted *drive waveform* on the horizontal output tube grid. This circuit is

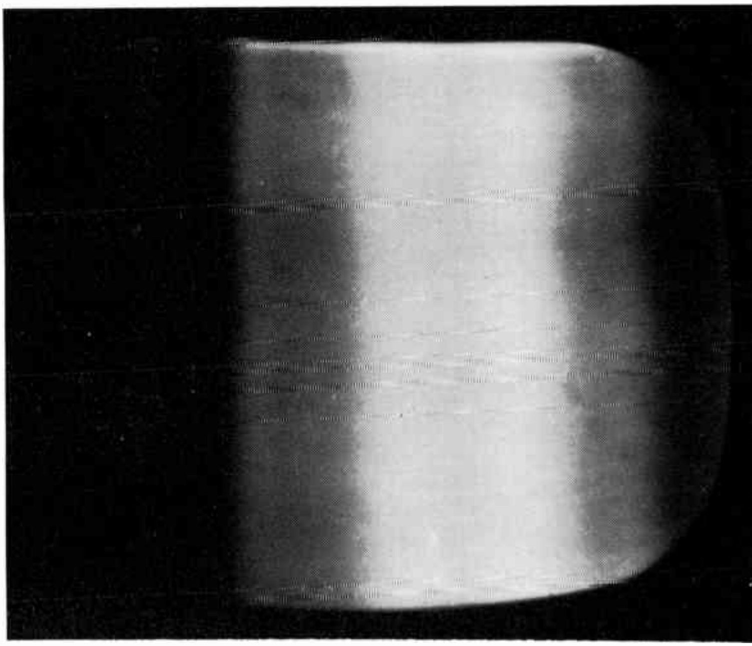


Fig. 404. *Effect of an open capacitor on the raster. Sometimes this can be masked by increasing the contrast or brightness control settings.*

pretty particular about what kind of signal it will accept to make the high voltage and sweep output. Distort this enough, and the critical circuits in the flyback, yoke, etc. simply refuse to work at all. However, in this case, if we feed a good drive signal into the grid, it works, thereby proving that there was nothing wrong in that section at all. Scope-testing the oscillator shows a pretty fair waveform output, so that's OK. Now, like some of our relatives, the two will work separately, but when they get together there's trouble! Why? Obviously, the trouble must be in some circuit that is *common* to both stages, and this is the *B-plus*. So, we investigate.

Finding trouble in filter capacitors

There are two ways to pin down this kind of trouble. First is by *bridging* (you'll also find us using the term *shunting;* means the same thing) a good filter capacitor across the circuit. If the old capacitor is open, it is the same as taking it entirely or partially out of the circuit. If we add a good capacitor, the circuit is the same as it was before the open happened. You can use a standard re-

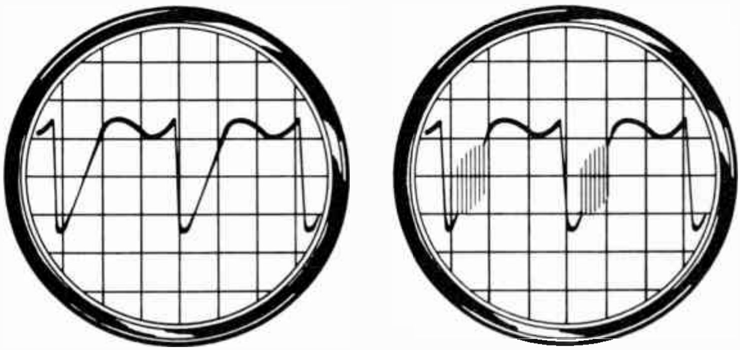


Fig. 405. *The normal waveform (left) can be disturbed into all sorts of waveshapes (right) when unwanted feedback is present.*

placement electrolytic of about the same size as a test unit, but there are disadvantages to this. You must either hold it in place or solder it into the circuit. After about three or four tries, you may find the solid wire leads breaking off the capacitor, which is rather expensive. (It ruins the new capacitor; you can't resolder the leads to the aluminum case!)

The best way is with a substitution box. These have several electrolytic capacitors, connected to a selector switch. Any size of capacitor needed may be chosen and connected into the circuit with the clip leads attached to the box. Fig. 406 shows one of these. A safety switch on the box leaves the circuit open until you're ready to test. When this is pushed, the capacitor is connected into the circuit. It is spring-loaded, and, when the test is complete, releasing the switch opens the circuit again, also connecting an internal resistor across the capacitor to discharge it. This avoids the possibility of accidental shock from picking up the test leads with a big capacitor charged to from 300 to 400 volts!

Another feature of this switch is also very handy: in quite a few cases, you're going to find electrolytics which are *intermittent.* They will show up bad; then, when a new capacitor is bridged across them, the surge of charging current in the new unit will cause the old one to heal and be as good as ever, for a while. This is about the most irritating thing that can happen. Why? Because this trouble won't show up again while the set is in the shop; however, it *will*, just as soon as you take it back to the customer!

To avoid this, the capacitors in the sub-boxes are never connected directly across the circuit. A small resistor is connected in

Fig. 406. *Electrolytic capacitor substitution box is a handy unit for bench servicing.* (Sencore, Inc.)

series with the switch, so that the test capacitor is charged more slowly. (The switch has three positions: off, charge and on.) When the capacitor has charged, the switch is pushed on to ON and the capacitor is connected across the circuit under test. Once the test capacitor is fully charged, it will not heal the suspected unit in the set (Fig. 407).

In quite a few cases, you're going to find that bridging any one capacitor doesn't cure the symptoms. It will help them, but will not eliminate them entirely. In such cases, or in all cases where you suspect a bad capacitor, try disconnecting the old unit then repeating the test. If the original happens to have fairly high leakage or high power factor, then bridging will not completely remove the troubles. It will always *help:* make the picture better, if there is capacitor trouble.

You will find that often the trouble is due to leakage between sections of a multiple electrolytic capacitor. This can cause some

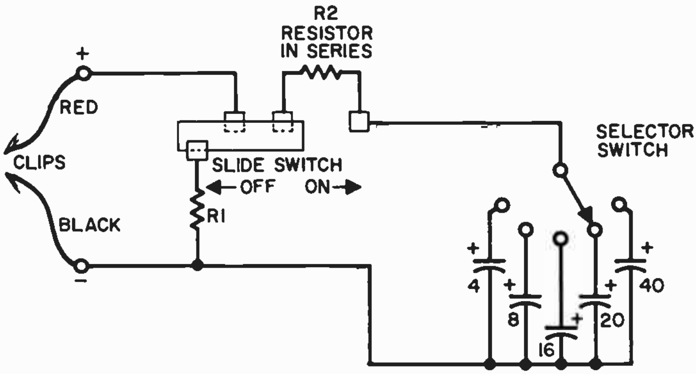


Fig. 407. *Circuit diagram for electrolytic capacitor substitution box.*

strange and wonderful symptoms, when they are all just a little bad! AXIOM: If one unit in a multiple electrolytic capacitor is bad, replace the whole unit! *Reason:* conditions inside that can are such that one unit has failed. Therefore, the same conditions are still there and, if you leave the other sections in the circuit, the same trouble will occur when they fail, as they inevitably will.

You may find it difficult to get exact duplicate electrolytic capacitors in some multiple-unit combinations. If so, get as close as you can. Electrolytics in this application have a very wide tolerance. For instance, you can replace a 40–40–80 with a 30–30–100, or a 50–50–60, and so on. The best way to find out is to connect the proposed substitute into the circuit: you can make it up out of substitution boxes, single-section replacement capacitors, or a combination of the two. Test the circuits with a scope, and by actual operation with a TV signal. If you do *not* have sufficient filtering, you'll soon find it out! A good rule of thumb to follow in such cases is: Use the next larger size when you can't get the original size. For example, if you need a 10-μf, and can't get it, use a 12- or 16-μf, both common sizes. If you can't get a multiple unit which will do the job, get one with as many capacitors of the right size as you can, then finish up with separate units mounted under the chassis. There will be plenty of room in the average TV chassis, even in the smaller printed-circuit sets. (Be sure to fasten the single-unit replacement capacitor case firmly to some solid part of the chassis, so that its weight doesn't pull connections loose. This is especially important in portables.)

Analyzing picture symptoms of incorrect horizontal oscillator operation

As we told you before it is possible to tell whether the horizontal oscillator is running fast or slow simply by looking at the picture. Where you get into trouble is the wide deviations from normal frequency, causing overlapping pictures on the screen.

For example, you might think that the picture as shown in Fig. 408 was due to too fast an oscillator frequency or a fault in the horizontal afc, because the blanking-bar is showing. Look closely: you'll see that this is actually *two* pictures! If the oscillator is too fast, the electron beam in the crt of the receiver completes one horizontal sweep line before the transmitter has finished sending it. This makes the blanking bar of each line move a little more to the right and we see the blanking bar slant up toward the left.

If the oscillator runs below normal frequency, the transmitter finishes sending a horizontal line before the electron beam in the crt has completed the link, the blanking interval (bar) between each line is progressively closer to the left and we see a blanking bar slanting up toward the right. Note the man in the straw hat, seated at the left. You can see the same character again on the other side of the blanking bar! So, we do have two complete pictures, or darn near it. If this were split-picture trouble, caused by a bad afc diode, we'd have only *one* picture; the left half would be at the right and vice versa. Here we can see one line of the horizontal picture information actually repeating itself, and from this we know that the oscillator must be running at or very nearly half-speed.

From this information, we can deduce that something in the oscillator circuit has increased in value. Why? Because, in oscillator circuits, the only way to reduce the frequency is to make some value larger. Since the inductance can't increase by itself (this would mean winding on more wire; the only way!)* or a capacitor value become larger (more plates!) this must be caused by a re-

*The change in inductance to reduce the frequency to half of its former value is considerable. (With a .01 μf capacitor this would mean the inductance would have to change from .01 henry to more than .04 henry.) Such a change in inductance value can be accomplished only by adding turns. Moving the core in or out won't change the inductance enough to halve the frequency, or to double it.

sistor which has increased in ohmic value. This, we know, *can* happen. So, with a careful look at the picture, we have identified the trouble and made a very close guess at its possible cause. (This was actually due to a plate load resistor which had increased in resistance!)

Remember that you can get a very *similar* picture if the oscillator is running at double normal speed. However, if you can get the

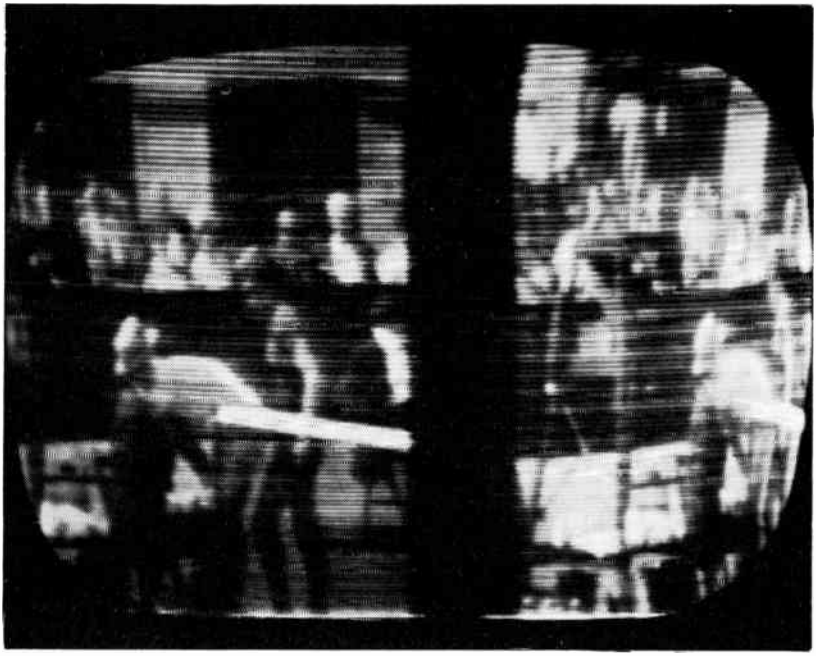


Fig. 408. *A blanking bar through the center of a picture does not necessarily mean sync-phasing trouble. A closer examination will reveal that there are almost two complete pictures side by side. This occurs when the horizontal sweep oscillator runs at half frequency.*

picture to stand still long enough to check details, you'll see that you actually have only half a picture or less on the screen. It will be overlapped and, usually, have a bright vertical line near the center where parts of the video information are being scanned on top of each other. Another clue will be the absence of the wide blanking bar seen in Fig. 408. This kind of picture means that the oscillator is running too fast (higher frequency). What do we do to make an oscillator run higher in frequency? Right: we *reduce* the size of some of the parts. Make them smaller! Now our field is not as limited. We could have a short in the coils, which reduces the inductance: an open capacitor, perhaps one of a pair of capacitors in parallel, reducing the total capacitance in the circuit, or a resistor could have become smaller in value, perhaps due to a short or overload which burned the carbon element. All of these will have to be checked.

Both of the preceding problems were discussed in the case where the horizontal oscillator suddenly jumped off frequency all by itself. No one had touched the setup controls except a front-panel horizontal-hold control or had been inside the cabinet.

If there has been tinkering with the adjustments, we have an entirely different situation! A do-it-yourselfer or some poorly trained technician may have been fiddling with the adjustments. Always watch out for signs of sabotage in such cases. For example, if you opened up a set having these symptoms and found the brass adjustment screw of the ringing coil unscrewed all the way out with part of the slot broken off, there is room for a definite suspicion that someone else has been there before you, and it wasn't Kilroy! Blobby solder joints and similar results of poor workmanship are good clues.

Make a careful check of all circuit components. There are many cases where wrong parts have been installed. This is the type of defect that is not normal, and you may overlook it unless you're alert. One favorite is the use of incorrect resistors! The writer will long remember an obstreperous horizontal oscillator circuit which simply wouldn't do anything right! Finally, a very close check of the whole circuit disclosed a gray–red–orange (82,000-ohm) resistor in a very important position, instead of the gray–red–*yellow* (820,000) which should have been there! Beginners and do-it-yourselfers are easily confused by color codes, so watch out! This type of problem can be very easily spotted by making a few resistance measurements in a circuit. Don't get *overconfident* and pass this important step by, as I did in the case just mentioned! After a few lessons, you'll soon learn to recognize the trademarks of the tinkerer or DIY (do-it-yourselfer) and be on the lookout for them.

Mysterious oscillator troubles, fake capacitor symptoms

Now and then, you'll find symptoms which would seem to point directly to an open capacitor. However, these refuse to respond to bridging with good capacitors. You'll get a big hum bar, plus bad pulling of the horizontal oscillator; something like Fig. 409. Fig. 410 shows the true cause of the trouble (this was a set with printed-circuit wiring). Near the horizontal afc diode connections, there was a tie point, as shown by the pointer in Fig. 410. This was in the filament circuit, and carried about 85 volts ac, since this was a series-string chassis. Moisture condensing on the PC board allowed ac to leak across into the horizontal afc, with the result shown!

The cure for such troubles is shown in Fig. 411: the tie point is simply taken out of the circuit, and a piece of insulated wire

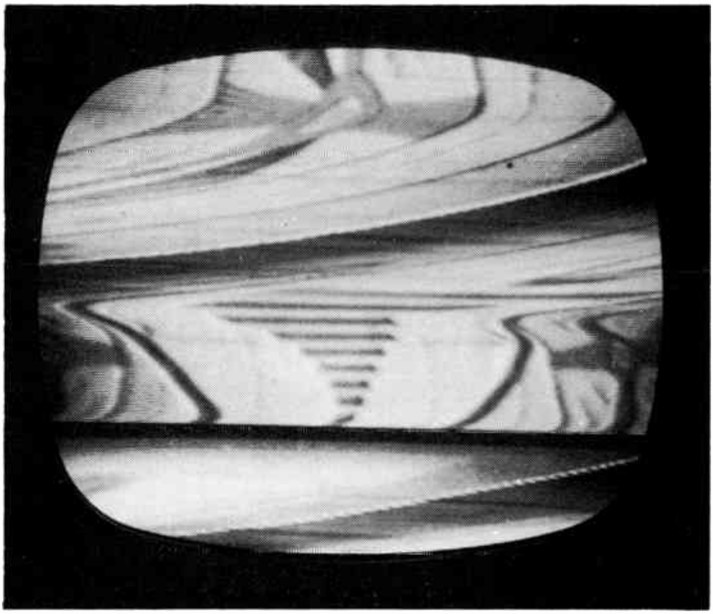


Fig. 409. *Strong pulling does not have to be caused by a component defect. Leakage between conductors on a printed-circuit board using a series-filament can apply considerable power-line ac to wrong circuits.*

used to connect the two points. This removes the high ac voltage from the vicinity of the sensitive afc diodes and stops the trouble. (Incidentally, this technique is very handy for repairing or testing PC boards for just such troubles. Simply replace bad wires with a piece of well insulated hookup wire.)

Another mysterious case of "afc trouble" is often caused by agc trouble, not afc at all! The picture will fall out of horizontal sync, bend and weave, etc. However, in these cases you'll get the key clue in the *appearance* of the picture. You'll see that it shows the distinct symptoms of agc overload; that is, picture details become very dark, and the whites very white. This is caused by a failure of the agc to hold the video gain down as it should. Some stage in the i.f. is being overloaded, causing clipping. Naturally, if we have clipping of the signal, what's going to catch it first? The sync, since it is always the top of the signal! So, this clipping action cuts off our sync, and the oscillator falls out of lock.

To be sure about this, try adjusting the agc control or overriding the agc with a bias box *before* you go into the horizontal oscilla-

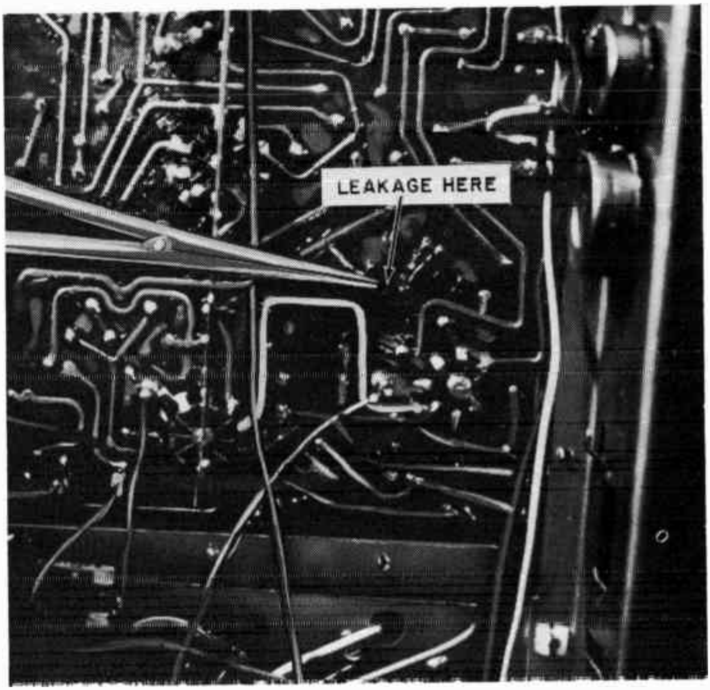


Fig. 410. *Leakage paths are not easy to find. Look for accumulation of solder flux, dust and discolored phenolic. Overheated or burned phenolic is carbon. This must be scraped or cut away to eliminate leakage path.*

tor or afc circuits. If this straightens the picture, let that oscillator alone! In a case of real horizontal sync trouble, the picture values will always remain the same; you won't have the pronounced black-and-white appearance that you find in the case of agc overloading. *Test:* try adjusting the agc control on a set in good condition to the overload point, and study the appearance of the picture. If you get familiar with this particular trouble, it will save a lot of time!

Still another, and one which has puzzled a lot of technicians, is the set which will make a raster, high voltage, etc. when the tuner is set to a blank channel; but when it is turned to a channel with a station, the raster goes out! So does the high voltage, horizontal oscillator and everything else! There is a very simple answer to this: stop and think a minute. While the oscillator is running free-wheeling, off-channel, it's OK. When we add the horizontal *sync* pulses, from the station, it kills the horizontal oscillator dead as a

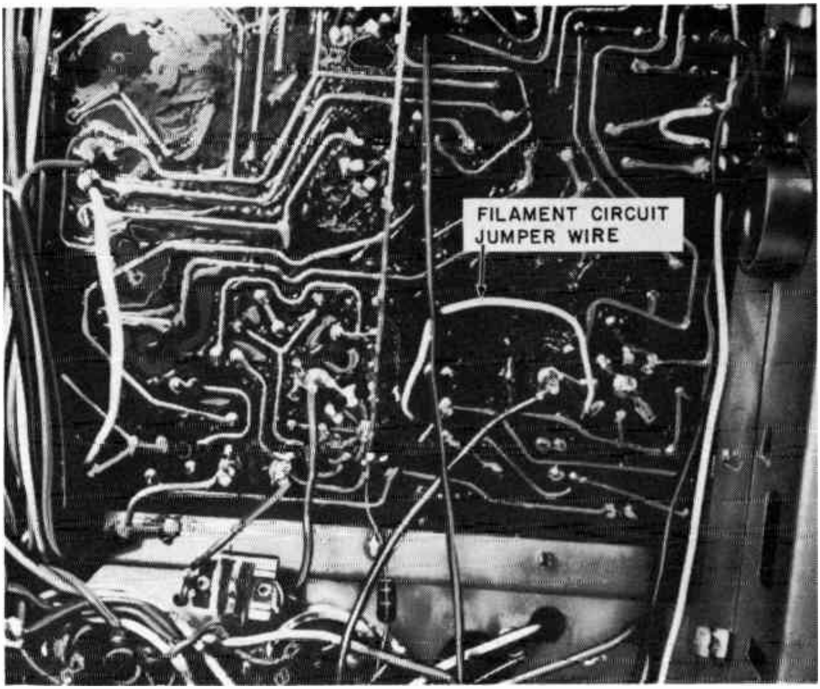


Fig. 411. *Here the trouble-making tie point has been cut away. Filament circuit is completed through jumper wire between tube socket filament connections.*

doornail! So, where's the trouble? In the horizontal afc; no other possible location.

Let's see what the reasoning is in this case. Our horizontal oscillator is running, making a raster, when there is *no afc action* on it. (Likewise, the horizontal output stage, etc. *must* be OK, since we do have a raster.) When we add the afc, by feeding horizontal sync pulses into it, the oscillator dies. Our horizontal afc is having exactly the *wrong* reaction. It is killing the oscillator! So, the trouble must be in that circuit. Investigation usually shows

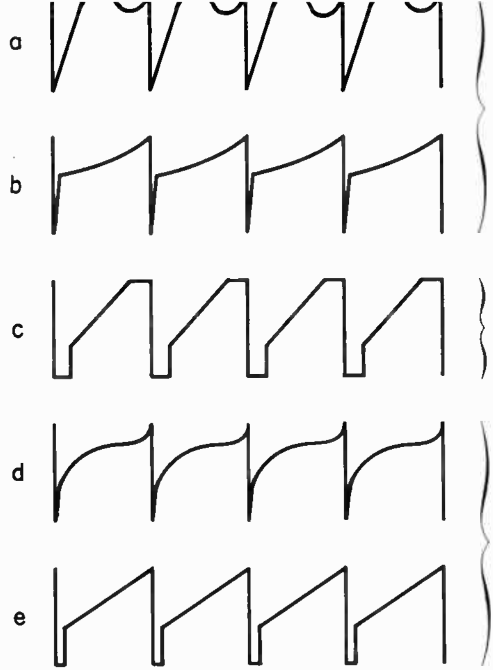


Fig. 412. *Horizontal oscillator waveforms.*

a badly shorted or open diode, or something which is *unbalancing* the afc so badly that it throws the oscillator so far out of frequency that it simply stops working. So, remember this one: if you get a raster off channel, but nothing at all on channels, dig into that afc and you'll find it.

Incidentally, although this is a little rare, you will find a set now and then that actually does the same thing, but does it *backward:* off channel, the raster goes out; with a signal coming in, a good picture! Same cause: afc. Something is unbalanced in the afc, causing the oscillator to drop out of operation while free-wheeling, but the action of the afc is able to pull it back within range, with sync, so that it works.

In all cases like this, you can get a quick verification of your diagnosis by quickly sectionalizing the oscillator–afc circuit as before to see just *which* part isn't doing its job.

Wave-shaping networks

We mentioned wave-shaping networks a while back, so now let's see how they work. You won't find too much trouble in these, in actual circuits, but they are a good thing to understand. Once in a while, a leaky capacitor or an open resistor gives trouble but that's about all. We need these networks to get the output waveform from the oscillator into the trapezoidal shape needed for the out-

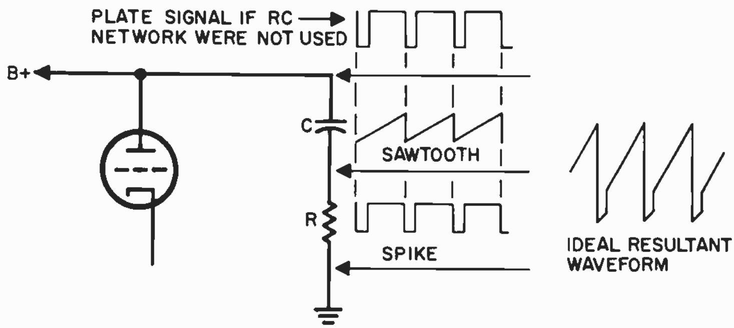


Fig. 413. *The tube plate load resistor (not shown) and capacitor C form the basic sawtooth wave. Resistor R controls spike amplitude. Too high a value will increase the discharge time of C. This also increases the retrace or flyback time.*

put tube grid driving signal. You're not going to find the ideal waveform on this grid, by any means. We have to begin with a waveform that looks somewhat like Fig. 412-a or -b. Instead of the ideal wave of Fig. 412-c, we usually get something that looks more like Fig. 412-d or -e! Pretty funny-looking, but quite practical. It'll work, and that's all we need. Sometimes we'll actually find a pretty severe deviation from a trapezoidal shape on the grid: this distortion is introduced intentionally to counteract other distortion in the flyback–yoke circuits! The end result is a nice linear sweep current in the yoke, and everything's fine.

So, to get whatever shape we need, we connect an R-C network across the grid–plate circuit of our tubes (Fig. 413). Here you can see what happens. Without the shaper, the output of the tube would be a rectangular wave. If we feed this across a series R-C circuit, we get the two voltage waveforms shown. The capacitor is charging through the resistor. (No matter which one is on top, since the charging current must flow through the *resistor*, too!) Since the capacitor voltage depends upon the charging current, it is going to rise gradually, and we get a sawtooth. Since the voltage appears across the resistor instantaneously, we get a peak or spike there. The combination of the two gives us a spiked-sawtooth waveform.

By juggling the time constants here, we can make the waveform have any shape we want. However, this has been done for us by the set designer; all we need to do is check the waveform to be sure that it is roughly the shape shown on the schematic. In general, the bigger the resistor, the more spike we get; the bigger the capacitor, the greater the sloping part, and the flatter this part of the waveform.

Defects in these parts will usually cause other troubles like loss of grid bias, loss of linearity, etc. They will show up first, before troubles due to a small distortion of the waveform. Regardless of what kind of picture you see on your scope at this point, always use the linearity of the raster as the final indication. If it's linear, then the drive signal is OK!

Fig. 414 shows the wave-shaping networks used in an actual chassis. You may find that some sets do not use quite as many parts as this, but this shaper will always be there, somewhere. If nothing else, the coupling capacitor and grid resistor will form a shaping network, with the output being taken off across the resistor! Redraw this circuit in your mind and you can see this.

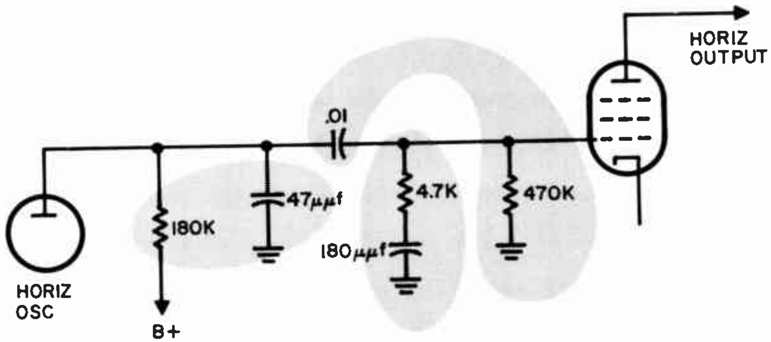


Fig. 414. *A change in any value of these components can be offset by complementary change in value of others in the same shaded area.*

Checking oscillator frequency with a scope

There will be times when you won't be able to tell from the picture *what* is actually going on! You'll find no raster at all, or such a mess of lines and bars that is hard to tell whether the oscillator is running fast or slow. In these cases, the scope can tell you very quickly what is happening. We *always* use a low-capacitance probe to take these measurements, because of the sensitivity of the circuits we're working in. The low-capacitance probe causes less circuit disturbance than the direct probe.

First, we need a comparison signal, since the scope is basically a comparison instrument. To make any kind of measurement with a scope, we use a standard or reference signal or voltage, then display our unknown pattern and compare it to the standard. In this case, we need a source of signals at 15,750 cycles which is accurate. We've got it, in the horizontal sync pulses of the video signal. So, with a signal on the TV set (or the signal from another TV chassis, in case this one isn't working at all!), we set up our scope so that it displays three "cycles" (lines) of the composite video signal at the output of the video amplifier.

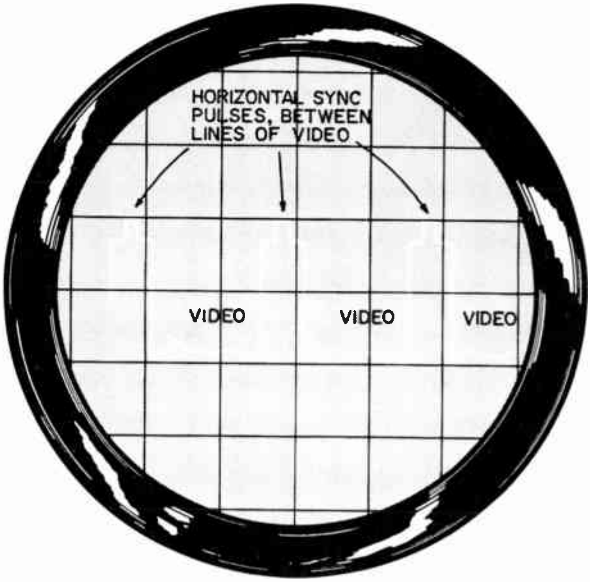
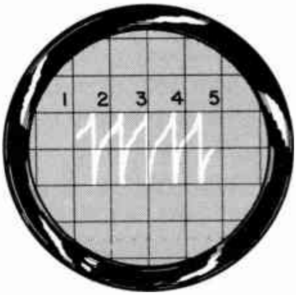


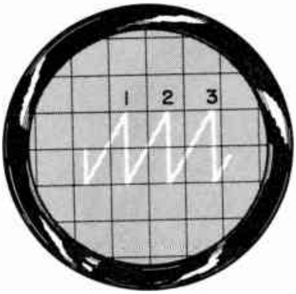
Fig. 415. *Scope sweep can be calibrated for horizontal sweep frequency. Use video test point or detector load as source of composite video signal. Keep scope sync at its lowest practical level to prevent it from affecting true oscillator frequency of scope.*

It doesn't really make any difference where we get this signal, as long as it is big enough to identify; we use the video amplifier plate circuit because it is handy. Also, it makes no difference whether you use two or three lines of video. You can use seventeen if you want, as long as you remember how many you had! For convenience, most of us use either two or three. We show three, in Fig. 415, with the video signals between the horizontal sync pulses. This means that our scope internal sweep is set at 15,750/3, or 5,250 cycles. For two lines, set the sweep at 7,875

a. TOO SLOW



b. TOO FAST



c. ON FREQUENCY

Fig. 416. *Change in TV sweep oscillator frequency will also cause a change in the oscillator waveform. Unless the off-frequency rate of the TV horizontal oscillator is in a direct ratio to the 15,750 cycles it will not lock in on the scope screen.*

cycles. Many service type scopes are equipped with a built-in sweep position, marked H, which automatically sets the inernal sweep at 7,875 cycles to show two lines of video, just for this purpose. (They also have a similar position which gives a 30-cycle sweep, marked V, for checking vertical sweep and video circuits.)

With our scope set up, let the *sweep-frequency* controls on it alone. Adjust only the vertical gain control, to get a suitable pattern height on the screen. Don't touch the sweep frequency at all until you finish these tests. Now, go back to the horizontal oscillator circuit. First, try checking the waveform on the grid of the horizontal output tube (Fig. 416). If the oscillator is running too slowly you'll get a pattern like Fig 416-a. It will be broken up into the kind of lines you see, because the scope sweep will not sync with it. If the oscillator is running fast, you'll see something like Fig. 416-b. Here, we have five cycles. Since our sweep is set to show three cycles this means the oscillator is entirely too fast. Fig 416-c is the correct pattern: three cycles of the sawtooth pattern which you should find on the output tube grid. You'll and variations of this pattern in different sets, of course.

However, in general, you'll always see more or less of a sawtooth, so that you can count the peaks and check the frequency. In fact, you can set the oscillator on frequency without ever looking at the picture! Simply adjust the horizontal hold control, ringing coil, Synchroguide transformer or whatever frequency control is used, until you see three cycles of signal. If you get confused,

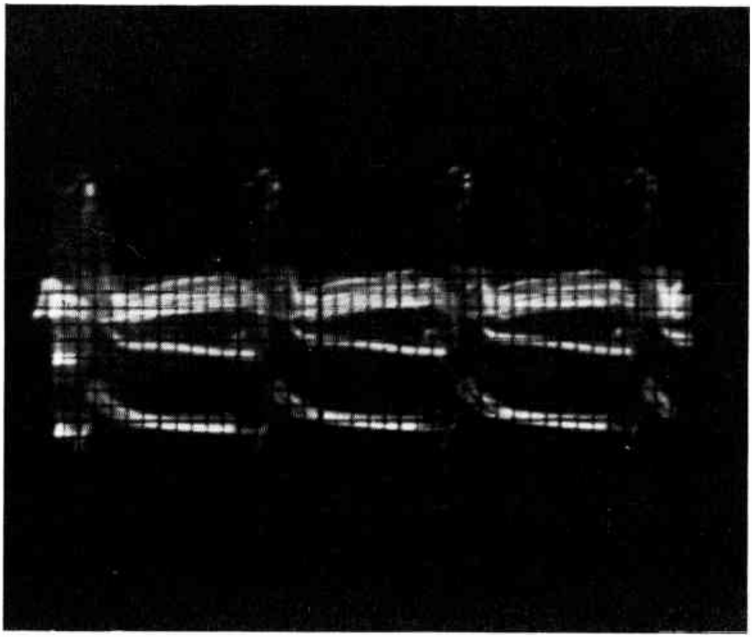


Fig. 417. *Scope pattern of typical "hash" seen across power supply when the B-plus filter capacitor opens. (See Figs. 401 and 402, pages 74 and 75.)*

move the scope probe back up to the video plate and recheck to be *certain* that the scope sweep hasn't changed frequency on you. Not a bad idea anyway. Be sure to set the 'Sync Lock' control on your scope to its lowest possible setting. Turn it all the way off, then advance it just enough to make the video waveforms lock in.

Bug-hunting with the scope, voltage measurements

The scope and low-capacitance probes are invaluable tools for locating various bugs in horizontal oscillator circuits. They can tell you things about this circuit that you can't find with any other instrument. They not only measure ac voltages, but show the waveshape of those voltages, a very important thing. Also, the combination is handy as a quick-check instrument, to find out whether there is any signal at all at various test points—something we need to know every now and then. Two tests are very useful: checking B-plus lines for hash and unwanted signals, and measuring peak-to-peak (p-p from now on, for short) voltages. Let's see how this is done.

For finding out how efficient the filtering is on any supply line, B-plus, etc. use a low-capacitance probe. Connect it across each electrolytic capacitor and check for the presence of waveforms or hash. Set the vertical amplifier gain fairly high, so that you can spot small amounts of hash. It doesn't take too much signal on these lines to cause trouble. It doesn't really make a lot of difference at what frequency the scope sweep is set, for this test; all we really need to know is, "Are there any signals here at all?" If there are, we've got a bad filter electrolytic. So look for vertical deflection. The normal reading on any B-plus point should be a *straight line*—pure dc. If you get a reading of 5 to 7 volts or so at *any* frequency, it means that the electrolytics are not doing their job.

Most technicians set up the scope to show three or four cycles at the horizontal frequency, so that they can get an idea of what the undesired signals look like. Fig. 417 shows horizontal hash as found on a B-plus line in a TV set. The spikes here are at horizontal frequency, but there is quite a bit of 60-cycle stuff present, too. Note the thickening of the base line between the spikes. A filter capacitor was open, the nonpolarized electrolytic connected between the boost and B-plus. So we have horizontal hash, plus some 60-cycle stuff which may have been strays, maybe not. At any rate, replacement of the capacitor cleared up the trouble.

In Fig. 418, we see a 60-cycle sawtooth pattern. This one was due to an open output filter in the power supply, causing a heavy 60-cycle component to be present. There is also quite a bit of horizontal-frequency hash in this waveform, as you can see from the thick, fuzzy waveforms. This illustrates the statement we made a moment ago: When a filter capacitor opens, you'll find all kinds of frequencies floating around on the B-plus lines. No matter what frequency or frequencies you see, on the B-plus, they are *wrong! Check*: hook the scope probe to the point where the hash shows up, and start bridging filter capacitors until you find one which will eliminate this waveform, leaving a straight dc line.

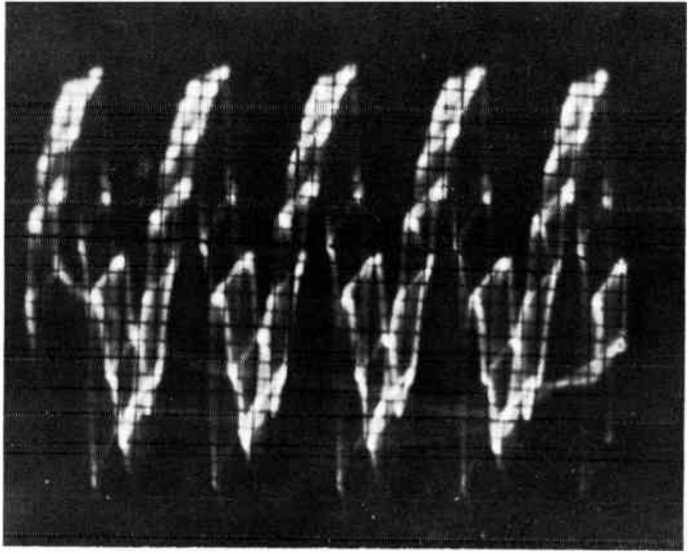


Fig. 418. *Sawtooth pattern due to open filter in the power supply.*

Stray pickup in the test probe

With the scope's vertical gain set fairly high, as it must be, you'll see quite a bit of scope vertical deflection when you get anywhere near the horizontal output stage. This is due to stray pickup in the probe tip. Voltages are so high in this neighborhood that even the tiny capacitance of the probe tip will pick up enough to cause quite a bit of vertical deflection on the scope. Pay no attention to this, as it will disappear when you connect the probe to a B-plus test point, *if* the capacitor is OK. In fact, you ought to get the same pattern on the scope when you connect the scope to *ground* as on a B-plus point! The B-plus point should very definitely be at ac ground potential.

To see how much of what you see is due to stray pickup, touch the probe tip to the chassis near the B-plus test point you've been checking. You may get some stray pickup if the body of the probe is close to part of the horizontal output stage—the damper socket, for example. You can reduce or eliminate this by moving the probe as far away from this stage as possible. In quite a few cases, you will be able to find a test point on the other side of the chassis, that is connected to the B-plus line you're checking.

For example, say we're checking the 150-volt line which feeds the horizontal oscillator in this circuit. Go over to the video i.f. plate supply point, for instance, which will be on the other side of the chassis and take your test reading there. Same point, electrically, and any hash which is really on the B-plus line will show up.

You can always pull the horizontal output tube to kill the high voltage pulses that are floating around. However, in a lot of cases, these are the actual cause of the trouble, because of their very high amplitude.

Peak-to-peak voltage readings

Now and then you'll run into a case where you need to check the amplitude of the output signal of the horizontal oscillator, to see if it's up to par. The scope is one of the simplest instruments for making this test. We can check oscillator operation by measuring the p-p voltage output, taking the reading at the control grid of the horizontal output tube. Fig. 419 shows the important features of this waveform. Right now, we're not interested in the waveform, only its p-p voltage. Because this is always a high-impedance circuit, we use a low-capacitance probe to make this test. Most low-capacitance probes have a 10:1 attenuation ratio, but this won't make any difference.

Here's the basic procedure for taking p-p voltage measurements with a scope. We use a comparison method. The unknown waveform is set up on the screen of the scope, and its height noted. Now, the scope input is connected to a source of variable voltage, with an indicator (meter). This voltage is adjusted to make a pattern of the same height on the scope, and the actual voltage read on the meter.

One way to check p-p voltage on the grid of the horizontal output is to connect the scope, using the low-capacitance probe, to that point. Set the vertical gain to produce some deflection on the scope screen. Use the calibrated screen (the graticule) on the face of the tube. Set the pattern to make a certain number of lines on the tube, say, 10. (Makes no difference how many, as long as you don't forget how many you used!) Now, move the scope probe to the calibrator, without touching the vertical gain control. Connect the probe to the calibrator, and adjust the calibrating voltage until the pattern on the scope is the same height as before. To make this easier to read, turn the horizontal sweep gain on the scope to zero, leaving a straight vertical line. This is much easier to read. When the pattern is at the same height, read the p-p voltage from the voltmeter on the calibrator. These meters are usually calibrated in p-p, average and rms voltages, to make things easier.

Incidentally, don't let the 10:1 stepdown ratio of the low-capacitance probe bother you. This simply means that the probe reduces the amplitude of the signal applied to the scope vertical am-

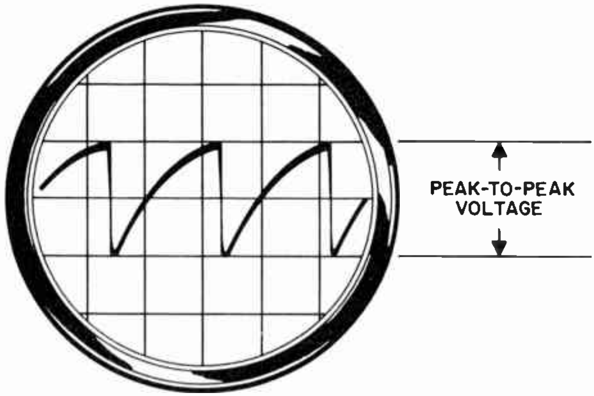


Fig. 419. *Waveform peak-to-peak voltage. A vom can be used to calibrate scope. Multiply rms meter reading by 2.82 for peak-to-peak value. A quick check—the 6.3 volt filament line on your tube tester is approximately 20 volts peak-to-peak (actually 17.76).*

plifier. However, as long as we touch the *probe tip* to two voltages which are *the same*, we will get an accurate reading. If we used a direct probe for this test, we'd get the same reading, barring any loss caused by scope loading of the circuit. However, we would have to reduce the *scope vertical gain* by a factor of 10 to keep the pattern on the screen. Fig. 420-a shows the probe connected to the horizontal output tube grid. We move the probe to the calibrator in Fig 420-b and match the height of the pattern, then read the voltmeter. A schematic of the calibrator is shown.

If you do not have a regular scope calibrator, you can make out by using other sources of variable voltage and a little elementary math. For example, your tube tester is a very handy source of adjustable ac voltage. Simply connect to the filament terminals on one of the sockets, and set the filament selector switch to whatever value of voltage is needed. If you need an exact value, measure the actual voltage with a good voltmeter. This isn't as handy as a calibrator but, in most of these tests, pinpoint accuracy isn't needed, and you can get within about 10%, of the accurate value.

Remember that the voltage indicated on the switch is not p-p but rms! You can get the p-p value by a quick calculation in your head. Multiply the rms voltage by 2.828 or, for a really quick result, by 3! This isn't too hard. An indicated voltage of 30 volts rms is actually slightly more than 84 volts p-p, or "about 90" which is pretty close. If you want to know the p-p value of a drive signal, for example, only 6 volts difference isn't going to stop the output stage from working! What you want to know is. "Is this somewhere within the range of p-p values I'll have to have?" This test will tell you very quickly.

Summary

Let's go back over some main points we have made. They are a very important part of the service technique. We introduced the "divide and conquer" technique. Because of the interlocking between the circuits in a horizontal sweep stage, there is only one way to check it and get answers: take it apart and check it a piece at a time!

We began with the horizontal oscillator, because this must be considered as the signal source for the horizontal output stage. It furnishes the driving signal which the output stage amplifies and makes into the sweep current, high voltage and so on. The oscillator stage must be OK before we can go any farther, so we check it first. It must be able to run on frequency, and have sufficient output voltage to drive the horizontal output tube to full capacity. Also, it must be tightly controlled by the afc, so that the picture will stay in sync horizontally.

So, there's the first step in horizontal sweep servicing: be *sure* that the horizontal oscillator is working. There's a very simple test that experienced TV technicians use to see what the horizontal oscillator is doing. They look at the screen of the TV set! (You just can't get much *simpler* than that!) If they see a raster, light on the screen, then they know that the oscillator *must* be working. If it weren't, there would be no sweep or high voltage. If the picture is out of sync, then there is trouble in either the oscillator or afc stages. *There is no way of testing these together,* so we take them apart, check them one at a time, then put them back together again.

Learn to make the simple tests *first*. Almost all of your troubles are going to be little ones: weak tubes, low operating voltages, etc. Follow this routine in all cases: replace tubes; check voltages. If any step is skipped or overlooked, you're in for trouble later on.

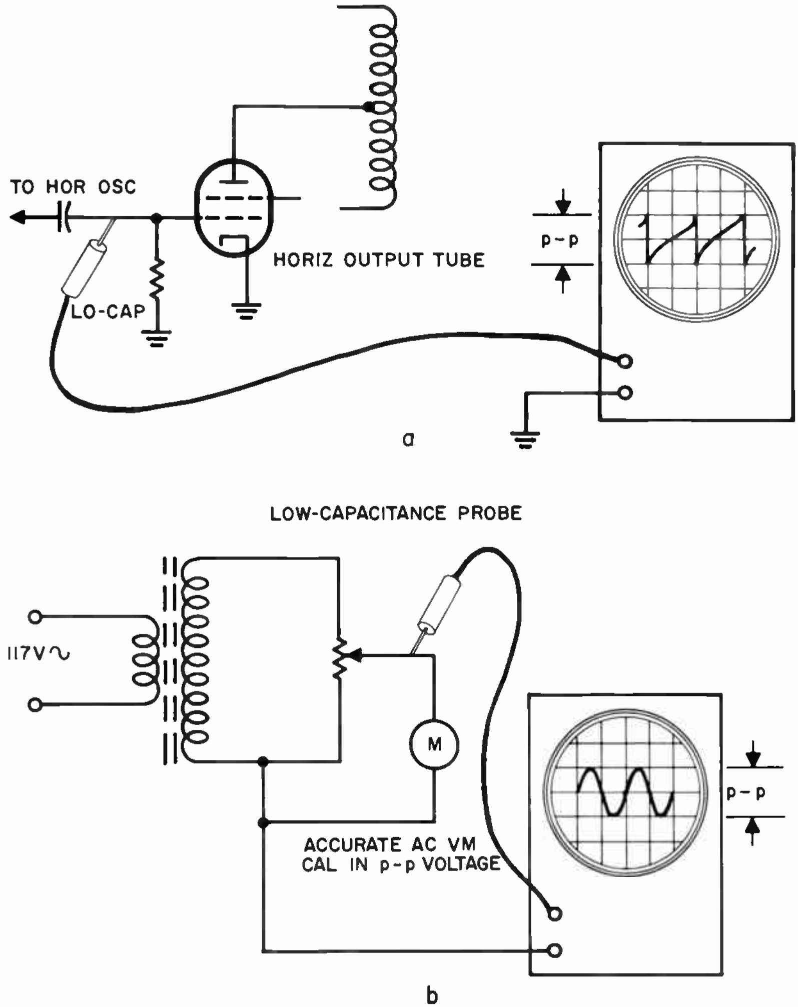


Fig. 420. *Basic method for calibrating scope: Connect scope lead to signal under test (a). Then adjust scope gain control to make pattern fill a convenient number of graticule boxes vertically. Connect scope across peak-to-peak meter (b). Adjust variable resistor voltage control until sine wave fills same number of boxes vertically and finally, read peak-to-peak meter.*

Never make complicated troubles out of simple ones: all complex defects are basically very simple–leaky capacitor, bad resistor, shorted tube and so on. All of these should be in good shape before we dig into the horizontal oscillator itself.

Check adjustments to be sure they haven't been tampered with. Run a complete setup procedure, as given in the service data, and see if the oscillator will respond to it. If there aren't any setup instructions in the service data, then check the schematic to see what kind of oscillator circuit is used, and set it up according to the standard procedures we have given earlier in this chapter. Just for luck, we'll repeat them very briefly here.

Synchroguide

1. Short out waveform coil (sine-wave coil).
2. Disable afc input.
3. Adjust frequency coil for a single floating picture.
4. Remove waveform coil short, adjust coil for locked picture or scope pattern of the right shape.
5. Restore the afc. Picture should now lock in.

Multivibrator

1. Short out the ringing coil (stabilizer).
2. Short out sync.
3. Set the horizontal hold control to make a single floating picture.
4. Take short off ringing coil; adjust coil for best locking.
5. Take short off sync and picture should lock in.

Using these methods, you should be able to spot troubles instantly. If the oscillator won't run with all controls taken off, *make it!* There are only a very few parts left in the circuit. If these are all tested, and any defective ones replaced with good ones, the oscillator will run. It ran once before, didn't it? Well, it will run again. If all parts check OK, but the oscillator won't operate, check the supply voltages very carefully, and especially the electrolytic filter capacitors, to see if B-plus feedback is killing the oscillator or making it work improperly. Bridge good filter capacitors across any suspected units. Pull the horizontal output tube, and see if the oscillator is capable of running all alone. Check the frequency by comparing it with that of the horizontal sync pulses in the video signal, using a low-capacitance probe on the scope. If it will run alone, but won't work when the output stage is added you've got filter trouble. Check some more electrolytics.

Never look at this circuit as something strange and mysterious. It very definitely isn't. It's just a simple little amplifier circuit with its tail in its mouth! Study the preceding chapters very carefully, until you are so familiar with oscillator circuits that you can draw them in your sleep! Once you learn the circuits, you won't take as long to find trouble in it. Now, let's get along to the rest of the sweep stage.

part 1

Chapter 5

Horizontal Output Stage

HORIZONTAL OUTPUT TROUBLES HAVE PROBABLY CAUSED MORE banging of soft heads against hard walls than any other part of the TV chassis. There's a reason for this. This circuit has to do three or four different things at the same time. We get an unavoidable interlocking of functions, and trouble which is actually in one part appears to be somewhere else. However, just as with the horizontal oscillator circuit, if you really *know* how it works, it's not so hard to fix.

We can use the same basic method we tried on the horizontal oscillator and afc circuits. Break the horizontal output stage into little bits and see if each one is working or workable. Testing is rough in these circuits because of the very high voltages and currents. Therefore, we must use special test equipment, or special applications of our regular equipment. We can't just stick meters into this circuit at random without upsetting its operation. Also, in some cases, it would upset the operation of the *meter*. (Like tying the meter pointer in a bow knot!)

Always remember one thing: each part has only a *single basic purpose*. If it isn't doing that, then we get unmistakable symptoms of its failure. All we have to do is learn to recognize those symptoms when we see 'em. Of course, when one part goes bad, it affects others. So what do we do? We learn to look for the absence of something, knowing that this means that a certain part somewhere else isn't doing its job. For example, the state of the boost voltage will give a lot of information on the yoke, damper tube and linearity circuits. When we find a certain booster voltage defect, we know that in most cases it means yoke trouble. Therefore, instead of checking in the damper circuit, where the trouble seems to be, we check the yoke.

The main thing to remember about working in this circuit is "Don't be *afraid* of it!" This does *not* mean that you can stick your little pink finger on the cap of the high-voltage rectifier without getting bitten! It means that you can fix it when you learn how this circuit operates—be thoroughly familiar with it and be able to recognize troubles when they occur. Not only recognize the trouble, but know *why* it happened, so you will be able to keep it from happening again right away. If we find a flyback transformer burned to a crisp, we must be able to go through the associated circuits and find out *why* it went up in smoke. If you have a thorough working knowledge of the circuit, this will be easy to do. There are actually only a very few things that can cause such damage. If you check all of the possibilities and find them OK, then there is only one conclusion: the flyback shorted out, internally, all by itself! Then, you can replace it, after checking circuit conditions to be sure that it is working within safe limits. Now, let's get into this circuit and see how it works.

How it works

A horizontal output stage is about as simple a stage as you can get. We have a high-powered tube driving a transformer. The transformer matches the plate impedance of the tube to the impedance of the load, for maximum power transfer, because this is simply a power amplifier. If you think this sounds like the output stage of an audio amplifier, you're right; it is. But, someone says, it's a lot more complicated than that, isn't it? Right. In TV circuits it looks a lot more complicated, but remember, we've still got the basic circuit—a tube driving a transformer. Tackle this circuit with that fact firmly in your mind, and it'll be a lot easier.

Actually, a horizontal output stage is about as ingenious a gadget as you can find anywhere. Here the set designers get more for their money than any other place in the set. How? Well, this stage is more efficient than others: more usable output for less energy input. We put the energy into the circuit, through the tube, and then get most of it back in usable form. We get the boost voltage from energy that would otherwise be wasted, and a very high voltage for our picture tube for only the added effort of another few feet of wire on the transformer.

Besides this, we can get pulses for keyed agc and afc, and, in some circuits, the designers even steal the high negative voltage from the grid of the tube and use it for bias voltage! All of this from only one tube and a transformer. Because of this interlocking series of actions, you can see that this workhorse circuit must be in perfect condition at all times. If it isn't you're going to have trouble, and the chances are this trouble will show up in some other part of the set that is being supplied from this stage. You'll have to learn to take away all of the "extras" in your mind and be able to see this circuit as it actually is.

Because of the high voltage involved, troubles can look pretty complicated. They're not. Treat this circuit exactly as you did the horizontal oscillator. Learn to strip it down to the bare essentials, check these out one at a time, and it'll be easy. In a lot of cases, we test one thing by measuring something else; so, you can see that you must have a good basic knowledge of exactly how the circuit is supposed to work before you can spot troubles in it.

What about high voltage?

Let me make one point clear. Many technicians think that the high-voltage section of this circuit is very important, very complex and tied in somehow with the operation of the circuit. Well, it is *not!* It is important, of course, since it must be working before the set can work, but so are all the other circuits.

Actually, we could take the high-voltage section of the circuit completely out, and the set would work just as well as it did before! (If, of course, we furnished some high voltage from another source; the picture tube needs it!) But, as far as the transformer action is concerned, the high-voltage part is nothing but a hitch-hiker going along for a free ride!

There are only *two* things that can happen to the high-voltage section of a flyback transformer that will affect the circuit. One is an open winding, which you can find with an ohmmeter. The other is a shorted winding—equally easy to find! Just look for the place the smoke is coming from! So, we're going to ignore the high-voltage section for now, and take care of the more important things first. As we said, if these are in good shape, then we'll get high voltage, automatically. If not, we'll know where the trouble is without having to look very far!

To test this circuit, we need measure but two things: the operating voltages and currents of the horizontal output tube. Why? Because it is through this tube that all of the energy used in this circuit must pass. If these operating constants are OK, then the circuit is probably in good shape. If there is any excessive load on the circuit, it will be reflected in an overload of current flowing through the tube.

We can detect troubles in the load circuits of the transformer or defects in the transformer itself by measuring the currents in the tube. *Example:* high-voltage troubles can be checked without ever touching the high-voltage circuit. There can be only three conditions in the HV circuit: open, shorted or good winding. The first will show up as no high voltage at all, although the horizontal output tube's cathode current will be very near to normal. This current reading indicates that the tube and transformer are operating normally. The lack of high voltage means that there *could* be an open circuit, so we use an ohmmeter test to be sure. A shorted HV winding will give very definite indications. In addition to the smoke, we'll have a very high cathode current in the tube, an overload, because it is working into a short circuit. Normal conditions, of course, show up as normal current, plus a good arc from the HV source or the end of the HV secondary winding. So, there you have it: only three choices, which can be checked out much faster than we can tell you about it.

Operation of the horizontal output stage

Let's get into a more detailed discussion of the operation of the whole stage and see how it does all these things. Earlier, we compared this stage to a radio transmitter. The tube is always a high-power beam type biased well beyond cutoff (class C). In this mode of operation, we get a much higher efficiency than in class A. The load on the transformer is tuned to resonance. Once again, this is done to increase the efficiency.

In the previous section, we made the horizontal oscillator furnish us with a special waveform. Because this signal is used to make a perfect *sawtooth* of *current* in the yoke, the *voltage* waveform must be of a special shape, a *peaked-sawtooth* waveform called a *trapezoidal wave* (Fig. 501-a). This waveform, fed through an inductance and resistance in series will produce a sawtooth of current (Fig. 501-b). Although there is usually no external resistance in the yoke circuit, still, all practical windings of any kind have a certain amount of resistance. We must take this into account when we shape our driving waveform in the horizontal oscillator circuit. This is the only reason for that shaping—so that the wave will be correctly shaped when it finally gets to the yoke.

This waveform causes the magnetic field generated by the horizontal yoke windings to increase in a linear fashion, meaning "in a straight line." This makes the beam in the picture tube sweep across the screen at a steady rate. If we get *nonlinearity,* the beam will change speed as it goes, and there will be picture distortion.

Let's compare the relationship between the horizontal sync in the video signal and the different parts of our sweep waveform, and get some of the names straight. Fig. 502 shows two complete

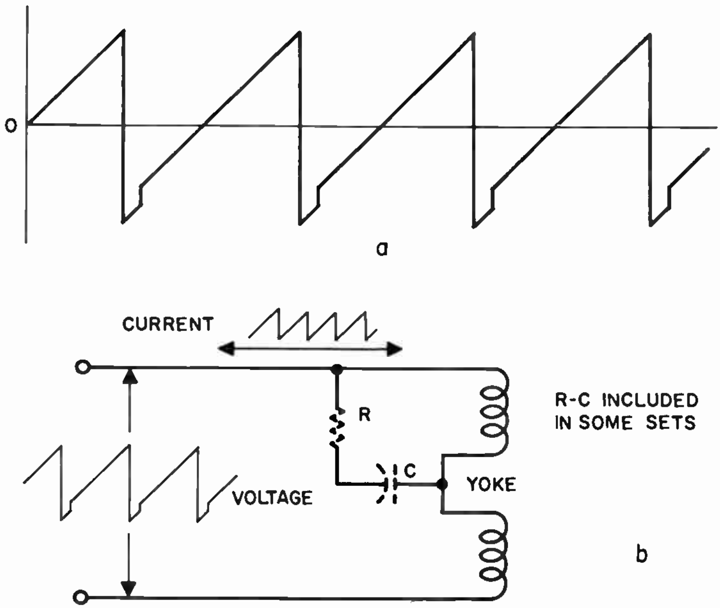


Fig. 501. *The trapezoidal waveform (a) is the voltage waveform needed to produce a sawtooth of current in the yoke (b).*

lines of video information, two cycles of horizontal sweep signal. At the top is the composite video signal, with the horizontal sync and blanking pulses. The sync controls the horizontal oscillator, for the sweep must be precisely in step with the video, so that the picture will appear on the screen in the right place.

The blanking pulses are fed to the picture tube. There, they cause the CRT beam to cut off: the screen goes completely dark, because they drive the tube into cutoff. During the time the beam is being snapped back across the screen (flyback time), the tube makes no light, and the horizontal retrace lines aren't seen.

Below the composite video signal is the sweep waveform. This could be called yoke current, position of the beam on the screen, or any of several things. Notice that it is linear, especially during the forward stroke of the beam (the 'active part' as far as the video signal is concerned). This linearity causes the beam to be swept across the screen at a constant speed.

Last is the peaked sawtooth waveform we find on the grid of the horizontal output tube. We'll also find this waveform across

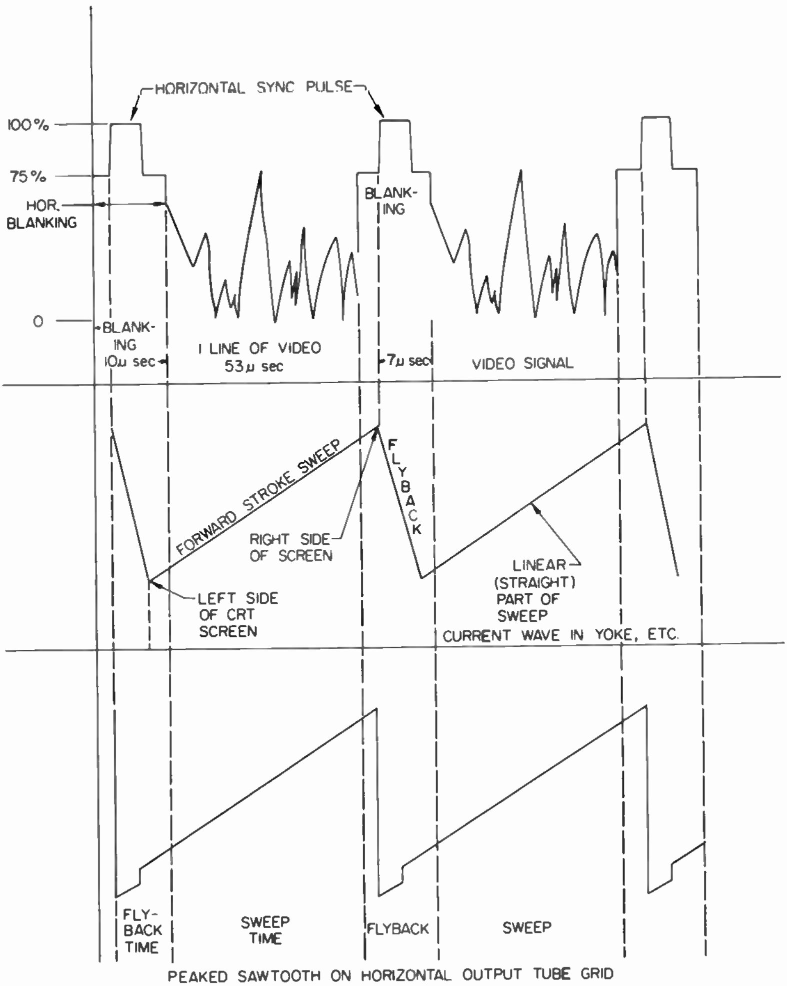


Fig. 502. *Composite video signal and its relationship to the current wave in the yoke and the peaked sawtooth on the horizontal output tube grid.*

the flyback secondary, as a voltage wave across the yoke, and in other places. It is always a voltage wave, and sometimes you may find it upside down. However, the shape will always be the same, for it will be the same wave.

How about the relationship between parts of these waves? We can see one requirement right away. As we said, the forward stroke of the beam must be very straight—linear. If it isn't, we get picture distortion.

Next, we must be very sure that all of the flyback action takes place during the horizontal blanking period. Since this is only 10 microseconds (μsec), we'll have to hurry! First, we've got to get the beam back to the side of the screen to start the next scanning line. Therefore, we feed in a very steeply falling part of the waveform, in the parts marked flyback. Notice that these are drawn to show that we use only 7 μsec of the 10 μsec available. This is done to be sure that retrace lines never show in the picture. (They're like stagehands on a TV show: they have to be there, but we shouldn't see them!)

In this part of the wave, a lot of important work gets done. For

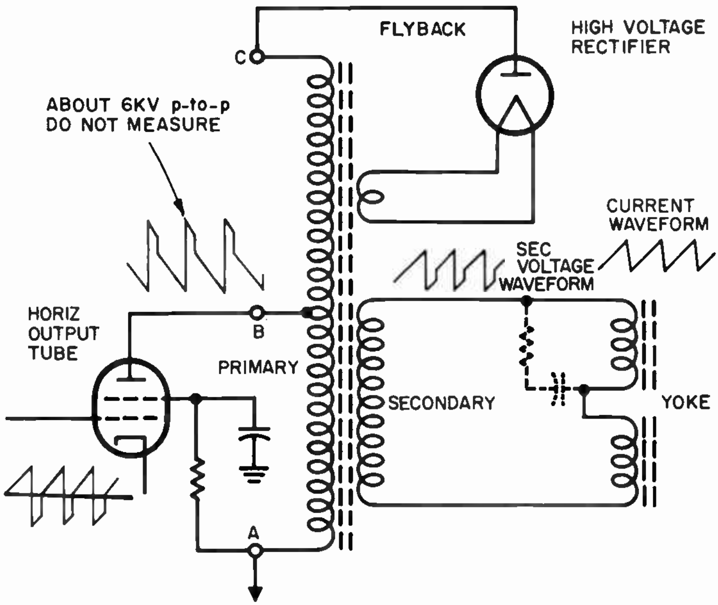


Fig. 503. *The basic horizontal output circuit. Waveform at output tube plate is inverted from that at input. Plate voltage is maximum when tube is cut off.*

now, just remember the time used for it, and the fact that this represents a very rapid *change* of current in the circuit.

Basic flyback transformer circuits

With this relation firmly established, let's see what some circuits look like. As we said a while back, the main parts of this circuit are a tube and a transformer with a load. Fig. 503 shows a basic circuit, used in some older TV sets. You can see some typical waveforms at different points in the circuit. Note that the primary winding of the transformer is in two sections, A–B and B–C. B–C is the stepup winding for the high-voltage supply, and actually has no function at all in the generation of the sweep.

What happens in this circuit? Let's trace the action of the drive waveform as we feed it into the control grid of the horizontal output tube. Incidentally, we might as well save some words: since we're talking about nothing but the horizontal circuit, from now on we'll simply say oscillator, output tube, yoke, etc. instead of horizontal oscillator, etc. The horizontal output transformer from now on will be flyback. We'll use the isolated secondary type for the basic explanations even though it is seldom used now—it's easier to study.

While we're saving words, let's take off a few nonessential parts of that circuit, so that the basic action will be clearer. Fig. 504 shows all of the things we need right now. The yoke is always drawn as you see it, with two coils, because an actual yoke does have two coils, one above and one below the neck of the tube. Now let's put some action into Fig. 504.

This shows what's happening during the forward stroke or sweep of the waveform. The sawtooth (Fig. 503) is yoke current, beam position, etc. If we feed the peaked sawtooth into the grid of the output tube, we get a sudden pulse of current in the primary of the flyback, of the same shape as the upper half of the wave. Note carefully that the grid waveform shows the cutoff bias for the output tube. Only the peaked parts of this rise above the cutoff level and cause the tube to draw plate current or conduct. Don't worry, we'll use up the rest of this waveform in a little while. In this busy little circuit, we use everything but the squeal! We don't waste a thing!

The pulse of current in the primary induces a pulse in the secondary. Because of the stepdown ratio of the transformer, we get a lower voltage but higher current. This is necessary because the yoke is a low-impedance device. It must be, to handle the

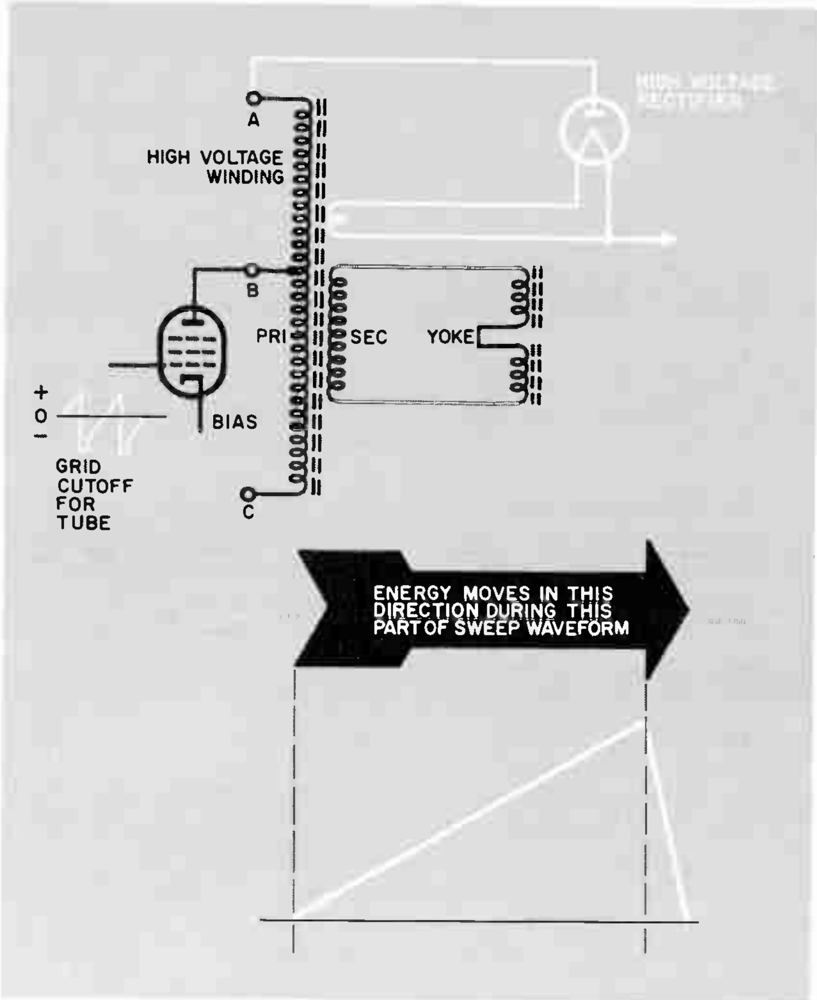


Fig. 504. *Horizontal output circuit reduced to bare essentials. Energy travels from the primary of the horizontal output transformer to the secondary and from the secondary to the load.*

necessary power. The current from the secondary flows through the yoke. As it does, it creates a magnetic field around the windings —a field which is constantly changing at a uniform rate. This magnetic field deflects the electron beam, and it is swept across the face of the tube at a constant speed.

The arrow shows the direction of energy travel—from the primary to the secondary, and then on to the load, the yoke windings. (Remember that!) Now, what happens to this energy? The yoke is an inductance. Like all transformers or coils carrying current it has a magnetic field around its windings. This field contains most of the energy we just sent over through the flyback transformer. It won't stay there, unless the current through the output tube keeps changing. If the current stops changing, the field around the yoke will collapse. So, when we reach the negative peak of the drive waveform, the output tube stops drawing current. Moving from a condition of current flow to no current flow is a drastic change, so away we go. Now several things all happen at once, all related. Let's take them one at a time.

The output tube has been drawing current through the primary (B–C) winding. So, the tube looks like a fairly low impedance to this winding. This current has been gradually building up in the secondary–yoke circuit. When we get to the peak of the waveform, notice how the grid voltage drops very suddenly to cut off, then on far below it (Figs. 503 and 504). It drops so far that the output tube is very definitely cut off. It couldn't draw current if it wanted to, because its grid is so far negative that it's blocked. Now we can take the output tube plate off the flyback primary circuit. It looks like such a tremendously high impedance that it isn't there at all, and will thus have no effect on the things that are going to happen in the next few microseconds.

When the current stops changing in the primary, it also stops changing in the secondary. An obvious statement, but true. Now, all this energy is piled up in the yoke's magnetic field, looking for some place to go. Without the bucking effect of the incoming current to stop it, it *goes!* Where? Back where it came from. Fig. 505 shows what happens now.

Notice that the arrow showing the total current is bigger. Why? This is because there is actually *more* current flowing now than there was during the horizontal sweep stroke! But, aren't we violating the law of conservation of energy or something? Where did we get all that free current? Answer: we didn't. This is the energy that has been stored up in the yoke during the 53 μsec of the forward stroke, all released at the same time during only 7 μsec of flyback time. To dissipate all of the *power* (volts × amperes) that we jammed into the yoke, we have to have a higher current flow now. This flows back to the secondary of the flyback, which now acts like a primary.

The flyback looks different now. With current flowing from right to left, it becomes a step*up* transformer, and what do we get? A

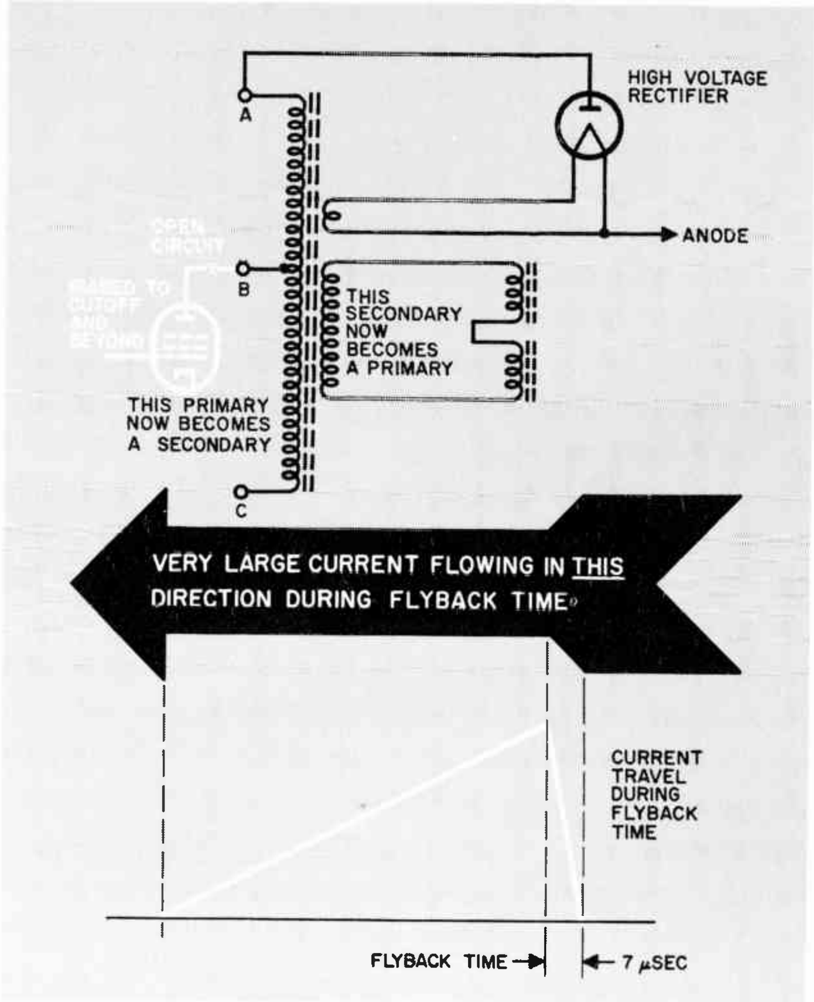


Fig. 505. *The breakdown of the flyback's magnetic field energizes the high-voltage circuit.*

tremendously stepped-up voltage across the original primary winding, which has changed horses and become a secondary while this is going on.

Now we can do something with that high-voltage winding, A–B which has been sitting there doing nothing. Because this is just a continuation of the B–C primary, we have added many more turns to the "secondary". This is where we get the 10,000-30,000-volt pulses which we rectify and make into the dc high voltage we need for the second anode of the picture tube. We feed it to a special diode rectifier, with very wide spacing between plate and filament to avoid flashover, and there's our high voltage, "free" by simply adding another winding to the flyback.

We will forget the high-voltage winding, rectifier, etc. once again. They've done their duty and we're through with them. They have nothing to do with the rest of the work we've got to do in this circuit. So, if you don't see them in the drawings, don't worry; they're there, but we were just too lazy to draw them. Simplifies the drawings anyhow.

Now, then. We've got our transformer, which will cause a suitably shaped current to flow in the yoke and make the beam do its forward sweep stroke, and we've got the reaction during the flyback time which generates the high-voltage pulse in the primary. (By the way, the fact that most of the work is done during flyback time is the reason we call this transformer a flyback.)

Everything looks pretty good, eh? There is only one wee difficulty. *It won't work!* Why? Everything's there, isn't it? We *do* have a complete circuit, everything we need? Yes, *but*. This, my friend, is a *theoretical circuit!* If we put this, as is, into an actual TV set, we'd have the biggest mess you ever saw. Now, let's see why, and what kind of refinements we must add to it, to make it into an actual working type TV sweep circuit.

A practical sweep circuit

In the first place, the time constants in this circuit are pretty bad. Time constants are very important here. We've only 10 μsec to do all the work. If we don't get through in that time, we're going to slop over into the picture signal, and we can't have that. So, the first thing we must do is be sure that we can complete our retrace in the time allotted, and have a little to spare, if possible.

What would we have if we tried to run it as it is now? Well, the energy stored in the yoke wouldn't see any particular reason to vacate the premises in any big hurry, since it just got there. It could discharge as slowly as it charged, and we'd have a waveform that looks like Fig. 506. Nice, but totally useless: this is a triangular wave, and we have to have a sawtooth. So, we're going to have to add something to this circuit to change its characteristics and make that energy in the yoke get out in a hurry. There are several ways; we'll take the easiest. We make the whole circuit *resonant*. How can that make it discharge faster? Let's see.

This is done when the flyback–yoke circuit is designed, and it's a lot simpler than it sounds. The yoke and flyback secondary are wound to have the right inductance for resonance with their own distributed capacitance, plus the stray capacitances, somewhere near 70 kc. Now, what happens in a resonant circuit if we feed a sudden pulse of energy into it? Right. It goes into oscillation. If we hit it with a single sharp pulse, it oscillates, and we get a wave-train of oscillations at the resonant frequency, dying out

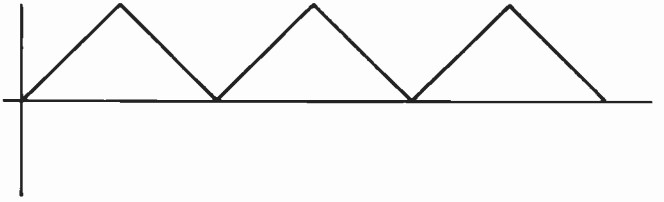


Fig. 506. *Triangular wave with equal trace and retrace times is not suitable for TV use.*

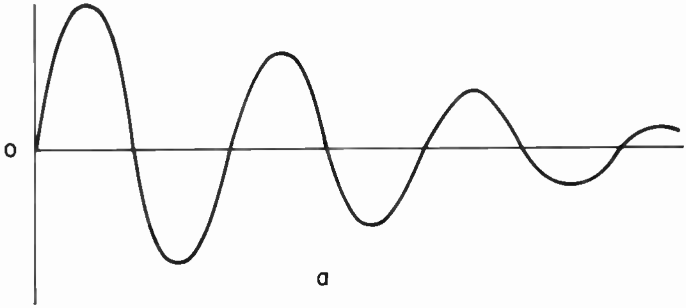
gradually from losses, like Fig. 507-a. If the circuit has a very high Q, or high ratio of inductance to resistance, the oscillations will hang on longer.

Ringing

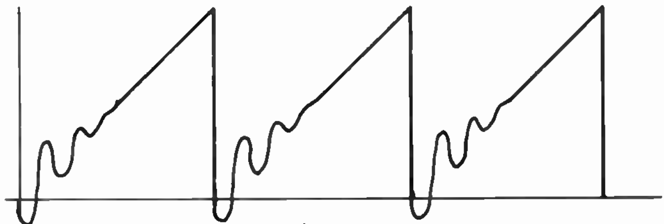
What would happen to our nice linear sawtooth if we had something like this in the circuit? It'd look like Fig. 507-b! In Fig. 507-c you can see what the picture-tube screen would look like. At the top is one line of linear sweep; the beam travels across the screen at a constant speed. Below that, we see the raster with weak oscillations left in it. The beam would start across, then speed up and slow down, start again and so on, retracting its steps several times. With strong oscillations it might even stop and go back and start again. The picture that you get from such a sweep waveform could be described by only one word: a mess!

The common term for this resonance in any circuit is *ringing:* the circuit rings like a bell which has been struck once, dying away at a steady rate. This has got to go: that is, all but the part we want to use. Oh, yes, we're going to use some of it; that's why we put it in there. There's a good reason for it, just like everything else in this circuit. We'll use what we want and get rid of the rest.

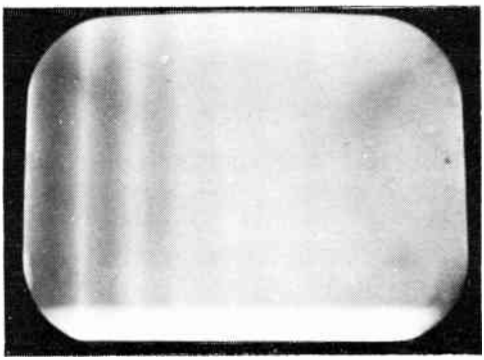
We said before that we make the circuit resonant at *about* 70 kc. This is near the fourth harmonic of the horizontal sweep frequency of 15,750 cycles per second (4 × 15,750 = 63,000 cps or 63 kc).



a



b



c

Fig. 507. *Ringing voltage (a) can occur in any high-Q tuned circuit. Its value added to that of the trapezoid gives the waveform at (b). Effect on the screen is shown in (c).*

Why? There's a good reason: the timing. Fig. 508 shows the relation between the ringing frequency, 70 kc, and the flyback part of the sweep cycle. One full cycle of oscillation at 70 kc equals 1/70,000 sec, or 14.3 μsec. But, you say, we can't use that! We've got about 10 to 11 μsec for the horizontal blanking time.* Correct; go to the head of the class. We can't use a whole cycle and we don't want a whole cycle. All we need is the descending part, or the first *half-cycle* of the 70-kc current!

Fig. 508 shows how and where we use it. One half-cycle is only 7 μsec, between points A and B. With the whole circuit resonant,

* According to FCC regulations, horizontal blanking pulses must be between 10.16 μsec minimum and 11.43 μsec maximum.

when the excitation is removed, the energy isn't going to simply drizzle off toward zero, it's going to try to go into oscillation at 70 kc! So, the first half-cycle of 70-kc current is going to shape the dropping current into something that looks like the lower part of Fig. 508. Of course, if we don't do something it will try to go back up almost to the point it came from. For now, we've done one thing: we have shaped the descending part of the sweep waveform, the flyback time, so that it drops from peak to zero within the time we have available.

Damping

We've gotten one thing done and gotten into more trouble (as

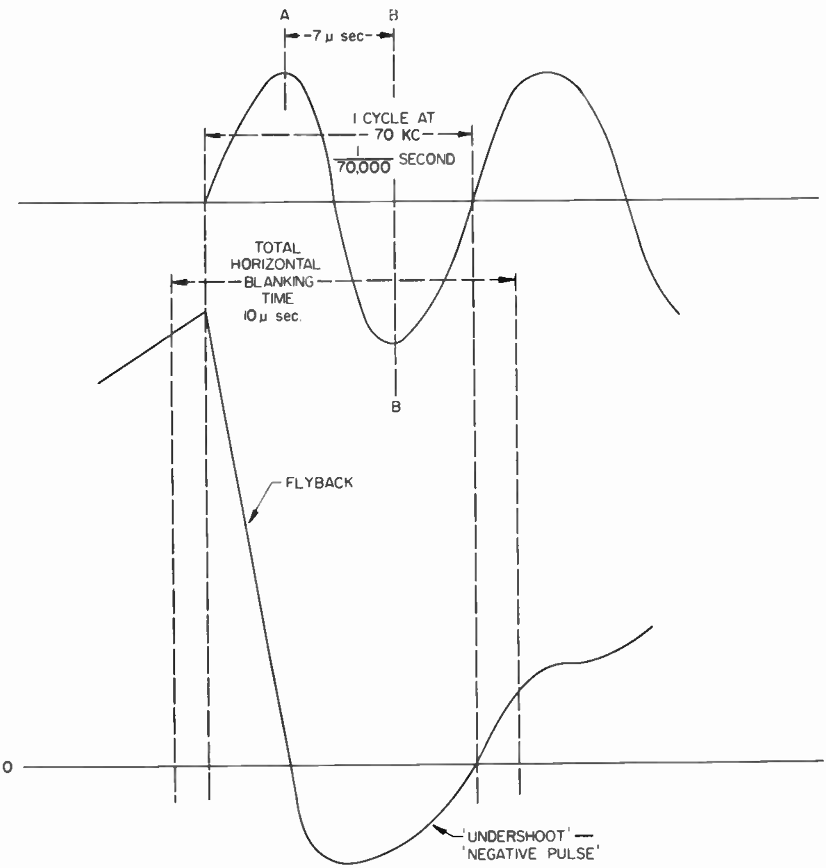


Fig. 508. *How the 70-kc oscillation shapes the flyback part of the sweep.*

usual). Now we've got the wave falling steeply, and what does it look like? Like Fig. 507-b! It's full of wrinkles and ringing, and we can't use it! We're as badly off as we were—or are we? No. We can fix. We can get rid of the rest of the 70-kc oscillation, using only the part we want and leaving the sweep very nicely linear.

There are ways to do this. We want to leave the circuit with its original high Q, for maximum efficiency, but we can *damp* it. This means to load it heavily. A loaded circuit will not oscillate as long as an unloaded circuit, although it will still try to oscillate for at least a few cycles. (That being what we want, it's fine with us.)

The forward stroke of the sweep, since it represents current flowing through a resistance (the yoke), causes a voltage drop to appear across it. Let's say that this makes the top of the yoke in Fig. 509 positive. The flyback part of the sweep means that the current has reversed direction, and is falling very rapidly. The energy in the magnetic fields is collapsing back into the yoke and inducing a larger pulse of current. This means a higher voltage across the same resistance. Since the current has changed direction, the voltage changes polarity, and the top of the yoke becomes negative.

Someone asks, "Why is the forward sweep voltage shown in Fig. 509-a a straight line, meaning a constant voltage, while the current is increasing?" A good question. This happens because the current is increasing at a steady (linear) rate, and it is the *change* in current, not the absolute value of the current, which causes a voltage to appear across an inductance. You know what would happen to a transformer if we connected it across a storage battery. The primary winding would burn out in a hurry, and there would be no voltage at all induced in the secondary, aside from the first charging kick. Same here.

So, in the flyback portion of the sweep waveform, things happen in a hurry. The current falls from peak to zero in 7 μsec. While it is falling off this electronic cliff, it is generating a tremendous voltage pulse across the yoke winding. This voltage is negative and larger than the original positive voltage (Fig. 509-b). It doesn't last long, as you can see (the actual duration of this voltage pulse is roughly 3 to 4 μsec), but it's there. Now, if we can find some way to damp the unwanted part of this 70-kc oscillation, we've got it made. We can, by taking advantage of a well known characteristic of a familiar piece of electronic apparatus: the vacuum tube.

The very first TV circuits to use this principle connected resistors across the circuit to damp the oscillation. This wasn't too practical,

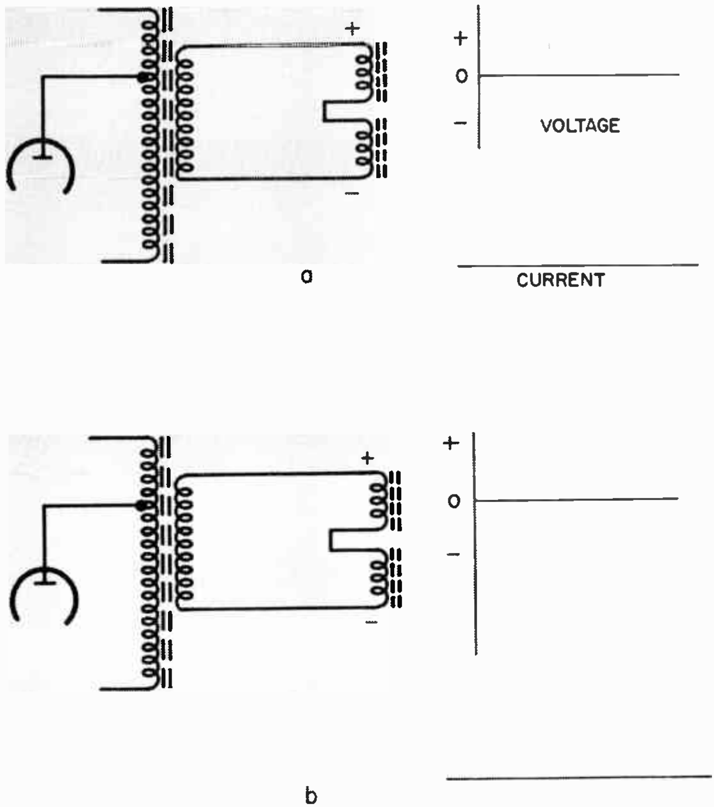


Fig. 509. *Sweep current and voltage on the forward sweep (a) and the current and voltage during retrace (b).*

because of the loss in efficiency, but it did work after a fashion. What we need is something that won't work during the forward (sweep) stroke, but will damp the circuit very heavily during flyback time. In other words, a "self-switching short circuit"! We have one—a diode vacuum tube! When the plate of a diode is negative with respect to the cathode, the tube appears as a completely open circuit to anything it is connected across. It has tremendously high impedance, since there is no current at all flowing through it. If the plate becomes positive, then current flows through the tube, and it becomes a medium to low impedance. Just how low depends on the characteristics of the tube, and the amount of current flowing.

This is an ideal arrangement: the tube can be used as that self-switching short circuit we wanted a minute ago. We hook it up as shown in Fig. 510, in shunt with the yoke. Now, what happens? During the forward stroke of the sweep, the tube's cathode becomes positive, which means that the plate is negative. No current flows: you don't have plate current in a tube with *negative*

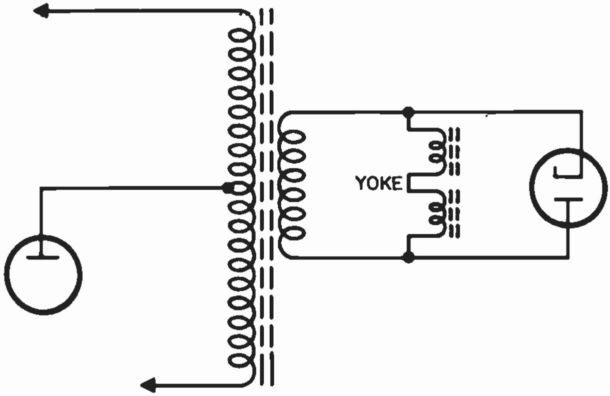


Fig. 510. *Diode tube connected across yoke to damp oscillations.*

voltage on the plate. The tube is an open circuit and might as well not be there at all. So, there is no disturbance to the sweep stroke.

On the flyback part, things start to happen. The top of the yoke becomes highly negative. We now have a negative cathode, or saying the same thing, we've made the plate of the tube positive. The tube now draws a very heavy current, becoming a "short" across the yoke, after the first half-cycle of the 70-kc oscillation. And, that's exactly what we want it to do: *damp* this circuit so heavily that it can't keep on oscillating after the first plunge of current from peak to bottom. So, for some reason which I can't think of at this time, this tube is called the *damper*. Its main purpose is to stop the ringing in the yoke circuit. It has a lot of other work to do, and does it very well, but the primary purpose is to stop that ringing.

Extra features of this type of damper circuit

When a diode tube draws current, we can take this current, pass it through a resistance, and get a voltage drop across it. With suitable filtering, it is a dc voltage we can use. This happens to be the same half-wave circuit you'll find in many TV sets, radios, etc. A rectifier works the same way whether it's a power rectifier or a video detector.

We have a heavy current flowing in this diode circuit, and we have to get rid of it somehow. So we use it. It is in the form of

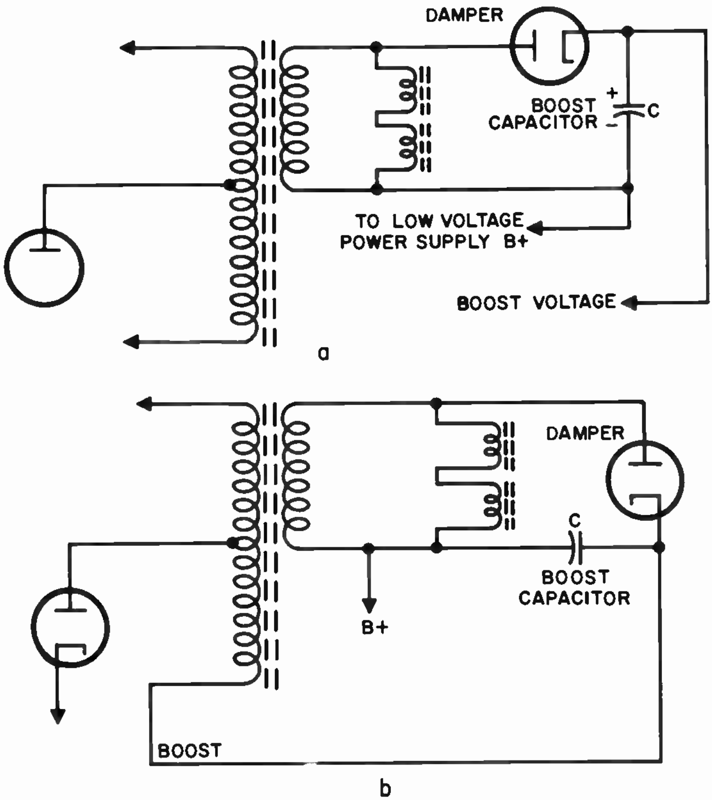


Fig. 511. *Capacitor C will pass the ac signal but it charges to the average voltage produced by the yoke circuit (a). This average voltage is put in series with that from the B-plus supply in the same manner you would put batteries in series for a higher voltage. Circuit is completed in (b).*

sharp pulses or spikes, at 15,750 cps, but it's still a pulsating dc. Remember, we said that this circuit used everything but the squeal! So, we take the current that we removed from the yoke circuit, because we didn't want it there, make it charge a capacitor, and we have a nice extra source of dc voltage!

We can connect the bottom end of this capacitor (see Fig. 511-a) to B-plus of the TV set's low-voltage power supply. Now, the voltage we develop on the damper cathode will be added to the voltage of the B-plus. Therefore, we call this the *boost voltage,* because, if we measure all the way from ground to the damper cathode, we will be reading the B-plus voltage *and* whatever voltage we are developing on the damper tube. So, we've effectively boosted the available B-plus by that much. (This runs from 200 to 400 volts, if you want some actual figures.)

In this drawing, it looks as if we've got an open circuit in the boost. Well, we have, now. Fig. 511-b shows a little more of the circuit. We are feeding the boost voltage to the bottom end of the primary winding of the flyback, so that we can get a higher dc plate voltage on the output tube. This increases the output of that tube; it's a very common use, and you'll find it in practically all TV circuits.

Someone raises the objection that this circuit isn't complete when the set is first turned on. How does the output tube get any plate voltage, through the boost capacitor and damper tube, which, in that condition are open circuits? The B-plus is apparently isolated by the boost capacitor and damper. There is no dc path from B-plus to the output tube plate!

Correct. There isn't. However, if you'll look at Fig. 512, you'll see how this works. There *is* a "road" for the voltage to get there. Naturally, we've got to have plate voltage on this tube, so that we can develop signal output, which will give us the boost voltage. Without plate voltage, the circuit won't work at all. By the way, this objection should have been answered by the very obvious fact that the circuit *does work* or it wouldn't be in there at all! It had to work, at one time, when the set was new, no matter what shape it happens to be in while you're trying to fix it! Try using this kind of reasoning, and a lot of problems will be very much simpler!

What happens is this, in simple language: Electrons leave the negative or ground end of the B-plus power supply. From there. they flow to the cathode of the output tube, then to the plate, and through the primary of the flyback to the cathode of the damper tube. Through the damper tube to the plate, then through the yoke/secondary parallel circuit and, what do you know!, here we are back at B-plus! The damper tube had a positive voltage on its plate, from B-plus so, it passes dc, like a resistor. At first, during warmup time, the damper in effect is nothing but a resistor in the circuit, as is the output tube, until the oscillator warms up enough

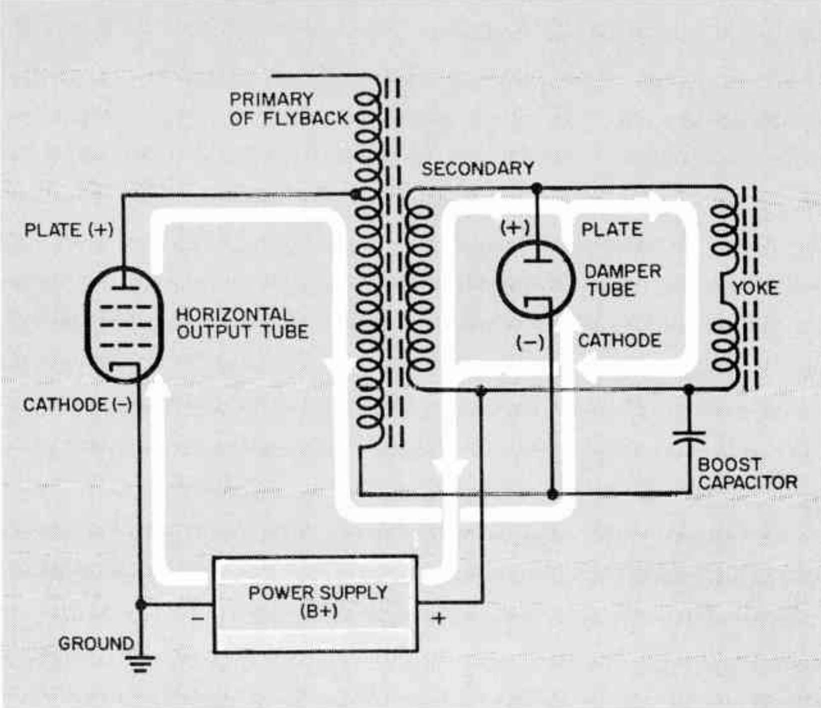


Fig. 512. *The path of the dc flow in the horizontal output circuit. The low-voltage power supply and the damper tube are connected in series between the plate of the horizontal output tube and ground.*

to put some drive signal on its grid. Current will flow in the normal manner, and we will have dc voltage on the output tube plate.

Variations in hookup of damper circuits

Let's get some things straight before we leave this subject. This circuit can be puzzling, especially in some of the hookups you're going to find in TV sets. Remember this one simple fact: it *always* works in exactly the same way we have shown it here! You'll find some pretty wild-looking circuits, and you may not recognize them at first. But, if you'll trace them out, you'll find that they are exactly the same as the simplified circuits we've been using. They have to be, if the damper tube is going to work at all.

Fig. 513 shows some typical variations. Notice that we've now drawn the damper tube inside the yoke/secondary (Fig. 513-a). You'll find it drawn this way in practically all schematics. Fig. 513-b is another variation, a most common one. Note the connection of the damper tube; apparently not across the yoke at all, but on taps farther up the flyback secondary! Not so! The damper tube *is* across the yoke. The reason for the stepup in the taps is to increase the boost voltage. We're making the secondary of the transformer have an autotransformer effect during flyback time. The discharge pulse of current from the yoke generates a larger voltage in that part of the secondary, compared to the part which is directly across the yoke, and we can get a higher pulse voltage to apply to the damper plate, hence a higher boost voltage.

Now, as to the boost capacitor, you're going to find that it will *always* be connected between the damper cathode and B-plus. It may appear to be in the damper *plate* circuit but, if you trace out the circuit, you'll find that it is connected to the damper cathode, with the other end eventually getting back to B-plus. In this connection, we are actually talking about a dc path which can be traced with an ohmmeter! If you'll check the circuit, you'll find that it does exactly what we said. No matter how many windings it passes through, the boost capacitor will have a dc path to B-plus, with the other end to the damper cathode.

There is another reason for applying the B-plus voltage to the bottom of this capacitor. We didn't really go too deeply into the actual circuit action of the damper tube; for reasons of simplicity and clarity, we gave you the basic action of the damper. However, those of you who have been wondering why the damper didn't conduct all the time, because we said that it had B-plus voltage on its plate, are about to find out! We make it a *biased diode*.

During the first few cycles of sweep, the damper tube conducts, as it is intended to. The boost capacitor may have 300 volts of B-plus across it. This would allow the damper to conduct all the time, because its plate is positively charged. However, our first few cycles of sweep cause current to flow in the damper. This charges the *top* plate of the capacitor to the 300-volt level and far above it. Now, we do *not* have positive voltage on the plate or negative voltage on the cathode, which is exactly the same thing. The damper diode is biased by the charge on the boost capacitor, and it will conduct current only when the applied voltage goes *above* this bias level, "bucking it out" or cancelling it, and allowing a net positive voltage to appear on the diode plate.

Summarizing the damper–boost-voltage circuit

As a final reminder, always remember these facts about this circuit. You're going to need them in the future.

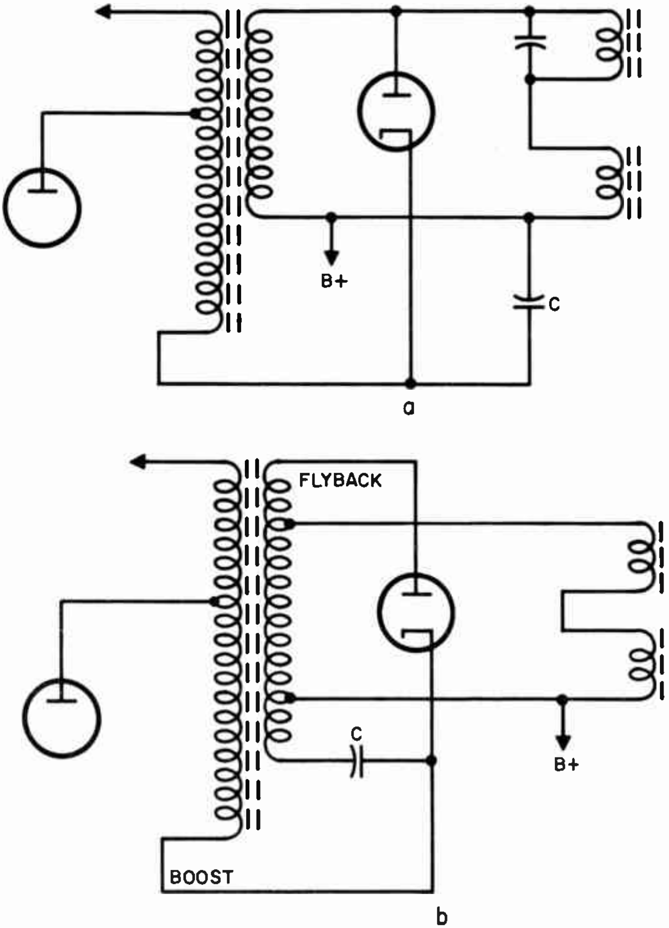


Fig. 513. *The basic damper circuit (a) is modified to provide a higher boost voltage (b).*

1. The damper tube is always connected *across* the yoke.
2. The boost capacitor is always connected with one plate on the damper cathode and one plate on B-plus.
3. The damper *plate* is always connected to B-plus, *cathode* to boost.
4. The *source* of the *boost voltage* is the *yoke*. If the yoke is defective, no boost.

The damper tube has a lot of extra work to do, in addition to what we've already talked about.

Horizontal linearity circuit: control and adjustments

We're coming to one of the most involved portions of this circuit's action. This is the relationship between the yoke current (which is directly related to the beam position, since it generates the magnetic field that moves the beam), the output tube's plate current, the damper current and the *shape* of the voltage waveform across the boost capacitor. All this? Yes, and more, but we'll simplify it as much as possible. Like everything else in electronics, this complicated circuit consists of a bunch of simple circuits tied together. This complex circuit action is nothing but a few simple actions happening at the same time and we'll try to explain them in that way—as if they took place at different times. They actually do, but they're so close together that you might say that they all happen at once.

While we're doing this, we'll bring in a new circuit. This is the *horizontal linearity circuit*. What it does is straighten out the sweep, keep it linear; that's where the name comes from. Simple circuit, but pretty complex in application, unless you understand exactly what it is and what it's supposed to do.

Now, let's rough-in the circuit action, then take it a piece at a time. Take an instant, after the circuit is warmed up and in full operation. The beam is in the exact center of the screen, so the yoke current at this instant is zero. See Fig. 514-a. The output tube starts conducting when the grid drive waveform raises the control grid voltage enough to allow it to come out of cutoff. This sends a pulse of plate current through the flyback-yoke circuit, and the beam is moved from A to B, at the right side of the screen. To do this, we've made the yoke current increase from zero to maximum in one direction.

Next, as we go along that grid-drive waveform, we see the grid voltage suddenly plunge to cutoff and far below. This cuts off the plate current of the output tube completely, and biases it so far negative that it couldn't pass any plate current if it wanted to. So, we have "disconnected" the output tube from the circuit. It has nothing at all to do for a while.

While it's taking a well deserved rest, let's see what the rest of the circuit is doing. Plate current stopped very suddenly, so the yoke discharged. The magnetic field collapsed back into the windings, creating a voltage across the yoke-damper circuit. The magnetic field also returned to zero. Then, because this energy was still moving, it went on to build up in the other direction. (This circuit is resonant, remember? So, it tries to oscillate.) This moves the beam very rapidly all the way across the screen to the left side. As the current falls through B–C–D in Fig. 514-b, the beam moves with it, as you can see. Yoke current has reversed direction.

This takes place in about 7 μsec, and now we're ready to start another scanning line. Where are we going to get the necessary "push", though? the output tube is still cut off, and the damper tube is conducting heavily to discharge all the energy from the yoke. So, where do we get the push? From the energy stored in the boost capacitor. Also, because the magnetic fields have discharged in one direction, and have then charged up again in the opposite direction (polarity) we have some energy in the yoke. This starts yoke current flowing again, but in the opposite direction. Now it is flowing in the same direction as it was during the first half-cycle of the sweep, from A to B. The beam is moving from

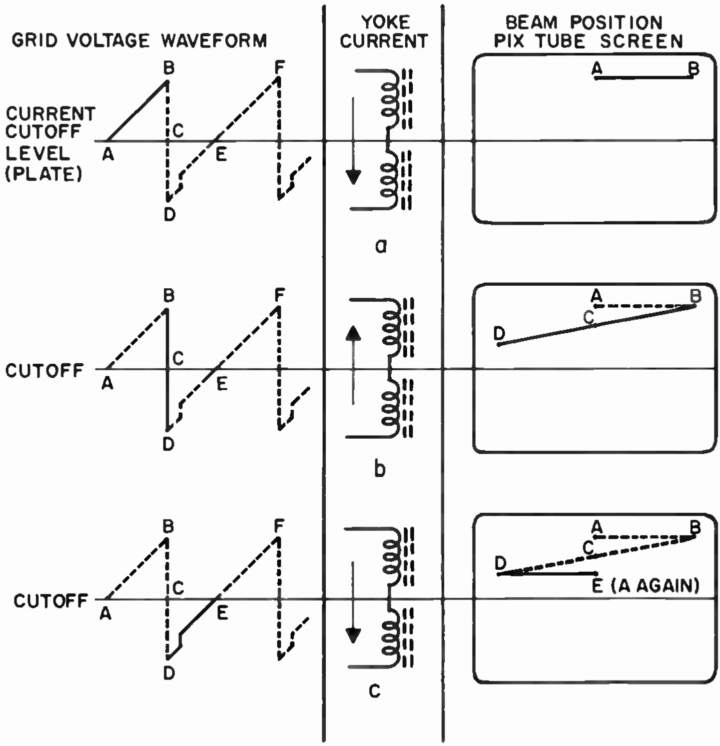


Fig. 514. *Signal voltages (left), and yoke current flow (center) that produce crt electron beam deflection (right).*

left to right, beginning at D. As this energy discharges, the beam moves back to the center of the screen, at the normal sweep speed of one trip across the screen in 53 μsec. Fig. 514-c shows this half of the cycle.

Now we're back in the center of the screen, and the output tube goes to work again. Its grid waveform has risen above the cutoff level, so it starts conducting plate current again, and the process is repeated from A. Now you see the key fact in this process: the complete horizontal sweep stroke is not one waveform, but comes in sections! The circuit puts these together to make one complete sweep of the beam across the screen.

Let's run over that again. The output tube furnishes the *right* half of the sweep; it moves the beam from center to the right half of the screen. This done, it folds its hands and sits back, saying, "I've done *my* part; now, you fellers do the rest. Call me when you need me!" The yoke and damper circuit then snap the beam back across the screen, very rapidly (7 μsec) and the *gradual* discharge of energy stored during the first half-cycle then moves it back to the center. So our *damper* tube furnishes the *left* half of the sweep.

Fig. 515 shows the relationship between the various positions of the beam and the yoke current levels. Here are the vital parts, so remember them. (They're the ones you'll use in making diagnoses of trouble in this stage, so study 'em carefully.)

1. The horizontal output tube takes care of the *right* half of the screen.

2. The damper tube takes care of the *left* half of the screen, also of the *flyback action*.

3. *All* of the *energy* (power: voltage × current) used in this circuit *must* come through the horizontal output tube, from the low-voltage power supply, the B-plus. The tube merely *controls* this energy. The energy furnished by the damper tube is a part of this same energy, which has been saved up. It's been put in the bank, as it were, until it is needed. The damper tube-yoke-boost circuit has absolutely no source of power of its own; it gets every bit of its supply through the horizontal output tube.

There are your three facts. We're going to use them in a lot of different ways as we go along, so be sure to put them someplace where you can get 'em when you want 'em! They are the abc's of the whole horizontal sweep circuit, and we'll need all of them to spell out some of the many troubles that we're going to get into later on. and to find a cure for them.

Now we get to another little circuit which was developed to fill a great need. We've been drawing the forward stroke of the sweep as a nice, flat linear wave. In actual circuits, this just isn't so. Where do we get this part of such a waveform? From the charging curve

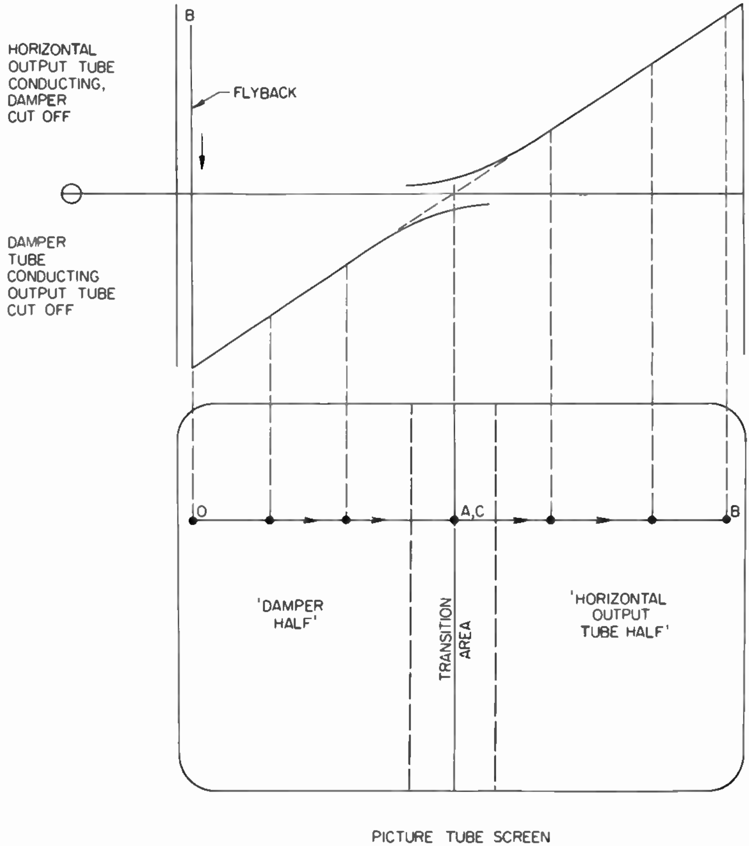


Fig. 515. *Relationship between sweep stroke and beam position on the screen.*

of a capacitor, back somewhere around the horizontal oscillator circuit. It's going to look something like Fig. 516-a, since nothing is perfect. This is the typical charging curve of a capacitor (in any circuit where a capacitor is charged through a resistance). This is a voltage waveform, by the way. So, we wind up with a grid-voltage waveform on the output tube that looks more like Fig.

516-b than the beautiful straight curves we've been drawing. Will these work? Yep. How, someone asks? Easy. (Comparatively speaking, that is.) We simply go ahead and feed this mess through our output tube, amplify it as we said, and then correct any undesired curvature (distortion) of the waveform *later on!* It's easier than trying to straighten the wave out first, then keep all of the other circuits linear! We apply our linearity correction at the 'last moment', in and around the circuit where we want it to be linear; the yoke and damper itself.

Two currents equal one waveform

So, our final yoke-current waveform *must* be made up of a combination of the currents from *two* tubes. We've got to 'join' these two so that they make *one* nice linear waveform. That's where the trouble starts. If we just 'jammed them together', they'd look something like Fig. 517-a. There'd be a big wrinkle or hump in the middle, where the two overlap. You see, if one tube would stop conducting very suddenly, and the other start just as suddenly, we wouldn't have any trouble. But, they won't do that, being practical

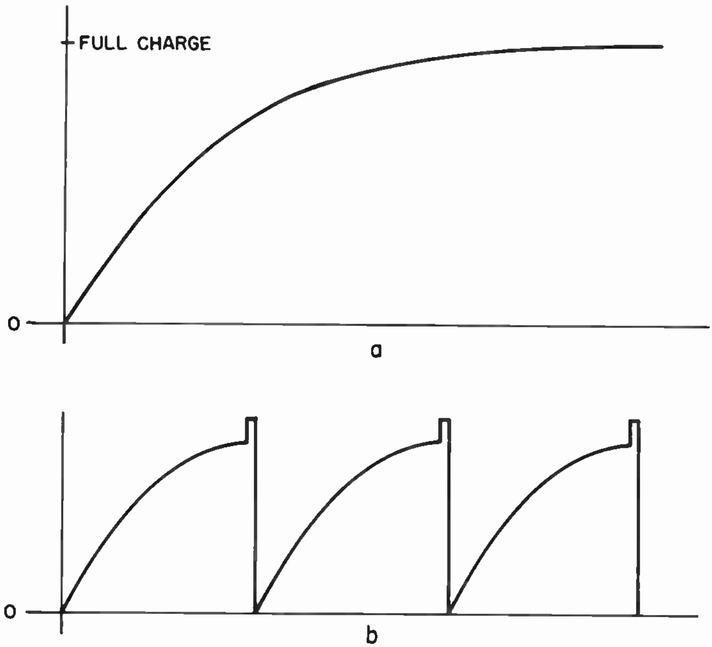


Fig. 516. *The basic R-C charging curve (a) is the source of the grid-voltage sawtooth (b).*

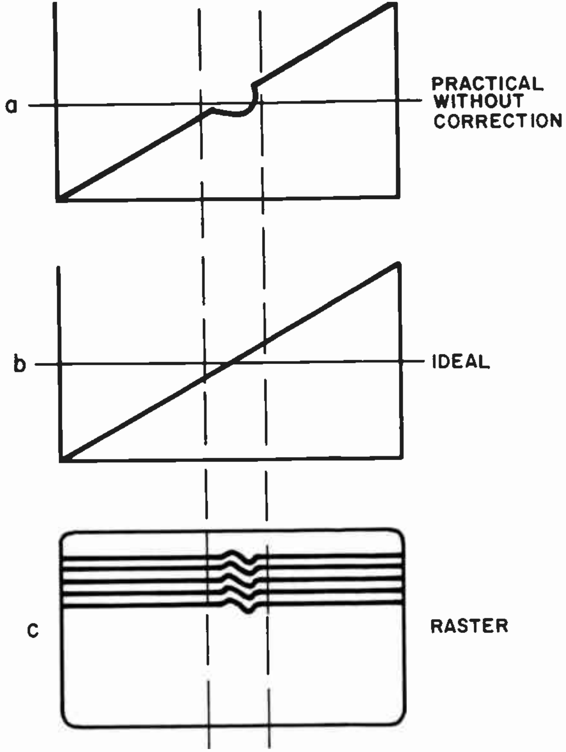


Fig. 517. *The yoke current waveform is a combination of the reaction scanning (left side to center of TV screen) and the horizontal amplifier currents. The humps and dips in the waveform occur during the change from one current flow to the other.*

pieces of electronic apparatus and not 'theoretical'! The damper tube conduction 'trails off' slowly and the output tube conduction starts slowly. So, we get an overlap period in the middle where *both* tubes are conducting at the same time. Instead of looking like Fig. 517-b, the ideal waveform, we get one that is more like Fig. 517-a, and a wrinkle in the middle of our raster (Fig. 517-c) where the *speed* of the beam is varying. Actually, the beam doesn't bend up and down, but that's the only way we could show it here.

So we've got to do something about this. What we need is a circuit which will act only during the transition period while the yoke current is changing between damper and horizontal output tube. If we had something that could correct this curvature at that point, we'd have it made. Well, we have. We simply add a resonant circuit between the damper cathode (boost) and the plate-return connection on the flyback, as you can see in Fig. 518. For some reason, we call this the horizontal linearity circuit.

How can this correct the curve in the sweep? We make it resonant at 15,750 cycles. The coil is adjustable, with a ferrite core, and its inductance is such that it can be made to resonate with the capacitor or capacitors at the right frequency. This isn't as high-Q a circuit as we made the yoke, so it won't have as *much* effect as that does. We don't want it to! We won't have the sweep voltage turned into a high-amplitude oscillation. What this does is cause it to ripple at the *horizontal frequency,* deliberately! Something like the waveform shown next to it in Fig. 518.

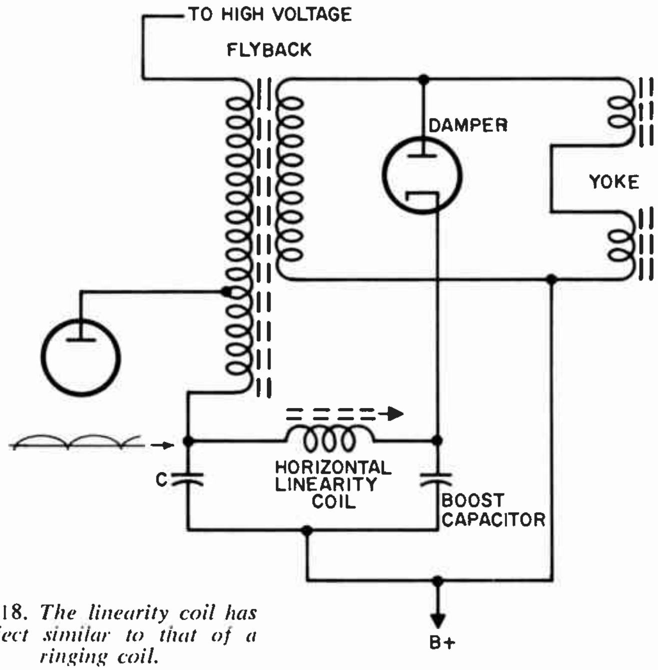


Fig. 518. *The linearity coil has an effect similar to that of a ringing coil.*

Since our coil is adjustable, we can make the humps (peaks) in this ripple waveform change in phase, just as we did with the horizontal waveform coil back in the horizontal oscillator circuit. This causes the humps to move back and forth, in time, with respect to the humps in the plate current, yoke current, etc., which are all in phase with each other, since they all come from the same source. Now, let's do something with this movable hump.

Look at the output tube. Its plate *current* shapes the current in the yoke-secondary winding, and also contributes to the humps in the yoke current coming from the damper. Since this linearity circuit is actually a part of the boost-voltage circuit, it's going to have an effect on that, too, isn't it? Now, since the *plate voltage* on the output tube has a very decided effect on the amount of *plate current*, if we can *alter* the plate voltage we can control the plate current. (The higher the voltage, the greater the current, and vice versa: plain vacuum-tube fundamental theory.)

In Fig. 519-a, we see the yoke current waveform, with a hump in it at the crossover or transition point. This is caused by a drop

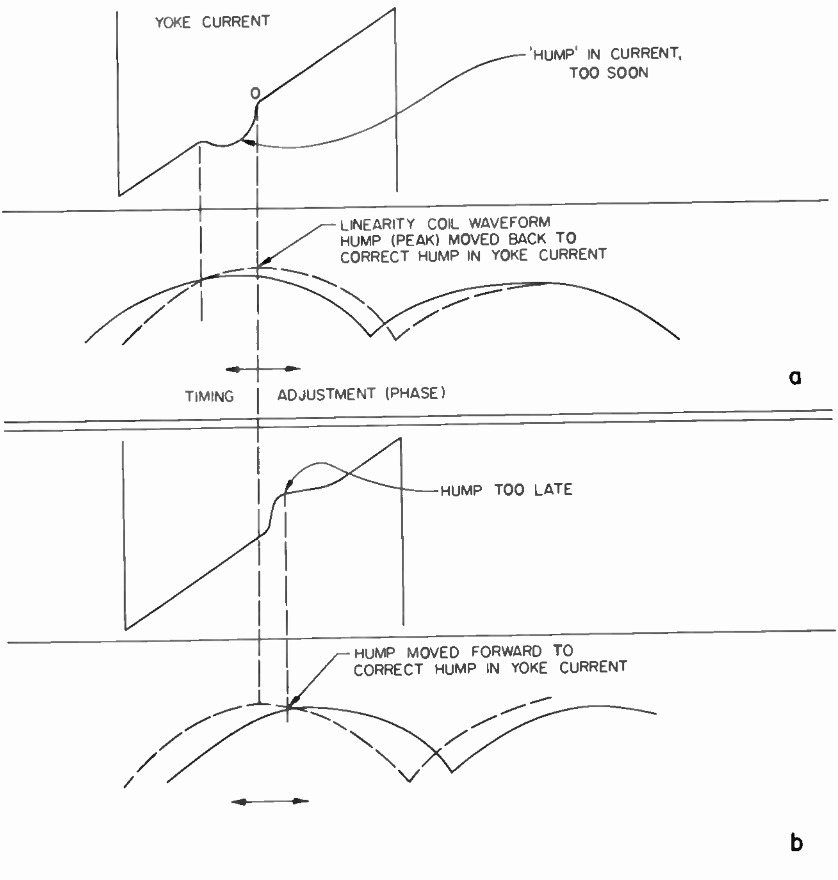


Fig. 519. *Drop in yoke current (a) is caused by decrease in damper tube current. Linearity coil peak is moved to correct for this. Improper timing adjustment (b) will also produce a hump in the yoke current.*

in the damper tube current, below what it should be at this time. How to correct this? Move a hump in the voltage over so that it is underneath this droop, and push it back up again! We can do this by moving the peaks or humps in the linearity circuit, hence the boost voltage, back and forth with respect to the yoke current. This is actually a phase shift, but it makes the hump appear earlier or later in the cycle whenever we want it. Fig. 519-b shows the opposite effect: the hump is too late, so we advance the hump in the boost voltage to compensate for it.

In simple language, what we do with this circuit is compensate for any nonlinearity that appears in the sweep, by raising or lowering voltage to control the currents. We do this by changing the timing of the peaks in the linearity circuit, which is in the boost-voltage circuit: this phase-shifting is caused by the variations in the inductance in the circuit.

There's another desirable effect, and one which we make use of in many ways. A while ago we said that this output circuit was like a radio transmitter's final power amplifier stage. If the load on a transmitter, the tank circuit and antenna, is resonant at the right frequency, it will absorb maximum power from the output tube. The stage will be at maximum efficiency (the most power output for the least power input). By making the circuit resonant, we can improve the efficiency of our horizontal output stage. The linearity circuit actually works as a resonant load on the output tube-flyback circuit. When it is tuned to the right point, we get maximum linearity of sweep, *plus* maximum efficiency!

In a circuit like this, and we're going deeper into this part very soon, the plate voltage doesn't "change". It's considered a "constant". So, minimum plate current means maximum efficiency, if this coincides with maximum output of rf power. Thus, we can tune the horizontal linearity control (the adjustable coil) while reading the plate current of the horizontal output tube. When we reach the point of *minimum* plate current, we know that the circuit is working at maximum efficiency. We tune for a dip in the plate current reading, and this is exactly like the tuning of the final stage of a radio transmitter.

There are several ways of checking the efficiency, and we'll show you all of them. For example, while the high-voltage output has nothing to do with the operation of this circuit, being a byproduct as it were, we can use it as an indicator of output.

part 2

Chapter 6

Horizontal Output Stage

WE'VE BEEN WANDERING AROUND IN THE MAZE OF CIRCUITRY IN the flyback and yoke and so on. Now let's take a look at the part that handles all of the power for this circuit: the horizontal output tube. This is a very important part of this circuit, and one you're going to be working with more than all the rest combined. Meaning you're going to replace a lot more output tubes than you will flybacks or yokes. You'll need to know all about this tube: what it does, how it does it, and above all, what you should find in its circuits in the way of voltage and current.

Unless you're thoroughly familiar with this tube in all its different versions, and know exactly what maximum power ratings are in each case, you're in trouble. When you replace one, you must be able to check its circuit and be sure that it is going to operate within safe limits. If some circuit condition caused the old tube to burn out, it will burn the new one out in a short while. So, you'll get a callback on the job, and the privilege of giving the customer a free tube! They always seem to go out just before the warranty expires!

This is *not* inevitable, though. You can avoid it if you'll take the time to make certain simple tests whenever a tube is replaced. If the operating voltages and currents are within safe limits, the new tube will not be damaged. Always remember this fact: in this circuit, a perfectly good tube can be ruined in a few hours by being overloaded, underdriven or operated with a wrong voltage. This is one of the very few circuits in a TV set where this can happen.

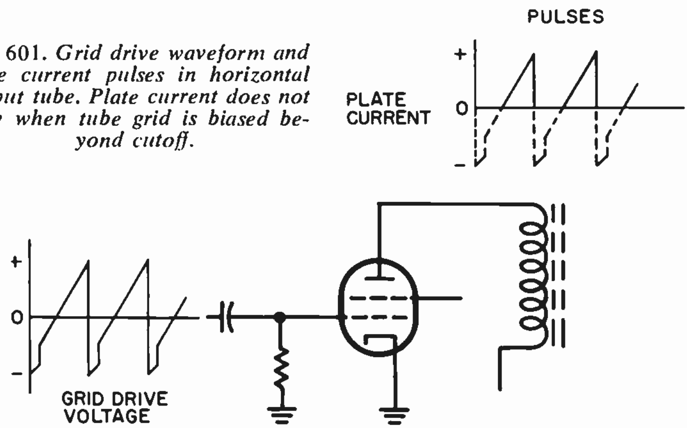
How the horizontal output tube operates

Power output tubes in CW radio transmitters work in class-C operation. So do horizontal output tubes in TV sets. Why? Because we can get far higher *efficiency,* the most output for the least input out of a given tube in this mode of operation. In class A, a tube works all the time. Its plate current flows continuously, throughout a whole cycle of the signal. In class C, plate current flows only for a small fraction of the cycle. We can feed a plate current like this (pulses) into a resonant circuit, and make the natural flywheel action of the circuit furnish the rest of the cycle! Our tube just gives the circuit a push at the right time in each cycle. So, by running in class C, we can get more usable power output from a tube, since the *total* power can be concentrated in one big push, rather than spread out over the whole cycle.

To make a tube work in class C, we bias the control grid far below the cutoff point. Then, we apply a signal to its grid which has enough amplitude to overcome this bias during part of the positive half-cycle. When the bias is overcome, plate current flows.

Fig. 601 shows how this works in this case. At the cutoff point in the grid voltage, plate current stops flowing. When the sawtooth

Fig. 601. *Grid drive waveform and plate current pulses in horizontal output tube. Plate current does not flow when tube grid is biased beyond cutoff.*



spikes rise above this level, then plate current flows, in a series of pulses or spikes. These pulses must be above a certain level of power (voltage times current) to get enough energy into the secondary (output) circuit to do the work. If we don't, then the efficiency of the circuit falls off rapidly. In this case, we'd get lowered high voltage and a loss of sweep width: a dim raster, pulled in from the sides. We need a tube which will handle quite a lot of power during these short bursts.

The tubes we use are designed just for this kind of service. Each has a total power dissipation rating, meaning the amount of power actually handled during one full cycle. This is quite different from the instantaneous power we are dissipating in most cases. Figured near the peak of the cycle, at full conduction, this is enormous. In a typical tube, which has a maximum plate dissipation rating of 11 watts, the maximum plate voltage is 5,500 and the current 100 ma. Figure this out: $5500 \times 0.1 = 550$ watts! Of course, this

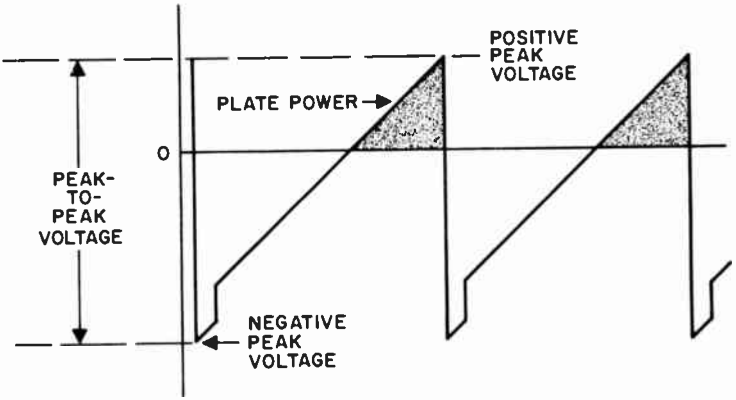


Fig. 602. *Shaded area above the cutoff line represents power (voltage times current) dissipated by the output tube. Plate power is dissipated for only a short portion of the complete cycle.*

condition lasts for only 1 or 2 μsec, and by the time we average this out over the whole time of one cycle, it's within limits. We actually overload the tube tremendously for a very short time, then let the plate cool off for the rest of the cycle, so that we can overload it again.

When we get into a circuit condition which causes some of these constants (operating voltage and currents) to be wrong, then we get such an increase in the *average* power that the tube burns up in a hurry. For example, you can see what would happen if we increased the time of conduction of the tube: our average power would go up like a skyrocket. Fig. 602 shows how this works. The shaded area here represents the amount of power being used. If we made this longer, by increasing the conduction time, you can see how much this area would be increased. It's not hard to find out about this: all we have to do is measure the plate current! Just as long as this is within the rated limits, we're safe. As to how to hold it within these limits, that's what we're going to take up now.

Biasing horizontal output tubes

How can we hold down plate current in a tube? By increasing the control grid voltage, the bias. The higher the negative bias, the lower the plate current. The normal class-C stage operates with bias far below the cutoff point, so that no plate current flows unless there is a signal of sufficient amplitude on the grid to *drive* it into conduction. It won't conduct current at all without this signal. There is another factor about this type of circuit which is very important; we'll get to it very soon. For now, let's consider that grid signal. Since it drives the tube into conduction, we call it *horizontal drive.*

All TV sets use grid-leak bias here. This is one of the oldest vacuum-tube circuits, used in radio many years ago, but the principle is still the same. Our drive signal is fed through a capacitor to the grid of the tube, as in Fig. 603. This applies a voltage to the grid of the tube. When this voltage goes above zero, or above cutoff voltage (not necessarily the same, depending on the tube design), plate current starts to flow.

Also, since the grid must be driven positive to get a very large plate current, we pick up a few electrons from the cathode, and *grid current* also flows. If the grid doesn't have a connection to ground, this charge will pile up on the grid, and cause it to become so highly negative that the plate current cannot flow. In other words, the tube is blocked. So, we connect a resistor between grid and ground to let this charge leak off; this, for some odd reason, is called the grid leak.

Now, the charge will build up on the grid and the electrons will flow to ground through the resistor. Since electron flow through a resistor causes a voltage drop across it, we get a negative voltage on the grid end of the resistor. How do we keep this voltage on the grid for use as bias? By charging the grid capacitor. When the grid builds up a large charge, it is also applied to this capacitor. If the grid-leak resistor is very large, it won't have time to leak off before the next cycle of drive signal comes along and recharges it. So we get a bias voltage on the grid proportional to the size of the grid capacitor and grid-leak resistor, and to the peak voltage of the applied drive signal. This circuit is designed to build up the proper bias voltage to make the tube operate in class C. and to draw plate current only during the right fraction of the input cycle.

Drive voltage waveform

Let's take a close look at some of the important characteristics of this drive signal. We consider this as the power source for the stage, as far as output is concerned. Of course, the *dc* operating power comes from the B-plus supply. But the drive signal can be considered as the power source, since it affects the performance very drastically. Any distortion or loss of amplitude will cause trouble in a hurry.

We can use the waveform of Fig. 602 to represent this drive signal. What are the most important parts? First, the peak-to-peak voltage. Since this is an ac waveform, part will be positive, part negative, measured to ground. The total voltage of the waveform, measured between positive and negative peaks, is the peak-to-peak

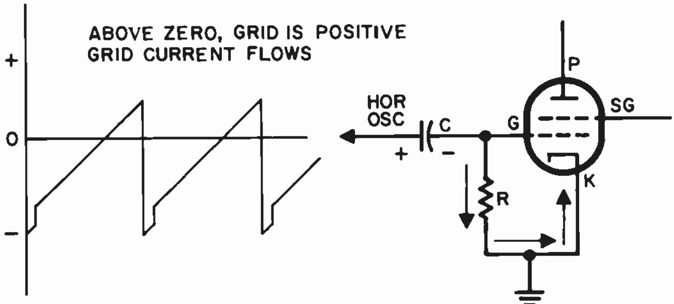


Fig. 603. *Grid leak action in output tube. Grid leak bias controls tube operating point. Loss of signal means loss of bias. This results in excessive current flow which can damage tube and flyback transformer if circuit isn't fused. Oscillator failure produces same result.*

voltage, abbreviated p-p. The amplitude of this determines the amount of bias developed on the output tube's grid. Also, the shape of the positive pulses determines the shape of the current pulses that will be sent through the flyback transformer.

The shape of the negative half, below the zero line, is equally important. This determines the amount of time the output tube will be held below cutoff, not conducting, out of the whole cycle. This determines the percentage of time the plate current flows, which is important in establishing the total power dissipation for the circuit. In other words, we could have properly shaped positive pulses but, if the negative parts aren't right, too, our circuit will not operate properly. Both of them have to be there in the right amounts! A shift in negative values (toward positive) would shift the operating point of the tube, by changing the bias, and away we go again; the power increases and the tube burns out.

The p-p value of the drive voltage establishes the grid bias by grid-leak action. Therefore, this p-p voltage will often be given on the service data, or should be. If it isn't, you'll know, with a little experience approximately how much drive is needed for each tube type. There isn't too much variation. Later on, we'll show you how to check this p-p voltage to be sure that the output tube has adequate drive signal. In fact, this will be one of the first tests we'll make when servicing actual TV circuits.

One fact which you must always keep in mind is that if the output tube has too little drive signal, it will draw too much plate

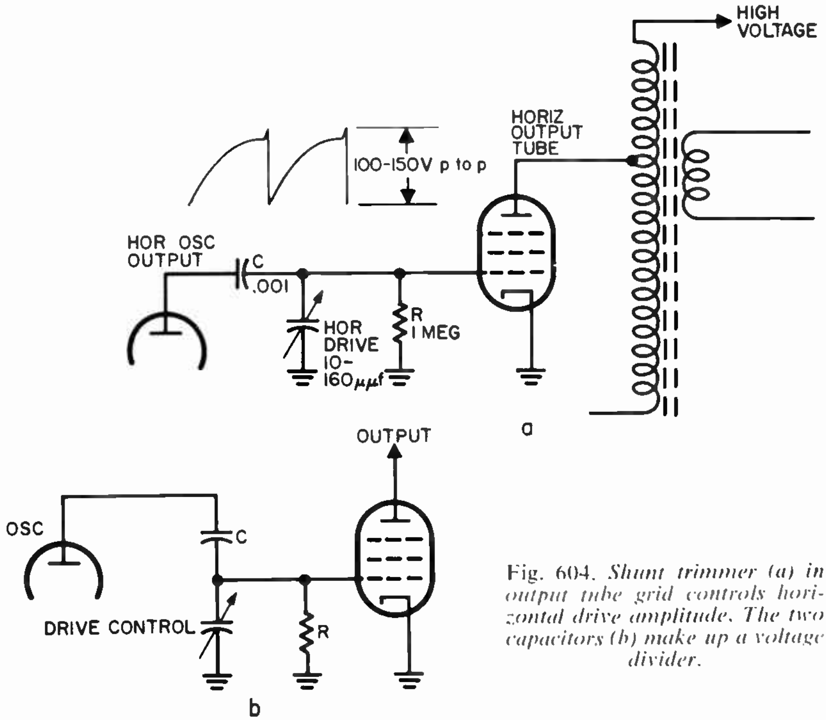


Fig. 604. *Shunt trimmer (a) in output tube grid controls horizontal drive amplitude. The two capacitors (b) make up a voltage divider.*

current. This will shorten the life of even a brand-new tube tremendously, and can cause other damage, such as burning up the flyback transformer by pulling excessive current through its windings, or popping the fuse in the horizontal circuit. Too much drive signal isn't as serious, although it does cause distortion, etc.

However, the thing we must learn to watch out for is too little drive, since this is the worse offender. Common causes of this are weak horizontal oscillator tubes, low supply voltages to the oscillator and defective parts in that circuit—leaky capacitors, burned resistors and so on. In marginal cases, which are the worst to spot, we can always get a definite and accurate indication of the condition of the drive by measuring the plate current of the output tube. Too much plate current, too much power loss and trouble. By developing the proper grid bias, the drive signal holds this plate current within its normal safe range.

Drive controls

Early TV chassis always provided a *horizontal drive control.* Unfortunately many later circuits omit this for the customary reason, economy. This isn't too serious: in an emergency, you can always add one if you have to. Several circuits have been used, including

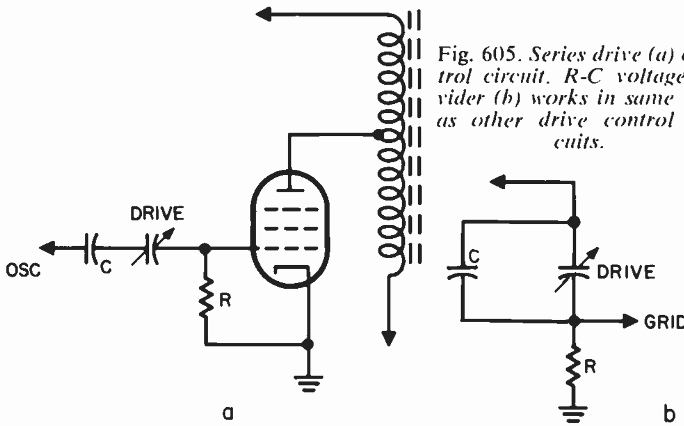


Fig. 605. *Series drive (a) control circuit. R-C voltage divider (b) works in same way as other drive control circuits.*

a variable resistor in the oscillator plate supply, but the most common is the simplest. This is a capacitive voltage-divider circuit in the output tube's grid, as in Fig. 604-a. This is a shunt circuit; redrawn as in Fig. 604-b, you can see how the small variable capacitor forms the lower half of a voltage divider. Since the signal is always an ac waveform, this works exactly like a voltage divider made of two resistors. The amount of the total voltage appearing on the grid is proportional to the reactances of the two capacitors, which can be expressed in ohms.

Another version of this circuit uses the trimmer capacitor in series with the coupling capacitor, as in Fig. 605-a. The circuit looks different, but it isn't. In some versions, you'll find fixed capacitor C omitted, and the trimmer itself used as the coupling capacitor. In still another, the fixed capacitor and trimmer are connected in parallel. All work the same way, of course. The voltage divider is still there, as you can see in Fig. 605-b. Now, it's an R-C divider, instead of being purely capacitive, but it still works the same.

The only difference is in the way we adjust the trimmer capacitor. In the shunt circuit of Fig. 604-a, tightening the screw, thus increasing capacitance, *reduces* the drive. The capacitance is increased and its reactance is decreased, so we have less voltage drop across it.

The series circuit of Fig. 605-a has the opposite effect: to reduce the drive, we *unscrew* the trimmer, to reduce its capacitance. This puts more reactance in series with the signal on its way to the grid. You don't really have to know which circuit is being used: a turn or two of the drive trimmer will tell you which way is correct after you look at the picture!

Drive circuit faults

You can have two possible faults in this circuit. Too little drive will show up as loss of width or brightness. If the drive falls below a certain value, the plate of the output tube will get red-hot. Table 6—1 shows the results of varying only the drive voltage in a test.

Table 6—1. What happens in the output circuit as the drive voltage is reduced. Everything else kept constant, only drive varied.

Drive, in p-p volts	Plate ma, output tube	Boost voltage	High Voltage
124	105	560	14,100
108	108	556	14,000
87	112	526	12,600
75	118	470	10,000

Note this key fact: as the drive voltage goes down, the plate current goes up in direct proportion. This was not carried low enough to show a damaging current overload on the tube but, as you can see from the last figure, it is drawing a current of 118 ma, which is over this tube's normal maximum rating of 105 ma. Tube life under these circumstances would be very short.

There you see one of the key relationships in this circuit, that between p-p drive voltage and the plate current of the output tube. Later on, we'll be using this plate current to determine the adequacy of the drive signal, among other things. For instance, if we read too high a plate current in testing, one of the first things we should check is the p-p voltage of the drive. If this is normal, then we look elsewhere.

Too much drive signal also causes trouble, but not serious trouble. If we overdrive the output tube, we will cause distortion

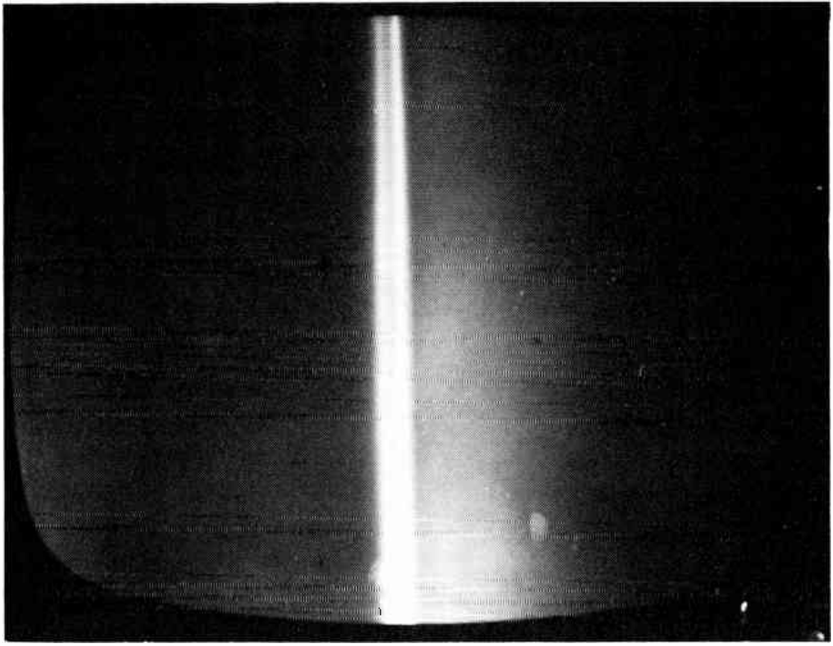


Fig. 606. *Overdrive appears as a vertical white line in the raster. It can be used to help set the drive control.*

of the drive waveform, by grid-clipping, etc., and upset the normal timing of the plate current pulses. If we make the output tube cut off at the wrong time, we upset the resonance relations in the secondary and distort the sweep waveform of the yoke. The invariable symptom of this condition is a foldover in the center of the screen, in the transition area between damper and output tube conduction. This appears as a vertical white line in the raster (Fig. 606) which is called a *drive* line. Of course, it should be called an *overdrive* line, but you know how we are. Whenever this line appears in the center of the screen, you know you've gone too far. Turn the drive trimmer in the opposite direction until the drive line just disappears.

Drive-line testing

This is an extremely useful little squiggle. It will give us a lot of information about several parts of the circuit. Let's see how.

You'll find this procedure in many drive adjustments in the service data: *Turn trimmer until drive line appears, then back off until drive line just disappears.* We can use quite a few different "reactions" to tell something about circuit conditions. What can we check here besides the drive on the output tube? The horizontal oscillator! If the drive control will make a drive line appear on the screen, this tells us one very important fact: the horizontal oscillator definitely has enough output! If it's weak, we won't get a drive line.

We can back into a test, as we just said. If we can't get a drive line on the screen, we'd better check out the horizontal oscillator, for it isn't putting out as much signal as it ought to. A weak tube, low supply voltage, etc. can cause this kind of trouble. If the oscillator circuit is weak, we want to know about it. Otherwise, it might fail after we have replaced the expensive horizontal output tube. If it does, the new tube will be ruined in about 5 minutes by overloading! So that drive line is one of the quick checks we have been talking about. It takes only a few seconds, but we get a lot of useful information from it.

Drive voltages

We can read the p-p voltage of the drive with a p-p reading vtvm, or a calibrated scope. In either case, the value should be compared with that shown on the service data. If it's more than 10% low, we'd better find out why. As we said, many modern sets have no drive controls. The designer depends upon holding close tolerances in circuit components to make the oscillator work within the proper limits. In most cases, this works out all right. In a few cases, you may find overdrive conditions which are mysterious. If you can't find any other way to correct them, install a small drive-control trimmer capacitor, and set the drive to the proper value. You can use any good mica-insulated trimmer with about 10–150 pf of capacitance, connected between the grid of the output tube and ground.

In a typical circuit, drive voltages will measure between 70 to 90 for some tubes, up to 120 or 140 volts for tubes used in 90° and 110° flyback circuits, which require higher drive. (These are p-p voltages, of course.) If a variable drive control is used, the circuit should be designed to provide total voltages of up to 150 p-p. This is then reduced to whatever value is needed by adjustment of the drive trimmer.

A scope with a low-capacitance probe is a very useful instrument for working in this circuit. Used with a voltage calibrator, it will show you, not only the p-p values of the signal, but also the waveshape of the signal. This is very handy in locating obscure troubles that you'll find in a few sets.

Flyback transformers

Flyback transformers are like girls. They come in quite a few sizes and shapes, but they're all alike. That is, they have the same basic functions and parts—to drive the yoke and make high voltage —and they can give you a lot of trouble if you don't understand how they work. (Flyback transformers, that is, not girls—*nobody* understands how *they* work!)

Let's clear up a few common misconceptions before we get started. For one thing, there's no such thing as "deflection angle of a flyback." Depending upon the B-plus voltage applied and the type of output tube used, you could scan any CRT from 50° to 90° with the same flyback! This is not ordinarily done, for several reasons. The flyback, yoke and other parts will be matched for use together in a particular circuit with a given picture tube. B-plus and all operating constants are chosen to give safe operation within the dissipation limits. Now, yokes, as we'll see in a minute, are designed for a certain deflection angle, but this is a function of their physical construction. Basically, all yokes are alike.

No matter what the flyback looks like, remember that it is just like the others, and has the same purpose. It does the same things, and we can use the same service methods and tests on all of them. There will be minor differences such as voltage polarity on the yoke, damper connections, auxiliary taps or separate secondaries, taps for convergence waveforms on color TV sets, and so on, but the basic purpose is still there: drive the yoke and make high voltage.

Types of flyback transformers: circuits

Flyback transformers are made for three basic circuits. There are variations, as we said, but the basic types are the same. We've been showing only one up to now, for simplicity: the one with isolated secondary windings. This circuit is seen in Fig. 607-a. Secondary windings match the plate impedance of the output tube to that of the yoke.

The second type is an *autotransformer* (Fig. 607-b). For many reasons, mostly economy as usual, this is a very popular circuit in later-model TV sets. Here, we have only a single winding, with the yoke tapped down on it, and the high-voltage rectifier's plate on the top end. There may be small isolated secondaries on this type of transformer, for agc pulse feed and so on, but the main winding will always be a single tapped winding.

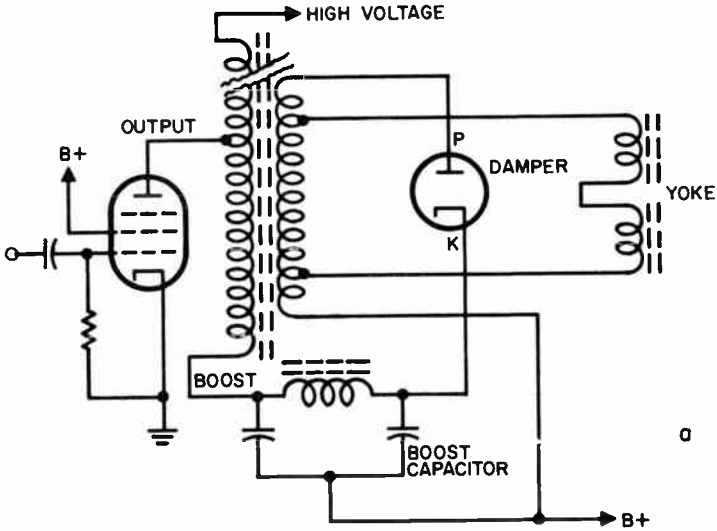
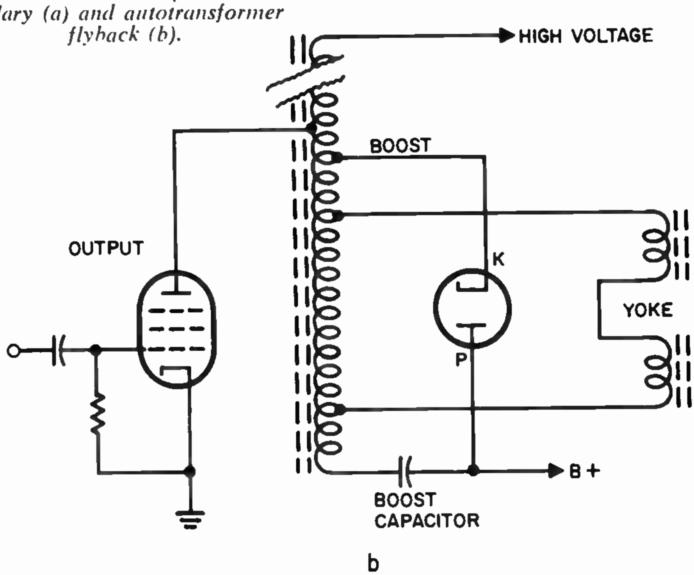


Fig. 607. *Transformer type flyback circuit with separate secondary (a) and autotransformer flyback (b).*



You'll notice several differences if you check this circuit carefully. For one thing, the damper tube is upside down. Why? Because we do not have the polarity reversal that we have in the separate secondary type. So the damper tube is reversed with the cathode connected where the plate was before. Actually, this only a *schematic difference*. As far as the yoke is concerned, the damper

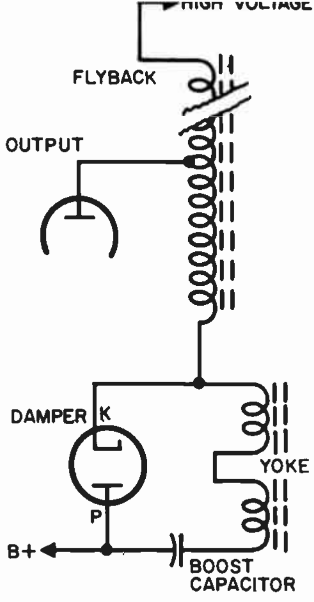


Fig. 607 [continued]. *Direct-drive circuit (c). The yoke is in series with the flyback.*

is *still* connected right where it was, with the plate on the same side. Circuit action of the damper tube is still exactly the same; so is everything else. However, you will note that schematics are often drawn so that the damper tube looks upside down.

A third circuit, an "oldtimer," isn't found too often any more, although it was very popular in some of the older sets. This is called *direct drive,* and is shown in Fig. 607-c. We will discuss some of the peculiarities of this circuit, in action, later on (and its got some, too, compared with the other circuits!). It works in the same way but the flyback transformer does *not* drive the yoke. The current which supplies the sweep comes from the output tube through the lower half of the winding, but it comes directly from the output tube itself; hence direct drive. Flyback and yoke are in series. The flyback transformer in this circuit can always be distinguished by the fact that it has only three connections (B-plus, output tube plate and high-voltage plate). It steps up the high-voltage pulse during flyback time. Aside from this, all circuit functions are exactly the same.

As you can see from the side-by-side comparison in Fig. 607, all of the same parts are used in the three schematics. Like girls, they're all the same, but arranged a little differently! For example, in some circuits the boost capacitor might be mistaken for a blocking capacitor to keep the B-plus from being shorted to the boost voltage. It does that, all right, but if you'll follow the circuit, you'll find that the capacitor has one plate connected to B-plus, and the other to the damper cathode, which makes it a boost capacitor.

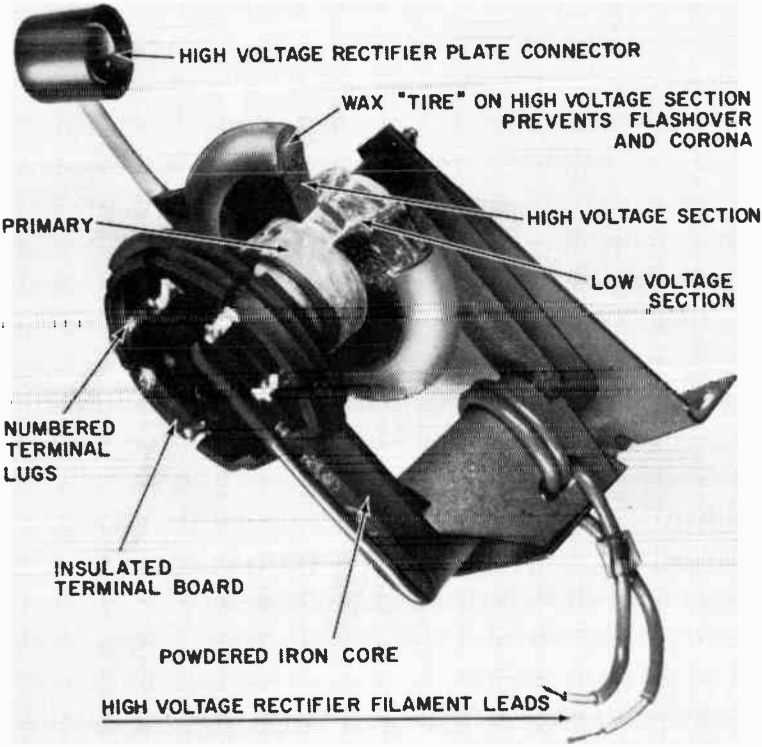


Fig. 608. *Construction of a typical flyback transformer showing essential parts.*

In some circuits the yoke has a blocking capacitor in series with it. Since the deflection signal through the yoke is ac, this makes no difference at all in the operation of the circuit. The added capacitor keeps dc out of the yoke windings, to prevent displacement of the raster. Sometimes, you'll get core saturation in the yoke if too much dc flows through it. In older sets, you may find controls which adjust the amount of dc flowing through the yoke; this dc is used for positioning of the raster. (Later a simple little permanent-magnet gadget replaced this complicated circuit.) In some circuits, the yoke is returned to B-plus through the capacitor;

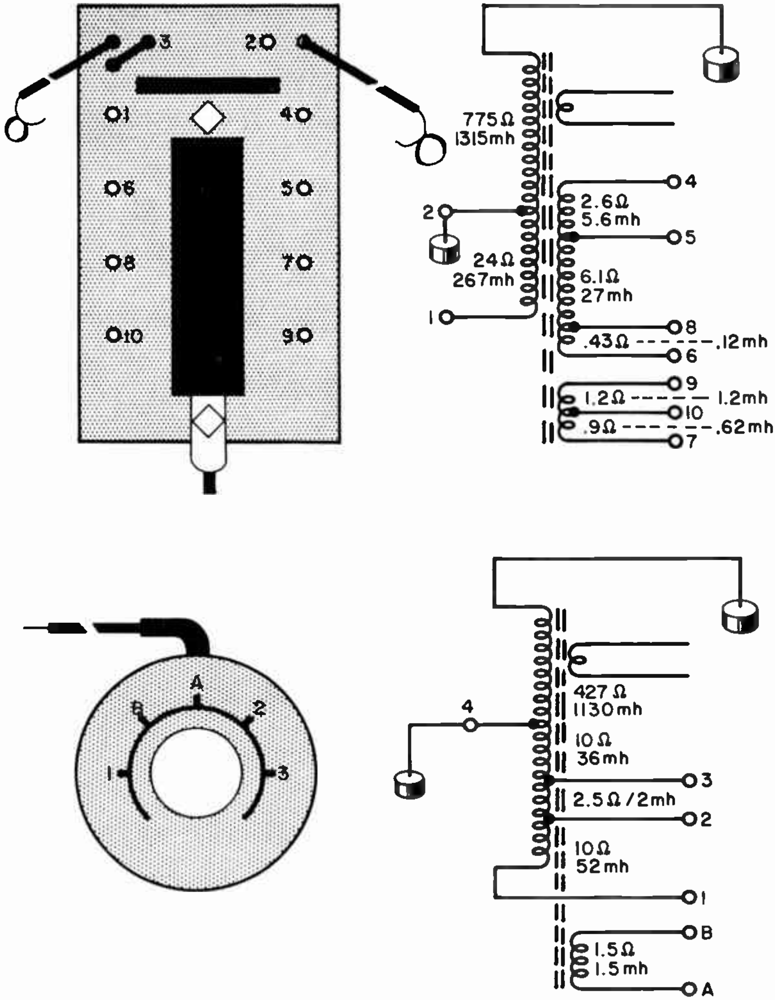


Fig. 609. *Representative flybacks with their terminal boards.*

in others, it may even return to ground through this capacitor. Since the B-plus should be at ac ground potential, this winds up as the same thing.

Physical construction of flyback transformers

All flybacks are made in about the same way. The core is made of powdered iron, in a box shape, except for the direct-drive fly-backs, which usually have a simple cylindrical core. This is done to increase efficiency, to give the transformer a higher Q. Fig. 608 is a cross-section view of a typical flyback transformer. The windings are the disc-shaped part in the center. The iron core passes through them, forming a closed magnetic loop with a small air gap at the bottom.

The high-voltage part of the winding is wound on the outside, in a thin wheel shape, for several reasons. One, to get the high-voltage parts of the windings as far from the core as possible to reduce the chance of a flashover. We've got peak voltages up to 30,000 floating around there, even in some black-and-white sets.

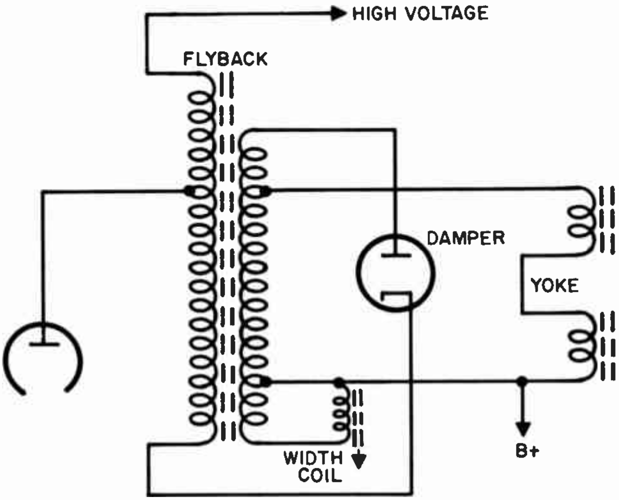


Fig. 610. *Width control. This is an adjustable loss across part of the secondary of the flyback.*

Some flybacks have a high-voltage winding wound separately from the rest; it can be replaced if it breaks down, without replacing the rest of the flyback.

The connections to the flyback windings are brought out to a high-voltage plastic or fiber terminal board, mounted on one end of the core. The taps are very fine wire, sometimes covered with spaghetti for protection. The solder lugs on the terminal board are always numbered for identification; you'll find these numbers on the schematic, for convenience in testing.

Fig. 609 shows two typical flybacks, with their schematic diagrams and the physical layout of the terminal boards. Note that on these, as on all flybacks, the lead to the high-voltage rectifier tube plate is brought out directly from the outside rim of the high-voltage winding, not fastened to the terminal board. In some units, you'll find the wire going through the terminal board, as in the one at the left, but not connected to it. This reduces the voltage stress on the insulating material. The other lead with a plate-cap connector is for the horizontal output tube plate. This usually comes from a lug on the terminal board.

Auxiliary windings: controls

You'll notice that in Fig. 609 there are several extra taps on the flyback windings that we didn't mention. Now let's see what these are for.

We need a way of controlling the width of the picture; that is, the length of the forward stroke of the sweep. By this we do *not* mean the timing or duration of this stroke: this is a fixed signal. What we must control is the *distance* the beam moves horizontally

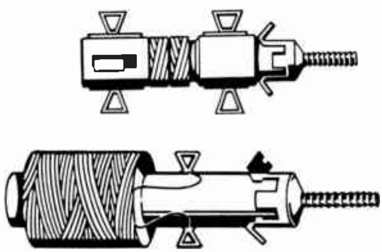


Fig. 611. *Typical width control coils. Width coils can have more than two terminals for a single winding. Additional windings or taps may be used to feed keyed agc circuits.*

during this time. If we can do this, we can make the picture fit the screen, whatever the size of tube we are using. Standard practice is to adjust raster width to give about a ½-inch overscan at each side. With this setting, we don't lose too much of the picture, and we make sure that the horizontal blanking bar will not show. Now let's see how we can do this.

There are several ways. The most common, in older sets, is with a width control connected to the flyback. Fig. 610 shows a typical circuit. This is an adjustable loss in the secondary circuit. We simply connect a small variable inductance in shunt with a section of the secondary; this reduces the efficiency of the whole secondary winding. So, we can control the sweep width.

Schematically, this looks very much like a horizontal linearity coil, doesn't it? It ought to; they're exactly alike. The only difference lies in their application. You can even interchange them, provided their values are alike. The inductance runs from .05 to about 30 mh, depending on the circuit design and the taps on the flyback where they are connected. Some need only .05- to 0.5-mh variation, while others may run as high as 4 to 28 mh. They're wound on a fiber form with a spring clip for mounting. A screw-adjustable powdered-iron core varies the inductance as needed. Fig. 611 shows a couple of typical width coils.

The major difference between width and linearity coils, as we said, is in the application. A linearity coil is always part of a

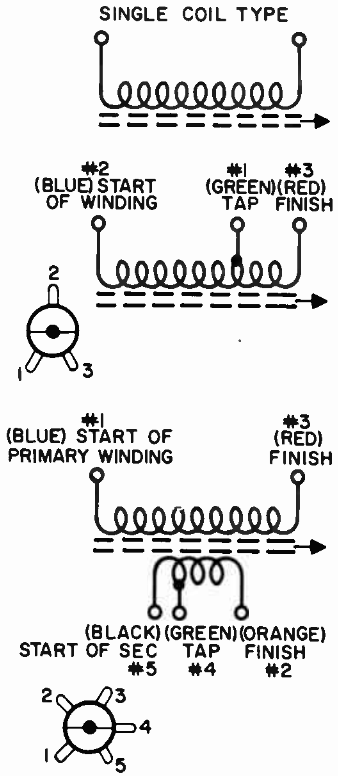


Fig. 612. *Width coil arrangements. Multiple windings have their terminals indicated by colored dots of paint.*

resonant circuit; a width coil, never. Width coils are used as adjustable losses in the secondary circuits. If we reduce the inductance of the width coil, we are putting a greater load across that part of the secondary, thus reducing the efficiency of the flyback by loading it down more heavily. If we do get resonance effects in a width coil, we've got trouble. They cause distortion of the sweep, parasitic oscillations, and usually overheating of the coil or flyback that will burn something up. In some circuits, you'll find a small capacitor connected across the width coil. One major purpose for it is to be sure that this part of the circuit will not be able to resonate at any of the various frequencies used in this circuit; that is, the sweep frequency and all possible harmonics.

Tapped width coils: dual-winding coils

In keeping with our avowed objective of using everything but the squeal in this circuit, we don't want to overlook the width coil! So, to get pulses for agc keying, etc., we sometimes wind a secondary winding on the width coil form. Now we can take horizontal frequency pulses off this for application to other circuits. This has two advantages: it saves winding a separate small secondary on the flyback, and it isolates the high boost voltage from our pulse circuits, where we would otherwise have to decouple it with a blocking capacitor or big resistor.

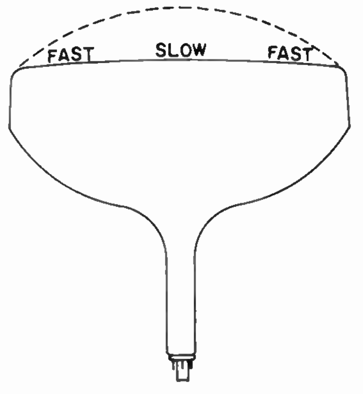


Fig. 613. *Flat screen produces symmetrical nonlinearity.* (Westinghouse)

We can get pulses of any desired amplitude by winding more or less wire on the secondary. You'll also find taps on the width coil, in some circuits, for the same purpose. Fig. 612 shows some typical width-coil symbols.

Combination width linearity control circuits

For a while, manufacturers left width controls out of circuits entirely. They depended upon the design of the circuit to hold the width. One major manufacturer even went so far as to design his set to have almost 3 inch overscan when new! As the horizontal output tube aged, the width gradually reduced, until it finally came within normal scanning limits! No width control of any kind was provided. Most manufacturers took up the practice of eliminating the linearity controls as well. By holding tolerances fairly close on the sweep circuit, they were able to build in fairly good horizontal linearity without adjustable controls. This worked out pretty well in most cases, *if* the circuits were carefully engineered and well constructed.

However, when the very wide sweep-angle tubes came along, with horizontal sweep of 110° to 115°, troubles popped up again. Sweeping over such a wide angle strained the horizontal deflection system, and the shape of the tube faceplates was no help, either! The newer tubes have an almost flat faceplate, in contrast to the semi-cylinder shapes of older tubes. As the beam swept across the faceplate, the beam seemed to be moving slower at the center and faster at the outsides (Fig. 613). To get rid of this effect, engineers developed a very ingenious combination width–linearity control.

If we use the perfectly linear sweep waveform we have been talking about, as in Fig 614-a, we'd have this apparent trouble of

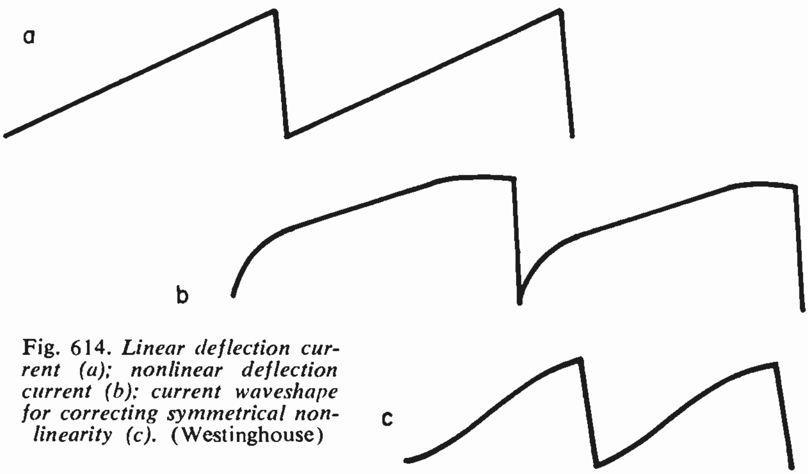


Fig. 614. *Linear deflection current (a); nonlinear deflection current (b); current waveshape for correcting symmetrical nonlinearity (c).* (Westinghouse)

two beam speeds. If we *alter* the shape of this waveform, we can control this effect. Nonsymmetrical nonlinearity (that is nonlinearity which gives us an unbalanced waveform, like that of Fig. 614-b), will mean distortion in any case. However, if we deliberately introduce a symmetrical nonlinearity, we can control this apparent raster distortion on the flat-faced tubes! So, we make the sweep waveform look like that in Fig. 614-c. We have slowed the beam down at the outside edges of the screen, and brought it back to normal speed in the center. This solves the problem. But, how is this done? A combination of width control and horizontal linearity control actions does this automatically in a special single winding that has dual cores. One is a powdered-iron core, used in the regular way as an inductive width control (Fig. 615). The core, mounted in the opposite end of the winding, is a permanent magnet.

The presence of the magnetic field alters the characteristics of the coil. It is now biased by the permanent magnet's field, and it will change impedance quite abruptly with changes in current. So, while a normal coil, by inductive effect, will oppose changes in current directly proportional to the rate of change, this will not. It has now become a saturable reactor, because of the presence of the fixed magnetic field and it will introduce a certain amount of nonlinearity into the sweep current. Fig. 616 shows the schematic of the deflection system with this type of coil.

By adjusting the two cores in this coil, we can add any correction necessary to the sweep waveform. What we are doing here is

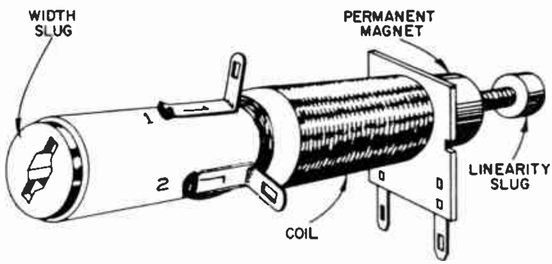


Fig. 615. *Special dual-core, width-linearity coil.* (Westinghouse)

introducing distortion into the sweep waveform deliberately, to make it have the desired shape. Then, on the "distorted" screen of a flat-faced tube, the sweep is actually perfectly linear! That's what we have to go by—the end results. No matter what the shape of the sweep current waveform if we wind up with a linear scan on the picture tube, we're fine! You'll find this same principle used later on, especially in color convergence procedures. We'll deliberately add some distortion or curvature of different kinds to waveforms, to get a certain result—which is what we want, results!

Older width-control circuits

You'll find several types of width controls used in older sets. A circuit very popular for a while used a potentiometer in the screen-grid circuit of the output tube. This controlled width by varying the screen voltage; hence the efficiency of the tube. Some few sets even varied the B-plus voltage applied to the output tube for the same purpose. One even used a variable resistor in series with the yoke! Needless to say, most of these were complicated and prone to trouble, so they have been gradually abandoned. Controls got noisy and burned out, and other troubles showed up. In fact, in some sets, you can even eliminate this type of control by substituting a fixed resistor for the variable and using a width-control circuit.

Other sets used a selector switch connected across taps on the secondary of the flyback. This worked like the variable width control, introducing variable load on the flyback.

Width sleeve

There is a very simple and practical width control. It showed up in TV sets around 1958. This, too, is a form of "losser" control, but its sheer simplicity appeals to everyone. It's just a thin brass sleeve slipped between the yoke and the neck of the picture tube! There, it forms a one-turn loop or a movable short. This reduces the efficiency of the sweep magnetic fields, hence the width.

This can be adjusted by sliding the sleeve in and out of the yoke. The father the sleeve is inside the yoke, the less sweep we get. In general, manufacturers using this method design for an overscan of about 1.5 to 2 inches when everything is new and all voltages are up to normal. The overscan is reduced by sliding the sleeve inside the yoke until the picture has the correct width. As tubes age, the sleeve is pulled out to restore width. When the sleeve gets all the way out, replace the horizontal output tube and start all over again!

This method can be used on almost any TV set, and is very popular among technicians because it's so simple. As we said just now, if you find an old set with the width control burned up, a screen pot or something like that, which would cost several dollars to replace, just replace the control with a fixed resistor of the right resistance and wattage to give best operation of the output tube. Then, if you have too much width, make a sleeve out of brass shim stock, and slide it into the yoke. Sheet shim stock can be bought at many auto supply stores for literally a few pennies.

Make the sleeve to go about 1¼ turns around the neck of the tube. Round the corners so that they won't cut through the insulation of the yoke wires. It's a good idea to attach a ground to the sleeve, and wrap insulating tape around it. This prevents arcing from the yoke windings to the sleeve. There is quite a bit of high voltage floating around in a yoke.

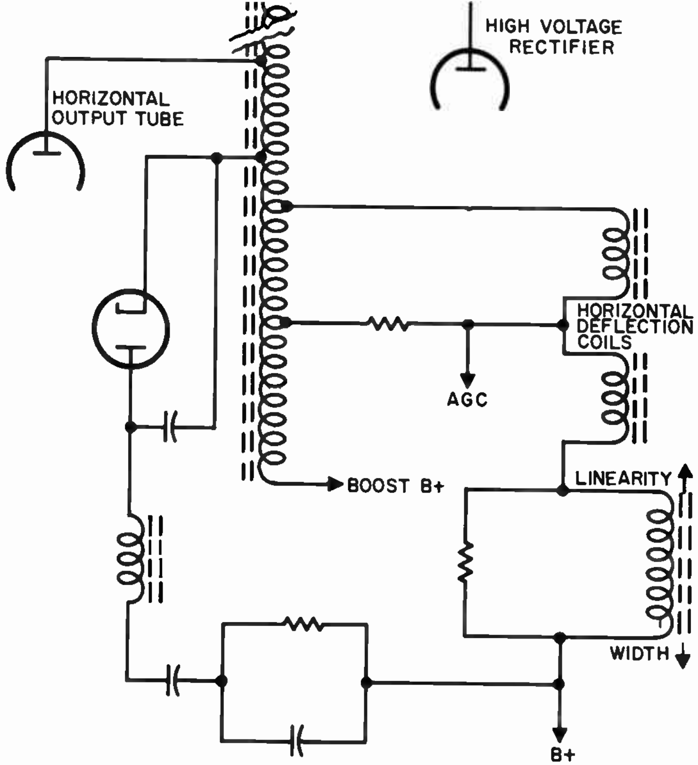


Fig. 616. *Horizontal sweep circuit using special dual width-linearity coil.*

In some sets, you'll find a slot cut in this sleeve. If you do, be sure to replace the sleeve with the slot in the same position. The position affects horizontal linearity. You'll usually find the slot pointing toward the horizontal output tube or the high-voltage connector button on the picture tube. The right position will be given in the service data.

High-voltage circuit

We said a while back that there was nothing to the high-voltage circuit, or words to that effect. This is still true. Only four parts are used in this circuit: the high-voltage winding on the flyback, the rectifier tube, its filament winding and the high-voltage filter capacitor. Fig. 617 shows the whole circuit. Of course, since all these parts must handle very high voltage, they're all special types. However, the circuit is so simple, electrically, that this isn't too much of a problem. It is completely tied in with the flyback circuit; that is, the horizontal output tube and its circuitry. If this part of the circuit is working as it should, then we'll have high voltage—barring two troubles: an open high-voltage winding or one with shorted turns.

An open winding can be spotted pretty rapidly. There will be no high voltage at all, and an ohmmeter will find the high-voltage

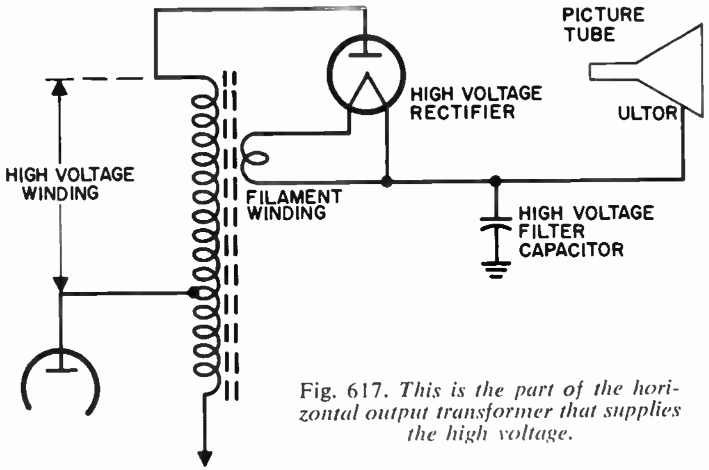


Fig. 617. *This is the part of the horizontal output transformer that supplies the high voltage.*

winding completely open. So, we'll say no more about that. Shorted turns in the high-voltage winding can be a bit more difficult, so let's see what we need to find them.

A badly shorted high-voltage winding will be easy to find: just look for the place where the thickest smoke is rising. If only a few turns short, it's harder, but still easily identifiable if you use the right methods. Shorted turns in a flyback or anywhere create a closed-loop condition. The current in such a closed loop rises to great heights, because it has nowhere else to go. This generally causes severe overheating of the flyback. In any case, it will cause the plate current of the output tube to rise far above normal. At the same time, the high voltage will be very low, because the short has reduced the Q and the efficiency of the flyback. There will be a very dim raster (if any) and reduced sweep width, together with the overload in the output tube.

In some cases, you can tell by measuring the dc resistance of the high-voltage winding with an accurate ohmmeter, comparing your results to the resistance value given on the schematic. This is far from infallible, though, because the flyback may have been replaced by one of a different make or been changed during production so that the high-voltage winding has the same inductance value but a different dc resistance. Never accept this as a final test, and never replace the flyback because of this test alone. Make several other tests to be sure.

The most reliable instrument is a flyback checker, a special tester used to indicate shorted turns in inductances. Other special sweep circuit testers have facilities for checking and measuring inductances and for measuring the rest of the circuit. Whenever possible, make several tests: for instance, dc resistance, high-voltage output, shorted turns, etc. If they all agree unanimously that the flyback is bad, then you can confidently replace it.

Corona discharge and arc-overs

Corona discharge is found in all electrical circuits carrying very high voltages. It takes a form similar to an electrical spray into the surrounding air, from connections exposed to the air.

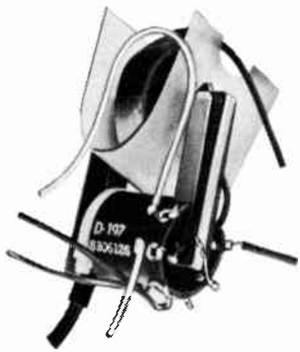


Fig. 618. *A thin layer of plastic, such as polyethylene, has very high insulating qualities. Here it is used to insulate the high-voltage winding.*

It is more apt to show up at a sharply pointed terminal. For this reason, all solder joints and other connections in the high-voltage circuit are carefully rounded off to reduce the chance of corona. When you have corona discharge in a TV set, you can often hear a very faint rushing or whispering sound from the HV cage. If you darken the room completely, you can see a very faint blue glow around points in the circuit. This usually looks like a blue fan in the air.

The corona discharge itself isn't harmful. Under some circumstances, it will sneak into the video or rf stages, and cause streaking in the picture. The most danger lies in the fact that a corona discharge may take place in the direction of some grounded part of the high-voltage circuit in the core of the flyback, the shielding cage, etc. This ionizes the air between the two points, making it conductive, and making it easy for an arc to form between the two points. A very large current flows through an arc. This can damage the flyback transformer or the wiring, and sometimes requires a hurry call to the fire department!

The remedy for this is insulation and the cheapest is air. Keep all parts of the high-voltage circuit as far from any grounded object as possible. If it must run near ground, use very heavily insulated wire. This has a very thick plastic insulation, and is usually rated around 30-40,000 volts breakdown. When working around this circuit, be very careful not to touch any of this wire with the tip of a hot soldering iron. The plastic is quite soft, and melting places on it like this will cause it to break down at that point later on.

Solid insulation also helps. Late-model flyback transformers often use separate high-voltage windings, with polyethylene between them and the rest of the windings, as in Fig. 618.

Arcing or flashover can sometimes be cured, if it hasn't been allowed to go on long enough to damage the winding or flyback. Burned wiring can be replaced, using high-voltage wire. A special compound can be used to patch damaged insulation. You'll note that there is a thick ring of wax around the outer edge of the high-voltage winding. Called a tire, it is made of very high insulating value wax. It insulates the high-tension parts of this winding and prevents corona discharges. If it has softened and melted from the winding, replace it with high-voltage putty or tape it back in place with plastic tape.

High-voltage rectifier tube and capacitor

Fig. 619 shows a typical high-voltage rectifier tube and socket assembly. This is sometimes made as a part of the flyback transformer, sometimes mounted on the chassis nearby. Notice the cylindrical object under the socket. This is the high-voltage filter capacitor, a 50-pf unit rated at 30,000 volts in most cases. Universal replacement types have threaded holes in each end. These make connections to the capacitor, and are also used as mountings for the capacitor and high-voltage rectifier socket. One is bolted through the chassis to ground the capacitor.

Below the socket is a ring of heavy solid wire. This may be soldered to some or all of the filament (cathode) connections of the tube. It is called a corona ring, and helps reduce the possibility

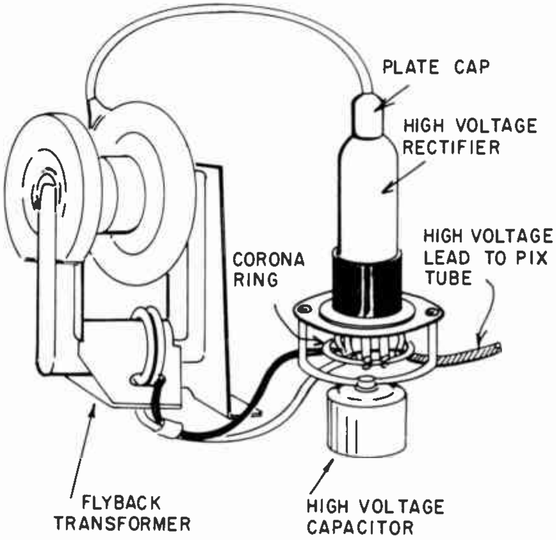


Fig. 619. *High-voltage rectifier tube and socket assembly.*

of corona discharge from the sharp points or edges on the socket terminals. Below this is another heavy U-shaped wire, which is used to hold the socket; it is electrically connected to the corona ring.

Since it would be pretty rough to insulate a filament winding on a power transformer for 40,000 or 50,000 volts, we need another source for the filament of this tube. Since it serves as the cathode, the high-voltage dc appears on it. So, we use special rectifier tubes. These have filament voltages of 1.25 or 3 volts, and draw only 200 ma of current. We can get this with only two turns of wire around the core of the flyback. Since this carries the high-voltage, it must be made of very highly insulated wire.

We must use special test equipment to measure this filament voltage. However, it is possible to use the glow of the tube filament as a guide. The filament should show only a faint reddish glow. After a little practice, you'll find that you're able to judge very closely the amount of voltage on the filament.

Many tubes are used for this kind of service. However, they're all basically identical—widely spaced diode rectifiers with very low filament current and voltage. A great many of them are interchangeable.

Last but not least: the yoke

Now, we have only one major component left—the yoke. There aren't too many troubles with yokes, and those we do have are simple. For one thing, they usually have nice definite symptoms; something we can't say about other parts! After all, a yoke is just two sets of coils, the horizontal and vertical—made in two separate windings, the horizontal coils above and below the tube neck and the vertical ones on each side. Usually they are electrically separated. In one circuit the vertical coils' centertap is connected to the horizontal yoke (in the yoke itself) to feed boost voltage to the vertical output stage. This isn't too common.

Schematically, a yoke is drawn like Fig. 620. In real life, a yoke assembly looks more like Fig. 621. It has the two sets of coils, with a powdered-iron core to increase the Q. At the back (toward the

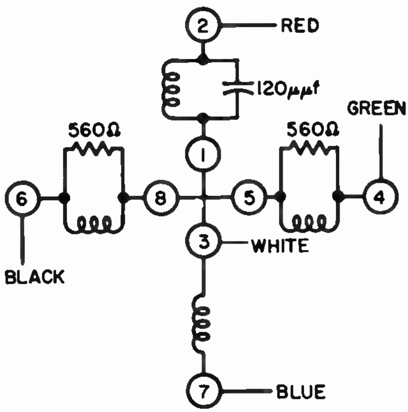


Fig. 620. *Schematic of a typical yoke. Vertical deflection windings can be identified by the resistors shunted across them. One horizontal winding will usually have a capacitor across it. Numbers indicate terminals. Colors are those of connecting leads.*

tube socket), a round insulating housing covers the terminals and protects the yoke and you. There's always hot stuff floating around a yoke, in operation.

Yokes were first mounted in heavy metal brackets on the chassis which actually held the neck of the picture tube up. Later when tubes were entirely supported at the front (by clamps around the faceplate), the yoke was slipped over the neck and held in place by a simple ring clamp. This can be seen at the left in Fig. 621. Also, you can see the tabs of the permanent-magnet picture-centering device.

Deflection angle of a yoke

The yoke is notably the only component (except for the CRT itself) which has a definite deflection angle. You must use a yoke

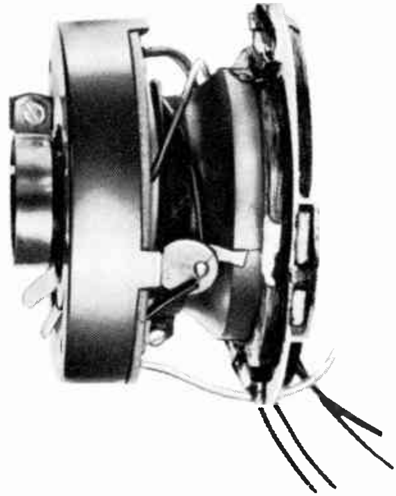


Fig. 621. *Yoke assembly for a self-focus crt. Clamp at left holds yoke in position.*

which is designed for the deflection angle of the picture tube. The windings are physically shaped for best results. Fig. 622 shows the evolution of the wide-angle yoke. In the original 50°–70° yoke (Fig. 622-a) the windings were quite compact, because we didn't have to sweep the beam so far. The deflection center of the yoke was pretty close to its actual center. This is the "pivot point" from which the electron beam swings in the tube.

The 90° yoke (Fig. 622-b) shows a change. The front edge of the windings is brought forward, and flared out. This gives the

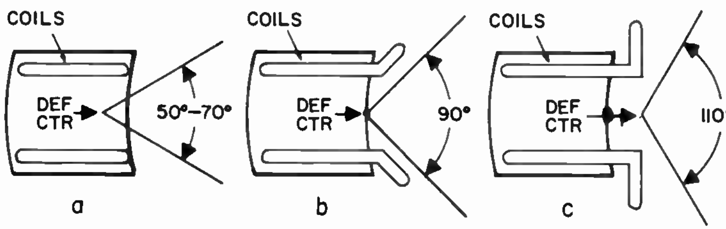


Fig. 622. *Flare of the coils in the yoke give some indication of the deflection angle.*

magnetic field a different shape. The deflection center has now moved forward. In the 110°–115° yoke (Fig. 622-c) the windings have a very decided flare, almost at right angles to the neck of the tube. and the deflection center is still farther forward. You can almost identify the yoke deflection angle by the appearance of the flare of its windings.

Yoke testing: characteristic picture-tube patterns

Yokes are easy to test because yoke troubles show very definite symptoms in most cases. For example, one easy one is the trapezoidal raster seen in Fig. 623. We've got two coils, one on each side of the neck, in both vertical and horizontal sweeps. If we lose one coil, either from a short in it or from incorrect connections, our raster deflection is going to be small on that side! Fig. 623 shows the trapezoid lying down. This means vertical yoke troubles, and always due to one coil or its damping resistor being bad while the other is OK. The small end of the raster always points to the defective section of the yoke circuit.

Like the high-voltage on the flyback, there can be only two troubles in a yoke—open or shorted windings. Anyone with a flashlight battery and a pair of earphones can find an open circuit, and a good ohmmeter or inductance bridge will show up a short. There are specialized yoke testers, but you can do about as well

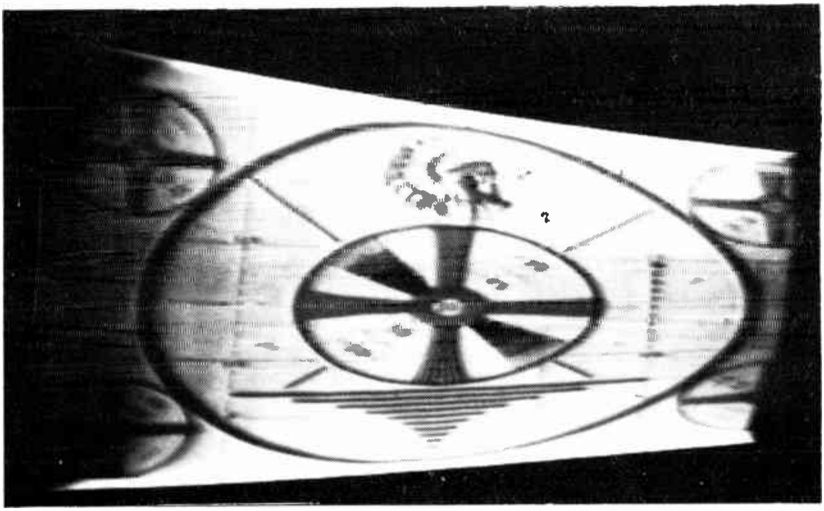


Fig. 623. *Trapezoidal raster, also known as keystoning, caused by short in one half of yoke winding. The small end always points to the shorted yoke winding. This is the vertical winding on the right side of the tube. Picture is often partially or completely out of focus.*

with a good ohmmeter. Yokes are always made with identical pairs of windings. Connect the common lead of the ohmmeter to the center tap, and measure the resistance of each half. If they don't balance, you probably have a defect. Use other symptoms to verify this opinion, of course. For instance, if you have a trapezoidal raster and the yoke winding on the small side shows about half the resistance of the other side, that's two tests pointing to the same conclusion. Replace the yoke!

There are several other tests which will help pin down yoke troubles. One of the best is boost voltage. If your damper tube shows nothing but B-plus voltage on both plate and cathode, check the yoke. Why? The yoke is the source of the boost voltage! A typical symptom here would be complete loss of raster and high

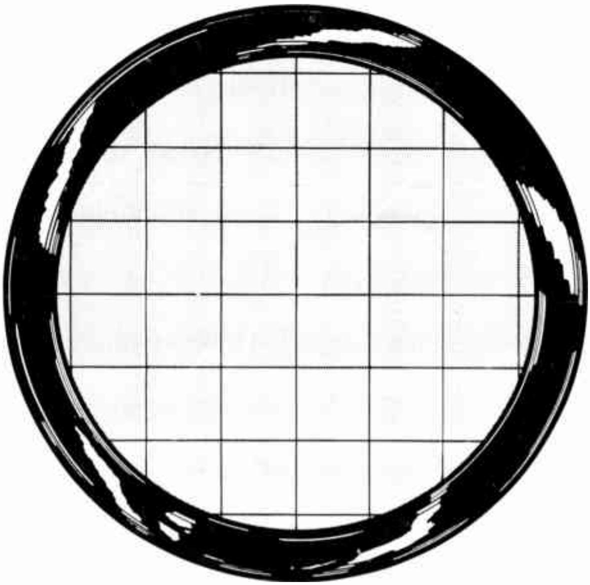


Fig. 624. *Ringing in the waveform is the result of a high-frequency oscillation, shock excited by the flyback pulse.*

voltage. A defect in the yoke bad enough to kill the boost voltage will also kill the sweep and, without that and the flyback pulse, you're surely not going to get any high voltage. Very low high voltage, say from 3,000 to 5,000 volts, is a good clue to a possible small short, one or two turns, in the yoke.

There's a really simple check for this one. Disconnect the horizontal yoke only from the flyback. Usually disconnecting the hot lead is enough, unless there are internal connections in the yoke. Pick up a yoke which has a horizontal winding with almost the same value, say within 20% of the inductance of the original, and connect it in place of the suspected one. You don't even have to take it out of the box; just run a couple of wires to the set. Turn it on and measure the boost voltage. If it comes up to normal, or

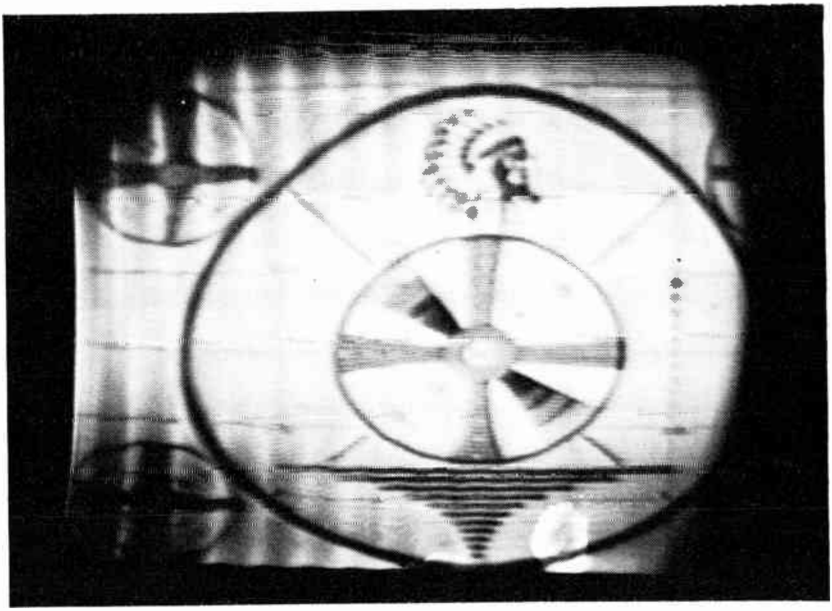


Fig. 625. *Ringing in the raster caused by incorrect yoke-balancing capacitor. This is an exaggerated case. Usually you will see only 3 or 4 lines at the left side of the screen.*

even half-normal, then the old yoke is defective. Get an exact duplicate and replace it.

Yoke ringing

There is one trouble, with a nice visible symptom, which is almost always within the yoke itself. This is *ringing*. We spoke about it a while back, in the section on damper tubes and their action. If we have ringing, it makes the sweep waveform look like Fig. 624 instead of a nice smooth sawtooth.

To get rid of this, we must balance the two halves of the yoke winding. Although they're theoretically equal, we will have a small unbalance between the two halves in actual operation. We are feeding some pretty hot stuff into the top half. (This is called rf although it's actually audio, of course. It does act like rf, and it'll burn you like rf, as an unwary finger poked at the high-voltage rectifier plate cap will verify!) A small capacitor is put across the top half of the yoke; sometimes you'll find a resistor in series with it. This balances the two halves, by bypassing some of the "rf" around the top coil.

These capacitors will be different values in each yoke. When a yoke is replaced, always use the capacitor recommended for that yoke, which may not be the same originally used. They must be rated at least 3,000–4,000 volts, for there are some terrific peak voltages floating around in here. If you still have ringing, try different sizes of capacitors; you'll find one that will eliminate the ringing. You can see this capacitor in the drawing of Fig. 620, and in all of them from this point on. We had been leaving it out to keep from confusing you!

Yoke ringing shows at least two unmistakable symptoms in the raster. You'll see several vertical white lines in the *left* side of the raster, as in Fig. 625. Note the bending of the horizontal lines in the test pattern, on the left. Fig. 626 shows a closeup view of a part of this test pattern. With true yoke ringing, you'll always have the bends in the raster scanning lines at the left side of the screen, growing fainter as they go to the right.

False yoke ringing

There's a similar symptom which can fool you unless you're alert. This is false yoke ringing. It's caused by pulse energy from

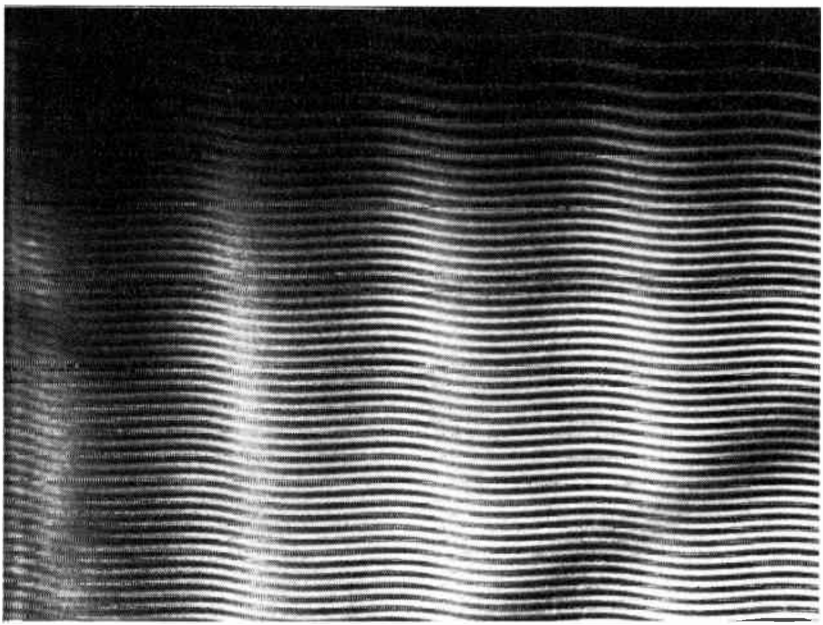


Fig. 626. *Ah, ha! There's the 'key clue'; scanning lines are* always *bent when the cause is yoke ringing.*

the horizontal sweep stages leaking into the tuner of the TV set. From a distance, the pattern looks exactly the same, but there's one key clue: raster lines will be absolutely straight; never bent! The pulses cause partial blanking of the picture tube, so the scanning lines get thinner and thicker, making vertical white lines show up.

The cure for this is shielding. Most of the time, it's due to leaving the shielding cage off the flyback. In some older sets, radiation from the yoke leads is responsible. Wrap aluminum foil or something like that around the yoke leads, loosely. Now, wind a long piece of bare wire around the whole thing in a spiral. Ground each end of the wire under a screw, or tack it with solder. In severe cases, you may have to replace the lead between the antenna terminal board and the tuner with shielded Twin-Lead; 300 ohms, of course.

Ringing after yoke replacement

If you replace a yoke and get very bad ringing where there wasn't any before, check the yoke balancing capacitor. The chances are you'll find it connected across the wrong half of the yoke winding.

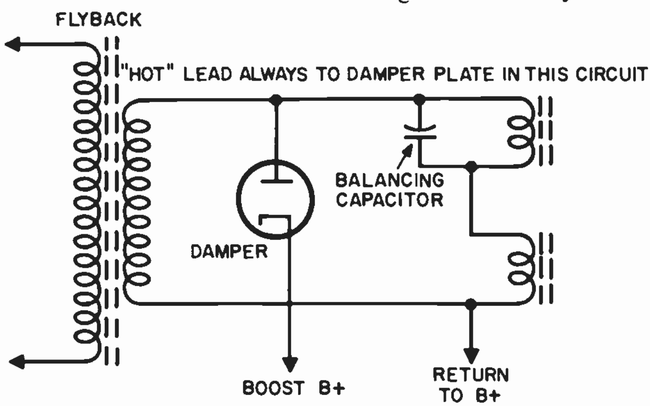


Fig. 627. *Transformer-type flyback with yoke, showing connection of yoke balancing capacitor.*

This capacitor should always be tied across the hot winding. From now on, we'll call the two connections to the complete horizontal yoke the hot and return leads. This is also called the high rf side in some cases. At any rate, our yoke is always connected between a source of current (the flyback) and ground. We mean ac ground, of course, since this is strictly an ac circuit. So, we can return our yoke to B-plus, which should always be at ac ground potential.

Fig. 627 shows the circuit of a transformer type flyback-yoke, with the balancing capacitor.

When we use an autotransformer type flyback, if you remember, the yoke connections and damper tube must be reversed, so that our yoke windings will have the proper sense or polarity. However, look at the connections of the balancing capacitor in Fig. 628.

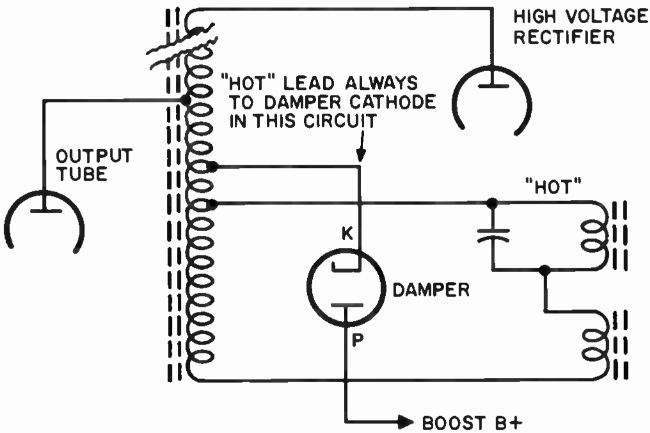


Fig. 628. *Autotransformer flyback and yoke with balancing capacitor. In this circuit, and also in direct drive circuits, the "hot" lead is always connected to the damper cathode.*

Note that it is still across the hot side of the yoke, at the opposite end from the B-plus return. So, this isn't really a variation at all. Damper connections have been changed, but our capacitor is still across the same end of the winding.

If the yoke is hooked up with the capacitor across the wrong half, you'll have ringing, and possibly a trapezoidal raster in some *but not all cases*. Sometimes, you may not get a raster at all.

Other circuits

Two other methods are also used to keep the yoke from ringing. One way is to connect the two halves of the horizontal yokes in parallel, as in Fig. 629. No balancing capacitor is needed. You may find small capacitors across the whole yoke, for phasing (timing) or width-control purposes. These will usually be found on the flyback rather than inside the yoke housing.

Another method of yoke-balancing is the yoke center-tap, as in Fig. 630. No balancing capacitors here, either. If the flyback is replaced, the replacement may have a center-tap connection for use in this circuit, and the original yoke can be converted by simply adding the center-tap connection. Be sure to remove the balancing capacitor used in the original yoke, though, or you'll add unbalance instead of taking it away.

Some replacement yokes will come with five wires. The fifth wire is almost always a yoke center tap, although you'd better check to be sure! If it isn't used, clip it off inside of the yoke housing.

Raster symptoms

A word of warning: these two circuits ordinarily will not make a "trapezoidal raster" when a part shorts or opens. They will be more apt to make a narrow raster, quite dim, or lose HV and

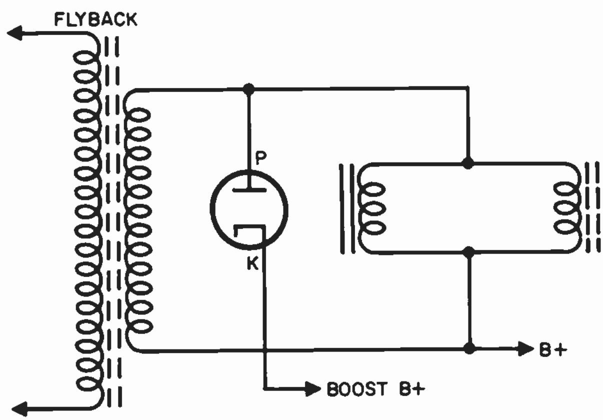


Fig. 629. *Horizontal yoke coils connected in parallel.*

boost entirely. There is always a chance that some peculiarity may cause them to keystone (trapezoidal raster, in slang) but not in most cases. So, check yoke connections to be sure.

Yoke replacements

This is the easiest of all—just get an exact duplicate of the original! (Not as hard as it sounds: many manufacturers specialize in making exact-duplicate parts for popular TV sets. They furnish highly detailed catalog listings of all makes.)

Yokes are always rated in inductance and deflection angle. A typical yoke might be "90°: 8.3 mh horizontal, 50 mh vertical." This is a complete picture of the yoke. You'll find inductance values listed in all service data, except for the very old TV sets. The manufacturers list inductance of each winding plus the deflection angle in their catalogs. So, finding a replacement should be simple.

We do *not* have to match inductance exactly, although we ought to get as close as possible. If we get within 20% of the original inductance, the yoke will generally work quite well. According to that our 8.3-mh horizontal yoke could be replaced by yokes with a value anywhere between 6.6 and 9.9 mh; the vertical, at 50 mh. anywhere from 40 to 60 mh. However, manufacturers

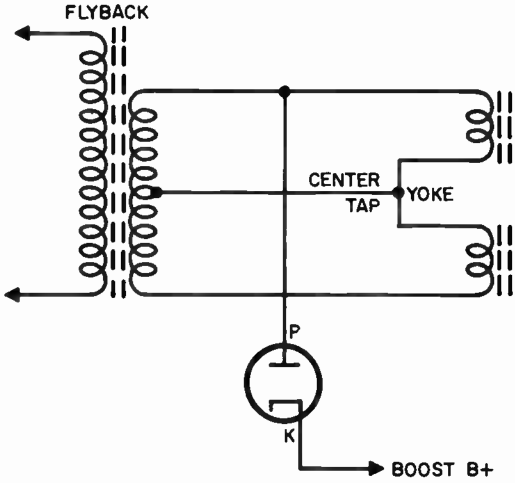


Fig. 630. *Center-tapped yoke circuit for balancing. Also refer to Fig. 808 on page 204 and associated text.*

now make such a wide range of yokes that you will probably be able to find a replacement with an inductance value within about 5% of the original. This simplifies things quite a bit!

Finding the inductance of an unknown yoke

You've got a bad yoke; open or shorted. No name, no number. This happens often enough to be annoying too. Now we must find out what its original inductance was. If we have the make and model number of the set, look it up in one of the transformer maker's detailed set listings. They should give the original part number, plus the number of a yoke recommended as a replacement for this set. Look this yoke up in the yoke listings, and you have the original inductance, or one that will work. This is the easy way.

Only slightly harder is finding the inductance by resistance measurement. Fortunately for us, there's a usable resemblance between the resistance of a winding and its inductance. This is accurate enough to be within the required percentage of tolerance. Table 6–2 shows the average resistance values of typical yokes; almost all yokes will have one of these values. You'll need a pretty accurate ohmmeter, of course, since the actual resistance is going to be pretty small, especially in the low-impedance yokes, down around 5 or 6 mh.

If one half of a yoke winding is completely open, simply measure the remaining half and double the reading. Remember to disconnect the shunting resistors used across the vertical windings, since they upset the reading.

Table 6—2. Resistance readings vs inductance values of yoke windings.

Horizontal resistance (ohms)	Horizontal inductance (mh)	Vertical resistance (ohms)	Vertical inductance (mh)
	70° yoke		
12.5	8.3	60	50
14	10.3	48	41.5
19.5	13.5	52	41.5
30	18.5	52	41.5
35	22	3.5	3.3
40	23	52	41.5
52	30	52	41.5
52	30	3.4	3.3
	90° yoke		
15	12	39	43
24	20	39	43
34	22	11	11
43	25	41	41
48	30	41	41
	110° yoke		
35	17.6	14	12.5

Connecting replacement yokes

When you replace a yoke, be sure to connect the new one *by functions* (horizontal, vertical) and never by numbers on the terminal board or wire colors! Even factory-duplicate yokes have been known to have different internal connections or wire color coding!

Since it's so easy to find out which winding is which, always connect by function. Here are a few general hints:

The horizontal winding will always be the one on the inside. It will be next to the tube neck, and should be on the top and bottom of it.

If a balancing capacitor is installed, it should always be connected on the hot side of the yoke and to the center tap. There may be a little resistor in series with it, but it will always be across these two points. The center-tap terminal of the horizontal coil windings will have two coil wires connected to it, from inside the yoke. The ends will have only one coil wire each, plus a lead going to the outside.

Replacement yokes from the good manufacturers will always have a connection diagram packed in the box, showing exactly which winding is connected to each terminal. Note that the inductance of each winding is also given, plus the rated deflection angle. With this vital information and the TV schematic, you can figure out where each connection goes.

If you reverse the leads to the vertical yoke, the picture will be upside down. Reversing the leads of the horizontal yoke, makes the picture backwards or inside-out, and you'll probably get ringing in the raster. This is because the balancing capacitor is on the wrong winding of the yoke now. If you use a test pattern for checking, be sure that the Indian's looking the right way! Best check: a commercial. If the printing reads right, fine. (Don't make the mistake one harried and hurried technician did! He was looking at the picture in a mirror, and hastily decided that things were fine, because he could read the printing! However, the customer objected to watching TV in a mirror!)

Check the original yoke leads. If they were tightly cabled, it may have been deliberate. A designer can pick up about 100 pf of balancing capacitance this way cheaply. If they were very obviously separated into vertical and horizontal pairs, replace them that way.

While this is not true in all cases, you'll find this color-coding used on many yoke leads: Heavy plastic, usually red, horizontal, hot lead. Thinner plastic, red or red/black, horizontal yoke return. Solid green, fairly heavy, vertical hot wire. Green/black or green/white, vertical yoke return.

Many yokes in the older sets used plug-in connections. An octal plug is the most common, although quite a few specials are found. Watch out for jumpers on the plugs. In a great many sets, the

B-plus is brought to two adjacent terminals on the yoke socket. These two connections are tied together on the plug. If the yoke plug is removed, the B-plus circuit to the output tube, etc. is opened. To service sets in this condition, you'll have to tack a short piece of wire (a jumper is easy) across the socket to complete the B-plus circuit.

All in all, a yoke is a fairly simple thing to service. We'll show you tests later on which will make it still easier. If you'll remember the characteristic symptoms of yoke trouble, you won't have any trouble finding out if a given yoke is really bad.

We've been hammering away fairly constantly on what sort of troubles you can expect to find in horizontal-sweep circuits and how to recognize the symptoms. In our next chapter you will find out how to become an expert in making tests in this section of the TV receiver.

Chapter 7

Testing Techniques

WE CAN USE TWO MAJOR METHODS OF TESTING. *Measurement* which includes voltages, currents and so on, and *substitution*. In measurement, we compare the results against standards, meaning the correct voltages listed in the service data. If we find significant variations which could be causing the symptoms we see, we follow them up to find out why. One of the important things about experience is learning the amount of variation we can expect; in other words, the tolerance. Don't waste time trying to find out why a screen grid voltage, for example, measures 140 instead of 145. This is only 5 volts difference, or 3⅓%. Since we have a standard tolerance of 10% on most resistors used in such circuits, 3% on vtvm's and 2% on vom's, this is well within the limits. If the voltage is more than 25% to 30% off, either high or low, then find out why. This is out of tolerance.

Using the second method, substitution, we can take a lot of shortcuts. We can substitute tubes, parts, drive signals and even whole stages in a chassis to find out if a circuit is supplying the proper output. By doing this, we can actually test a whole stage at once, with all of the parts in operation. If it checks out, then we can skip that part and go on to the next.

Static and dynamic testing

We have two options in testing. We can test the stage in full operation, to see if each part is putting out the type of signal it should, or we can shut it down and test individual parts. Needless to say, the first–operating or dynamic testing–will give a lot more useful information than static testing. We want to find out one thing: will a given part work in this circuit? What better way to find out than actually making it work in the circuit and measuring the output? So, we use dynamic methods whenever possible.

This is where our substitution method comes in. Each stage has a certain normal output. In the oscillator stage, normal output is a drive signal of a certain shape (waveform) with a certain frequency and a certain amplitude. In the flyback stage, output is a specified amount of high voltage, a certain amount of sweep current, plus a certain amount of boost voltage, etc. By feeding the correct input into a stage, and measuring its output, we can tell pretty rapidly whether it's working or not.

Example: we suspect the flyback transformer. So we substitute the correct amount of drive from an outside source, one we know is good. We could even substitute the B-plus voltage from a known-good source. Now we measure the output of the flyback, in high voltage, sweep, boost, etc. If they now are what they ought to be, we know that the flyback is good, and that the trouble is due to a lack of external supply from some reason–grid drive, B-plus, etc. We put the original sources back, one at a time, until the trouble shows up again. Now when the symptom reappears, the *last one* we connected is the cause of the trouble!

This circuit is interlocked with others, as we have said several times before. Trouble in one place can show up as any one of a number of different things. Example: yoke trouble affects not only the sweep, but the boost voltage and the high voltage. If we see all three of these symptoms, we should think of the yoke as the most likely cause. On the other hand, if we find sweep low, high voltage low but boost *almost* normal but low, then we should suspect a lack of drive either from low B-plus voltage, lack of drive from the oscillator, or some trouble in the horizontal output tube circuit–weak tube, low screen voltage, etc. We must base our diagnosis on the most likely cause for the *combination* of symptoms that we have in a particular case.

Tube replacement

Tubes are easy to replace. Tubes cause most of the trouble in horizontal sweep circuits. From these two facts, we are going to draw a conclusion: the first thing to do in all cases is to replace the tubes. Certain tubes in most cases; all tubes in some cases, depending upon the symptoms. From this point on in this discussion, we're not going to mention tubes. We will assume that the tubes are always good, since you should have replaced them before doing anything else! (There are certain qualifications to this statement, as usual, but we'll take them up in the section on horizontal output tube replacement.) Tube replacement may save you the time taken to pull the chassis out of the cabinet; especially helpful in servicing in the home.

Servicing in the home

To save time, we want to fix as many sets as possible in the home. For the same reason, we must learn to make a fast, accurate diagnosis. Certain things can be fixed easily in the home, others can't. We have to learn to recognize these "Unfixables" as soon as possible. Then, we can load 'em up, haul 'em to the shop, fix 'em and get 'em back in the shortest possible time. The less time we spend on a job, the more money we make. So, we look for those symptoms which always say, "To the shop!" Now let's take a typical home service call.

We've talked about the list of troubles that you must know. Now let's put it to some use. We're going to assume that you've been called to a home to service a TV set which definitely has horizontal sweep trouble. We're going to go over these tests as rapidly as possible, and we'll give reasons whenever possible. If you find yourself in doubt on any of them, go back and reread the section earlier in this book on that part of the circuit! Now, here's what you do, and why you do it:

1. Turn it on and see what happens

This sounds pretty asinine, but it's exactly what you do! Right here, let's talk about the danger signals you have to watch out for.

- **a.** Smoke, or a burned smell. This indicates a short-circuit or badly damaged part.
- **b.** Plate of the output tube red-hot. This means that there is no drive on the output tube: dead oscillator tube, or shorted output tube or both. Alternative? Bad part in the horizontal oscillator circuit, or a short circuit somewhere in the flyback, yoke, damper, etc.
- **c.** Fuse blown; new fuse blows immediately. Dead short somewhere in the B-plus circuit. If the new fuse does not blow immediately, but blows inside of 15–20 seconds, this means that the short is in the boost circuit. Why? Because it does not blow until the boost voltage comes up. There will be no boost voltage at all until

the damper and horizontal output tubes have warmed up to full operating temperature.

d. Arcing, flashover or smoke from the high-voltage cage.

Most of these (subject to the limits we'll take up in a minute) mean "take it to the shop."

2. Make a preliminary diagnosis

If there is smoke or a burned smell, we can begin checking things to see why. A good place to begin is with the owner. Question him to find out just how the set acted when it went out. Did it fall out of sync, suddenly black out, make "flashes on the screen" or what? You'll have to develop a certain skill in interpreting what owners say! You'll get some *very* peculiar answers! Above all, find out if the set was intermittent.

First, is there a raster—light on the screen? Let's say that there is. Now examine this raster. Ask yourself the following questions:

a. Is it in sync?

If it is, this means that the horizontal oscillator and afc are probably OK. (One suspect eliminated!)

b. Is it wide enough?

If the raster is in sync but narrow, the trouble will be in one of two places: the horizontal sweep circuits or the low-voltage supply, the B-plus. We replace the output tube first, as the most likely suspect. If this doesn't help, then replace the low-voltage rectifier. To be sure, change the damper and oscillator tubes, too. In transformerless sets using selenium or silicon rectifiers, measure the B-plus, since it's not so easy to change rectifiers. B-plus in transformer sets should be about 275–300 volts. In half-wave rectifier sets (only one rectifier used), it will be about 130–140 volts. In sets using doublers, as almost all of them do nowadays, between 240–260 volts.

If the loss of width is small, say only ½ inch on each side, check the setting of the width control. If the set uses a width sleeve, pull this out and see if you can get enough width. If you can overscan the screen by ½ inch on each side, fine. If you can barely cover the screen, one of the tubes is weak, and it will probably continue to shrink. Explain this to the owner and in most cases, he'll tell you to go ahead and replace the tube. However, if you do leave it like this, be very sure to tell him about it! Then when the inevitable occurs, you can always say that you told him! (And charge him for another service call!)

c. Is it bright enough?

Turn the brightness control wide open. If the brightness is normal, good. If not, then check the high-voltage rectifier tube by replacing it. Also, and don't overlook this, check the setting of the ion trap, if there is one on the picture tube! This one can really throw you a curve, and the number of misadjusted ion traps you'll find is amazing!

Blooming, that is, the picture gets larger instead of brighter, when you turn the brightness control up, means a weak high-voltage rectifier tube or an increased-value filter resistor. If this tube is weak, when the brightness is turned up the high voltage goes down. The weak tube simply won't carry the current needed for higher brightness, even though this is only about 50 microamps. The sweeps are set to cause the beam to be deflected a certain amount with the right high voltage. When this high voltage gets low, then the same amount of sweep will cause the beam to be moved farther. The beam becomes softer, as we say, and sweeps over more than the right distance. This has the effect of making the picture bigger, off the screen.

In a few cases, you may find no raster at all. If the brightness control is turned all the way off, then turned up very slowly, the raster will come on, dimly, at one point, then bloom very badly and go completely dark again. This means that the high-voltage rectifier is very weak indeed. There are other causes of blooming, but we'll take those up later. In 95% of the cases, the tube is responsible.

A dim raster, with plenty of width but no blooming, means one of two things: low high voltage, or a weak picture tube. You can measure the high voltage directly, with a high-voltage probe on your vom. If you get more than 10,000 volts, check the picture tube, on a good CRT tester. If it is weak, you'll lose brightness *and* contrast, too. Try installing a filament booster; this will often bring weak picture tubes back to normal brightness.

d. Is it out of sync?

If we do have a raster, bright enough and wide enough, but out of sync, this eliminates quite a lot of parts. The B-plus, output tube, damper, flyback, yoke and high-voltage rectifier *must* be OK. If they weren't, we wouldn't have a good raster. Now that's a good shortcut test! See how many different things we can eliminate by simply *looking* at the raster.

Sync trouble is one of three things: bad horizontal oscillator, bad afc or weak sync. Taking them one at a time, if the oscillator is bad, it won't respond properly to the horizontal hold control. You can turn the control all the way through its range, without being able to bring the picture into sync. Try a new tube first, as usual. Next, check the setup adjustments: the Synchroguide transformer, ringing coil or whatever is used on this particular set. Someone may have been tinkering with it; an ever-present possibility, even without the owner's knowledge!

If the picture is badly out of sync, showing only slanting lines, but these lines are fairly stable, this means that the afc is usually OK—the pattern is stationary. The oscillator here has changed frequency. Either the controls are set off or some part has gone bad. To find out which, do the setup adjustments.

If you can make the oscillator go *through* the right frequency; that is, make the slanting lines change from one side to the other (from slanting up to the right to slanting up to the left, or vice versa), then the oscillator is capable of running on frequency! It isn't doing it at the moment, but it can if it wants to! If this is the case, we go back to the afc.

If this is one of the sets which brings the core of the ringing coil, Synchroguide frequency coil, etc., out through the front panel and has a knob on it to act as a horizontal hold control, the trouble could be here. These knobs are provided with an ear, and there will be a stop on the front panel. This limits the range of this control to slightly less than one full turn. If this ear has been broken off (Fig. 701), the knob can turn farther than it should. Normal adjustment of this circuit is made (by the technician) by removing the knob, turning the control until the picture is in sync, then replacing the knob.

Customers, or customers' children, often pull these knobs off, turn the shaft several turns, throwing the picture away off sync, then claim, straight-faced, "Nobody's touched it at all!" Always take this with a large grain of salt and check it to be sure!

You may find these sets so far off that the screen is covered with very thin horizontal lines. Actually, they slant, but the slant is so small you can't see it. Turn the

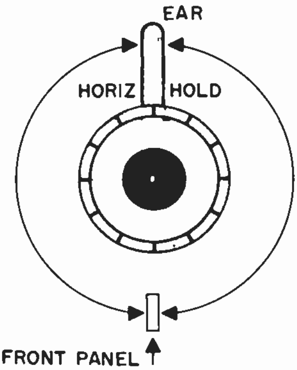


Fig. 701. *A broken ear on this type of horizontal hold control is one way in which frequency control can be lost. A heavy-handed do-it-yourselfer can turn the control too far counterclockwise and pull the core from the threaded rod. Turning the threaded rod clockwise will drive the core in but having come loose from the rod, it will not come back out again.*

control and watch the lines. If they get wider and fewer and slant more, you're going the right way. If they get thinner and increase in number, turn the shaft the other way.

To be sure, check the set's horizontal hold action. Set the hold control near the center, where the picture is locked in, and change channels. The picture should always snap into sync. If the hold control is just a wee bit off, the picture will flutter for a few seconds, then pull into sync. Move the hold control slightly whichever way is indicated, and try again. When both horizontal hold and afc are good, you'll get only one reaction: the picture will snap in on each channel just as soon as the tuner hits it, and will stay in. Anything else means insufficient hold control action and further trouble.

e. Afc troubles

If the oscillator is OK, you'll be able to make the picture flip from one way to the other, but it won't hold in the center or lock a picture. This is afc trouble. Why? Because the oscillator is obviously capable of running both above and below the right frequency, but it won't hold it. So, the trouble must be in the control circuits, the afc.

Try substituting a new afc tube or the diodes. Then try a new sync amplifier or clipper tube to see if the trouble is due to weak sync. Check the setting of the agc control. If this is wrong, it can cause clipping of sync. However, you won't be bothered with this too often because of the definite symptoms of agc overload that you'll be able to see: a very black-and-white picture, with bending and a buzz in the sound.

Noise-cancelling stages, if used, can cause this type of trouble. If the control isn't correctly adjusted, this kind of stage has a revolting tendency to clip not only the noise but the sync too. If there is no adjustable control, try pulling the tube, unless it's a part of another circuit, which it sometimes is.

If the trouble is in the sync circuits, you'll note that both horizontal and vertical sync will be affected. Check the sync rather than the afc and oscillator. This would mean that the defect was in some stage which handled the composite sync.

Sure check: short out the sync, and see if the oscillator is capable of making a single picture while free-wheeling. Many sets provide a terminal on top of the chassis just for this purpose; look it up in the service data. If not, you can sometimes use a test adapter for the afc tube, to let you get at the afc circuit.

Dead set: no light on screen; sound ok

Now, let's take the other major class of trouble: no raster, at all, but sound OK. After taking the elementary precaution of turning the brightness control up, we'll have to go into the back of the chassis to check this one. Take the back off the cabinet, turn the ac switch on and turn the sound completely off. We may have to listen for some very faint noises, corona, etc. and, besides, the sound from soap operas and commercials certainly doesn't help in clear thinking! Put a mirror in front of the set so that you can see at least part of the screen. In most sets, you'll be able to see through the bulb of the picture tube, and tell if the screen is lit up. However, some of the heavily aluminized tubes are hard to see through from the back. Connect the cheater cord to the ac outlet, and get ready. If the horizontal output tube is inside the HV cage, lift the top or take the shield off; we must be able to see it. This will often expose the high-voltage rectifier tube and flyback too.

First tests

Locate four tubes on the chassis: the horizontal oscillator, horizontal amplifier, damper and high-voltage rectifier. The last three will be easy, because the output and high-voltage rectifier will be the only ones with top caps, and the high-voltage rectifier will connect directly to the flyback winding "tire". The damper tube usually sits very close to the output tube, and the oscillator tube is usually on the other side. A tube-location diagram can often be found somewhere on the inside of the cabinet or back cover, or ought to be. If not, look it up in the service data. After a while, you'll learn the tube numbers used for everything except the oscillator.

Now plug the cheater cord into the set. Keep one hand on it, close to the interlock plug, while you watch those four tubes. You're looking for a red-hot plate on the output tube, arcing in the damper, or any sign of corona or arc-overs on the flyback. If any of these show up, or if smoke starts curling up from under the chassis, yank the cheater cord out *immediately!* If you see arcing inside the tubes or signs of gas (a very soft blue glow *inside* the electrodes, *not* a blue flickering light on the glass bulb), pull the cheater cord and replace the tubes; they're definitely bad.

If this cures the trouble, fine. If not, or if you see smoke, then the chassis must go to the shop. Not only for replacement of the burned parts (usually resistors) but mainly to find out *why* they burned up. This is invariably caused by a short; so, we've got to find it and clear it up, so the new parts won't burn up.

In most cases, nothing happens; the set just sits there, dead. Our job is to find out why. So we make some tests, as quickly as possible, to get an idea of where to start.

First of all, are all the tubes lit? A dead tube is easy to spot. Watch out for half-dead twin triodes commonly used as horizontal oscillators. These have two cathodes and one of these can go out! If you don't happen to be on the alert, you might see the good one lit up and assume that the other is also. Of course, if you follow recommendations and replace all four of the tubes in this section, you'll catch this trouble easily.

Next, let's check for high voltage and rf around the flyback. A small neon tester, made especially for this, is very handy. Fig. 702 shows it in use. If you hold the bulb end of this near the high-voltage rectifier, it will glow brightly, showing that there is a strong rf field around there, as there should be. Holding it near the output tube plate will also give you a glow, but not as bright since there isn't as high a peak voltage present.at this point. However, the tester ought to glow, if the tube is working. The high-voltage can

Fig. 702. *Neon lamp tester will glow when brought close to high-voltage rectifier plate cap.*

be checked with this tester by touching the metal tip to the HV connector on the picture tube. If there is high voltage present, the bulb will glow.

Screwdriver testing

There is another way of doing this. You'll find that there are always three or four ways of making each of these tests. Use the one you like best. (Me, I like the little neon tester!) Holding the blade of a screwdrive near the HV rectifier plate cap will generally draw an rf arc. You hold it by the well insulated handle, of course! (If you don't you will the *next* time!) This should give an arc of about 3/4 inch, bluish in color (Fig. 703). A sort of weak reddish arc that will only jump about 1/4 inch indicates that the rf is weak at that point.

You can also draw a small arc from the plate of the output tube with a screwdriver. *Don't* ground the blade of the screwdriver to make this test! If you do, you'll overload the flyback and may damage it or the high-voltage rectifier tube. An arc can carry a

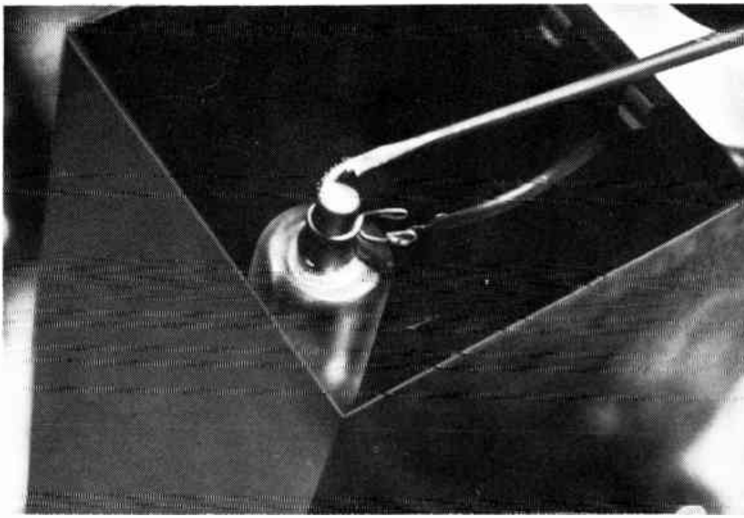


Fig. 703. *It isn't necessary to ground the screwdriver to draw an arc from the cap of the high-voltage rectifier or horizontal-amplifier tube. This isn't an incomplete circuit. As with the neon tester, the path for the rf current is through the stray capacitances to your hand and through your body to ground. The rf will also arc to an unwary fingertip, ear or nose—so watch it!*

tremendous amount of current, once it is established. You will always be able to pull enough of an arc for testing, by keeping the screwdriver clear of all grounds. Actually, the current is flowing through your body to ground, but it's so small that you can't feel it at all. (Unless you slip and touch the blade of the screwdriver!)

Arc testing

Another method, recommended in the older service manuals, is to disconnect the high-voltage lead to the picture tube and arc it to ground. I don't like this, personally. There are easier ways, and this one is not only dangerous, but it's hard on the high-voltage rectifier tube and filter resistor.

If you get a good rf arc from the high-voltage rectifier cap, but no dc high-voltage, replace the high-rectifier tube; it's dead. (That and the filter resistor are the only things between there and the picture tube!) In a few cases, even with the very wide spacing between plate and filament of these tubes, you'll have a short. If so, you won't be able to get any arc at all from the plate cap. To be sure, slip the plate connector off the tube cap, and see if you can get a good rf arc from it. If not, replace the tube. If the high-voltage rectifier tube is gassy, it will light up inside with a soft blue glow, and there may be arcing. You shouldn't have anything but a very dim reddish glow inside a properly operating tube, and if there's a fair amount of light in the room you may not be able to see even that.

A weak arc on both high-voltage rectifier and output tubes usually means weak output from the flyback or output tube. Replace the output tube. If this doesn't help, then change the low-voltage rectifier tube or check the B-plus voltage on semiconductor rectifiers. Change the damper tube and oscillator tube, this last on general principles in this case. If none of these brings back the high-voltage arc, it's a shop job.

You can use a high-voltage probe on your vom, if you want to read the exact value of the high voltage. This usually won't be necessary, in the home. Most of the time you'll be able to judge the high voltage by the brightness of the raster. One case where using the probe would be handy is in dim-raster jobs. As we said before, the picture tube could be weak.

There is one other case we should cover before we leave this section. Always check all voltages on the picture tube *before* taking the set to the shop, in cases where you have high voltage but no raster. Two things can cause loss of the raster, besides the high voltage. One is excessive bias on the picture tube, which cuts the beam off. Check the voltage between grid and cathode of the picture tube—*not* between there and ground. Read it on the picture-tube base to be sure! In the average picture tube, 40–50 volts of bias will cut the beam off completely. If your cathode reads 50 volts positive with respect to the grid, or vice versa (grid −50 volts to cathode), you're not about to get that tube to light up! This is caused by trouble in the video plate, defective resistors in bleeder networks in the B-plus, etc.

The other cause of no raster is the loss of the accelerator grid (Ga) voltage on the picture tube. This is usually taken from the boost voltage, except in the low-G2 tubes, and should read up around 450 volts (on pin 10, in most standard picture tubes). If this voltage is not present, because of a broken wire, bad socket connection, etc., the picture-tube screen won't light at all. Check these things before hauling the set to the shop to try and find a mysterious loss of raster!

If you find a narrow raster and low high voltage, or if the horizontal oscillator has failed, you're going to have to replace the horizontal output tube. In fact, this one tube is going to furnish a very large percentage of your in-the-home tube replacements.

However, it takes more than simply plugging a new tube in the socket. We must answer one important question: what made this tube go out? Old age or an overload? If the tube was burned out by an overload of current, then a new tube isn't going to last long unless we find the cause of that overload and clear it up. We should *always* check the circuit, whenever we replace an output tube. This takes only a few minutes, with the proper equipment. If we don't do it, then the new tube may pop out within a couple of weeks. We'll have the pleasure of donating the customer another new tube, free, under the warranty, plus our time taken on the callback! Plus the time it will take to fix the real trouble, which the customer will probably object to paying for! All of this butters no toast for the working technician!

For maximum income and minimum callbacks, take the time to run these simple tests on *every* set where this tube is replaced. If you do find troubles, then you can repair them and charge for it without a qualm. Replacing an output tube without checking the circuit is about like patching a flat tire without pulling the nail! It's going to to be flat again, pretty soon!

The one thing that must be checked is the plate current. We can do this very quickly with a simple home-made tube-base adapter or a special tester. Of course, we can break the cathode circuit, and read cathode current on an 0–500 dc milliammeter. This includes the screen current, but we're interested in the total amount of power this poor little tube has to handle, so that's fine.

Each type of horizontal output tube has a different maximum plate-dissipation rating. If we go over this, the tube doesn't last long. Since power, as we speak of it here, is the product of plate voltage times plate current, we can check the cathode current and see if it's within safe limits. Table 7—1 shows a list of horizontal output tubes and their safe limits. You can copy this list and carry it in the tube caddy, although after a little while you'll have memorized it. If you regularly carry a tube manual, you can find the information in it too.

Table 7—1. Normal and maximum cathode currents (total tube current) for different types of horizontal output tubes.

Tube Type	Normal Cathode Current (ma)	Maximum Cathode Current (ma)
6AU5, 6AV5	90-100	110
6BG6	85-105	110
6BQ6, 6CU6	80-105	110
6CD6	100-160	200
6DQ6	105-120	140
6DN6	100-145	200

(Any of these tubes may have different heater voltages: 6DQ6, 12DQ6, 17DQ6, etc; they're all the same as far as this rating is concerned.) You can make your own additions to this list from tube manual data. If you find tube type numbers have had letters (A, B, C, etc.) added it means that some characteristic has been changed. Check the manual—maximum current rating may have been changed.

This test catches a lot of troubles before they get a chance to happen. For instance, if the screen bypass is a little leaky, it might not affect the raster width or brightness too much with a brand-new tube. However, the added leakage current causes a lower screen voltage, which changes the plate current and cuts down efficiency. (Too *low* or too *high* screen voltage upsets things in this circuit!) No matter what it is, if it's harmful, it's going to show up in the cathode current of that output tube.

What we want to watch out for especially is the set drawing slightly more than normal current. For instance, some trouble in the circuit could cause a particular tube to draw about 125 ma. This might not show up on ordinary visual tests. However, the tube is rated at 110 ma *maximum*, and we like to work 'em at about 85–90 ma for longer life. So, this poor little tube will hold up for perhaps 30–40 hours and then fall flat on its face! Needless to say this always happens before the warranty expires. If we take a little time to measure the cathode current and set it within safe limits, our new tube and the whole set are going to work better for a much longer period of time.

Curing arc-overs and corona

One more thing which can usually be done in the home is curing arc-over and corona discharges in the flyback and high-voltage cage. Most of this trouble is caused by dust or dirt, which holds moisture, or insulation weakened by age. We blow the dust out of the high-voltage cage, and cover everything possible with insulation.

The easiest way to do this is by spraying on several coats of the pressurized acrylic plastic compound sold under many trade names. This dries fast, usually within 5 minutes. You'll get better results by spraying on a thin coat, letting this dry, then spraying another over it, rather than trying to spray a thick coat on all at once. Let it dry about 5–10 minutes between coats.

A similar compound is put up in small bottles with a brush in the cap for applying it. It's usually a special varnish, with a very high breakdown voltage after drying.

A special compound, a high-voltage wax of puttylike consistency, can be used to replace wax tires which have loosened or fallen away from flyback windings because of heat or old age. It is also handy for packing into cracks, etc. around the flyback where flash-overs have occurred or might. It doesn't dry out, but remains soft for a long time, so that it stays where it should.

If there has been an arcover from the high-voltage wiring, burning the plastic insulation, replace it. It's much faster. You can carry a short length of 25,000-volt wire in your tube caddy for the purpose. If you don't have this, cover the burned wiring with heavy plastic tubing—spaghetti. You'll probably have to trim off the blobs which form where the wire insulation broke down. Unsolder one end of the wire and slip the spaghetti over it. Resolder it, then put a dab of high-voltage putty on the solder joint, to avoid corona. When making solder joints in the high-voltage section, always make them well rounded. Never leave a sharp point on a solder joint; this will encourage corona to form at that point.

Plastic electrician's tape can be used in emergencies. Soften this by heating it slightly, then make at least two tight wraps around the damaged place on the wire, covering it at least 2 inches either way from the break. Spray the repair with acrylic plastic or paint it with corona dope. Let this dry thoroughly before turning the set on again. The solvents used in almost all of these liquid insulations are flammable. If power is applied before they dry, you may have a brisk blaze on your hands! Incidentally, *never* spray plastic into a high-voltage cage with power on; same reason.

Final answer

Now we should know the final answer: can it be fixed in the home or must we haul it to the shop? Let's go over our test questions and see. Although it has taken about 3 days to write this, and you about half an hour to read it, you ought to be able to make every one of these tests and get an answer in less than 10 minutes.

1. Are the tubes lit? (Horizontal circuit tubes, that is.)
2. Is there smoke or a burning smell?
3. Is there any high voltage?
4. Is there any rf at the HV rectifier plate cap, etc.?
5. Are the tubes OK? Replace all at once; might have two bad ones!
6. How's the cathode current on the output tube? High, low, normal? (Too low—weak output tube, low B-plus. Too high—low drive, short in flyback, yoke, damper, etc.)

If the answers to all these are negative; in other words, if you've gone through this whole test sequence and been unable to pin down the trouble, then the set goes to the shop. And of course, if you have found some trouble that has caused damage to parts (resistors, capacitors, flyback, etc.) then the set goes to the shop for replacement of parts and thorough checking. By this time, you ought to have a pretty good idea of where the trouble actually is, but it's better to work on more complex troubles in the shop, where you have the advantage of better working conditions, more elaborate test equipment, etc.

In-the-home testers for horizontal sweep circuits

There are quite a few different special sweep circuit testers. Most of these provide substitute signals for driving the output stage, peak-to-peak voltmeters for measuring drive, and even substitute yokes for test purposes, etc. These can be used in the home or shop. One of their greatest advantages in home servicing is helping you to make a more accurate diagnosis of trouble before the set is removed from the cabinet. In a lot of cases, this will save you doing an hour's work only to be told, "That's too much; we just won't have it fixed!" We will give a detailed description of these in the chapter on test equipment. Now let's go to the shop and see what kind of jobs we get into there.

Chapter 8

Shop Testing

WE'VE FINALLY GOTTEN THE SET INTO THE SHOP. ALL OF THE preliminary tests should have been made in the home: tube substitution; visual checks for output, raster, high voltage, sync, etc. We should have at least a partial diagnosis, or some idea of where the trouble is. If we don't, we ought to! Now we can use the more convenient bench instruments to pin down the cause of the trouble. There are lots of tests which are very simple in the shop, but difficult in the home.

There will be two classes of shop jobs: the first are those where the diagnosis has been completed, and we have to take the set in for major parts replacement, flyback transformers, etc. The second class is the tough dogs, those sets with mysterious ailments which are very difficult to locate in the home. You'll get better results in the shop on these, for several reasons. The biggest of these is psychological—you're not under that pressure to fix it fast, with the owner leaning over your shoulder! Besides, in the familiar atmosphere of your own shop, you'll find that you can think much more clearly!

Tests

There are three kinds of tests we can make: (1) Measure the actual operating conditions in the circuit, with special testers. These usually use plug-in adapters, to give us access to the circuits. (2) Find shorted turns in flybacks or yokes with an instrument which measures the Q of the windings. (3) Apply substitute drive signals to the various stages, to test actual performance with a known-good drive signal.

There are test instruments which will make all of these tests. Some give you almost the whole list, while other have only a single function. Every one is useful in some way. The only choice between them is personal—your own likes and dislikes, plus some price considerations. Many are built in combination with other test instruments to give you even more value for your money. To get the most value, take the instrument which provides the most tests. Once you have the basic chassis of a test instrument, it costs very little to add other test functions. And some test gear provides an amazing number of tests.

Tests and methods: go and no-go checking

Let's get down to some actual testing. First, what do we want from these tests? Information! Information as to what is actually going on in the circuit. From this, we should be able to tell whether the circuit is actually in operating condition. In other words, is it

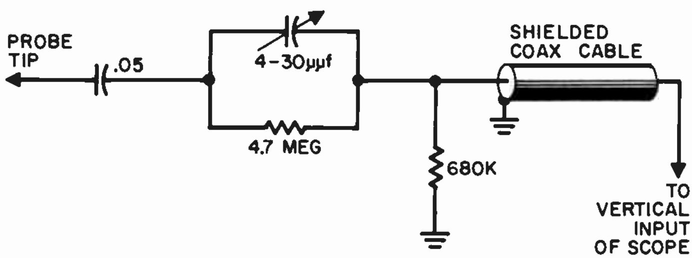


Fig. 801. *Low capacitance oscilloscope probe circuit.*

GO or NO-GO? This is one of the most important things you'll have to learn—to be able to check a circuit and recognize what the test results mean. We're going to describe NO-GO results, so that you can recognize them when you see them!

Suppose we start at the beginning, and run through the whole test series. Remember, you can skip any of these if you begin checking in the middle and get a GO result. This means that everything back of that point is OK, and we can go on toward the output.

Horizontal oscillator

Always a good place to start, this stage has to be working before anything else can work. We measure its output by reading the peak-to-peak voltage on the grid of the output tube. There is only one instrument that can do this accurately, and that's a scope. We use a low-capacitance probe, with a circuit like that shown in Fig. 801. Because of the high impedance of the grid circuit, we can't add too much capacitance without disturbing the circuit operation. Now we measure the p-p voltage of the drive signal and its frequency; that's all we need to know.

Voltage readings with a scope are always taken by comparison. We put the probe on the grid of the output tube, and set the vertical gain of the scope to give us a pattern of some definite height, say, four major divisions on the scope graticule. Next, we turn the horizontal gain of the scope to zero, completely off. This

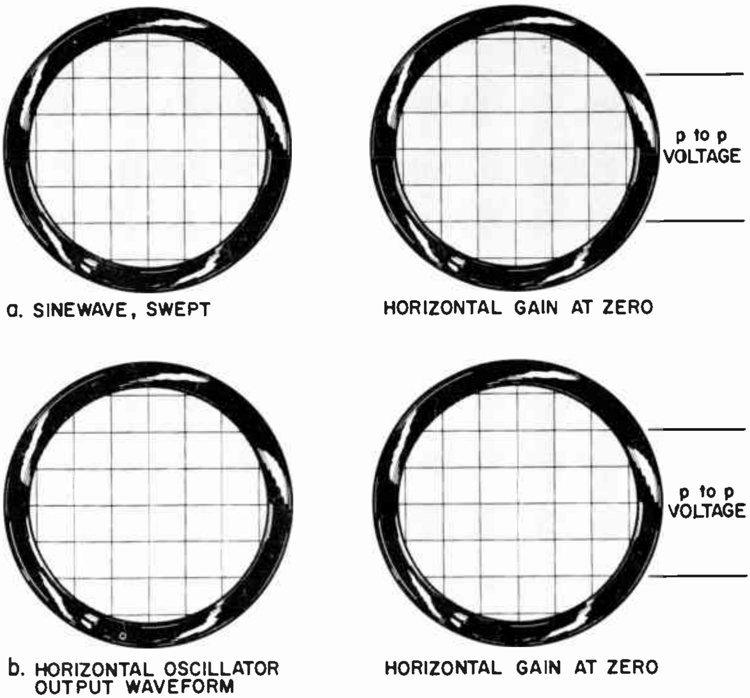


Fig. 802. *No matter what the waveshape, sine wave (a) or horizontal oscillator output waveform (b), we can measure p-p voltage by reducing horizontal gain of scope to zero, and measuring length of vertical line.*

leaves a thin vertical line on the scope. Why? Because we're not interested in waveform right now, only p-p voltage. Waveforms of any shape can be measured on a scope in this way (Fig. 802). If we set up for a vertical line, all we have to measure is the total height of this line; it's easier.

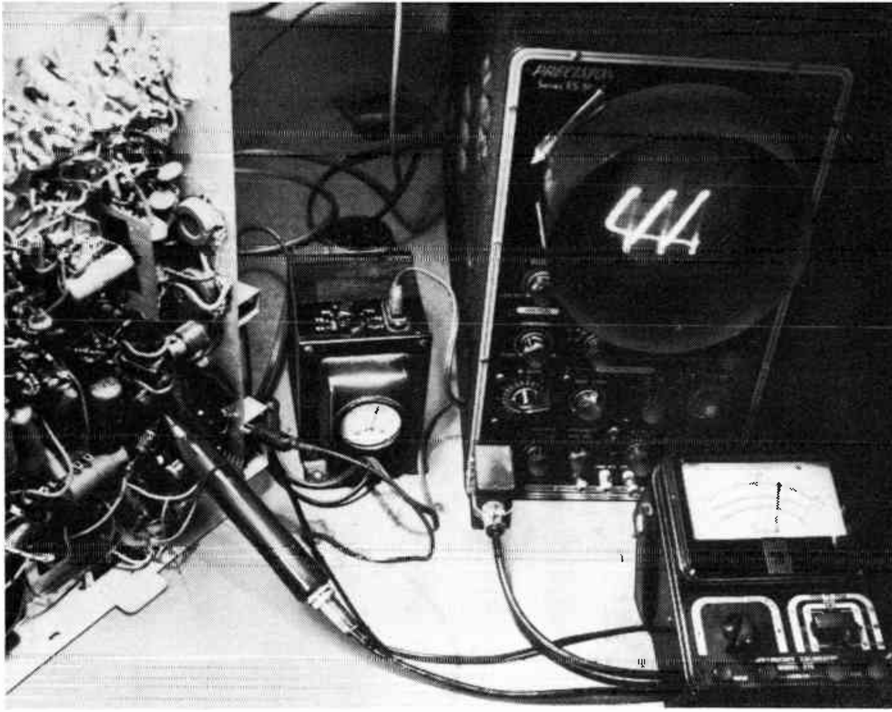


Fig. 803. *Scope calibrator is shown in lower right-hand corner. The transformer sitting between the set and the scope is a variable voltage transformer. The waveform on the screen is being taken from the receiver.*

With our drive signal represented by a four-unit line on the scope, we move the probe tip to a calibrator. After we get the scope set up for this test, we *do not move any* of the scope controls! We vary the voltage of the calibrator, until we get the same vertical height that we had when the signal was connected. Then, we simply read the voltmeter on the calibrator, which is calibrated in p-p voltage. This reading gives us the value of the unknown p-p voltage, the signal.

A calibrator can be any source of variable ac voltage. The most convenient, of course, is a commercial scope calibrator, of the kind seen in Fig. 803. This is a 1-to-1 transformer, with a voltage divider across the output and a potentiometer across the input, for coarse and fine control of the voltage. Fig. 804-a shows the schematic of this instrument. The voltmeter is calibrated in the three important values of an ac signal: rms, (root-mean-square),

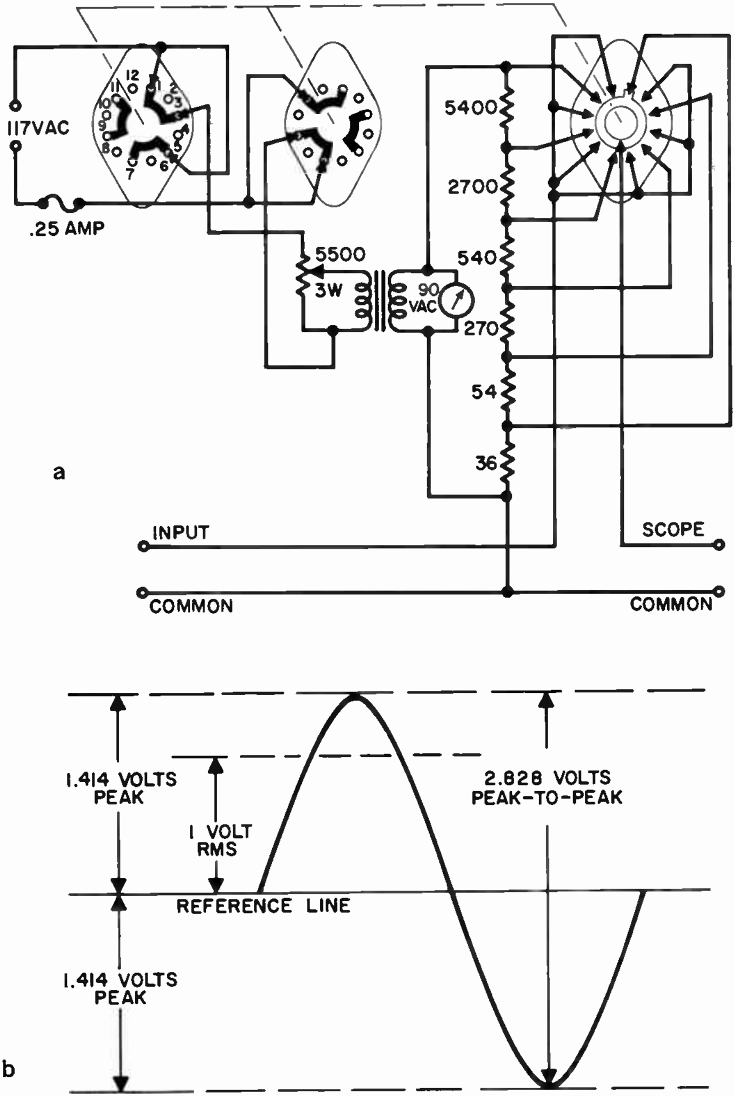


Fig. 804. *Schematic diagram of a voltage calibrator (a) and rms, peak and peak-to-peak voltage measurements of a sine wave (b).*

peak and peak-to-peak voltages. Any single reading on this meter can be interpreted three ways: for example, 100 volts rms is the same as 141.4 volts peak and 282.8 peak-to-peak. Fig. 804-b shows how these values are taken from a sine wave. In our case, we're interested only in the p-p voltages, so we just ignore the others! (They're not accurate anyhow, since this meter is calibrated for sine waves. Asymmetrical waveforms, such as those we have here, won't work out on rms and peak values, but peak-to-peak, of course, will always be right.)

That's all we do to make this test: set up a pattern on the scope, note its height, and then connect the calibrator to make a pattern of the same height. The calibrator voltage is then equal to the unknown. Fig. 805 shows the details of this test on an output tube grid circuit.

If you don't have one of these useful instruments, you can use any source of variable ac voltage. The filament voltage on your tube tester, for example. Set up exactly as before; get the signal pattern on the screen, and note its height. Now, connect the probe tip to the filament terminals of any of the sockets. Set the filament voltage-selector switch to give a vertical line on the scope as close as possible to the line made by the drive signal. *(Hint:* easy way to connect scope: plug in one of the tube-base adapters made for checking voltages on top of the chassis. These have lugs on each socket terminal!) In most cases, you'll be able to get close enough to the right value so that you can tell *about* what the p-p voltage of the drive is. If you can get within 10% of it, that's close enough for practical testing.

You can get a very close reading, if you want, by setting the filament voltage as the coarse adjustment, then varying the line-voltage adjuster pot on the tube tester until you get exactly the same height. Then measure the voltage at the socket with an acccurate ac voltmeter. Remember, this meter will probably be calibrated in rms volts. You'll have to multiply this reading by 2.828 to get p-p voltage. Some vtvm's have a peak-to-peak ac voltage scale; if so, you can use this instead. Some vom's also have p-p voltage scales. However, because of the low impedance, you may get a shunting effect, and a reduction of the actual voltage if you try to read the drive with these. If the vom is one of the very-high-impedance types, then it will be fine.

The normal voltages you'll find here will be somewhere within these limits:

75 to 90 volts peak-to-peak	50° to 70°	TV chassis
125 to 150 volts peak-to-peak	90° to 110°	TV chassis
150 to 200 volts peak-to-peak	Color	TV chassis

If your reading shows within 10% of these voltages, this circuit

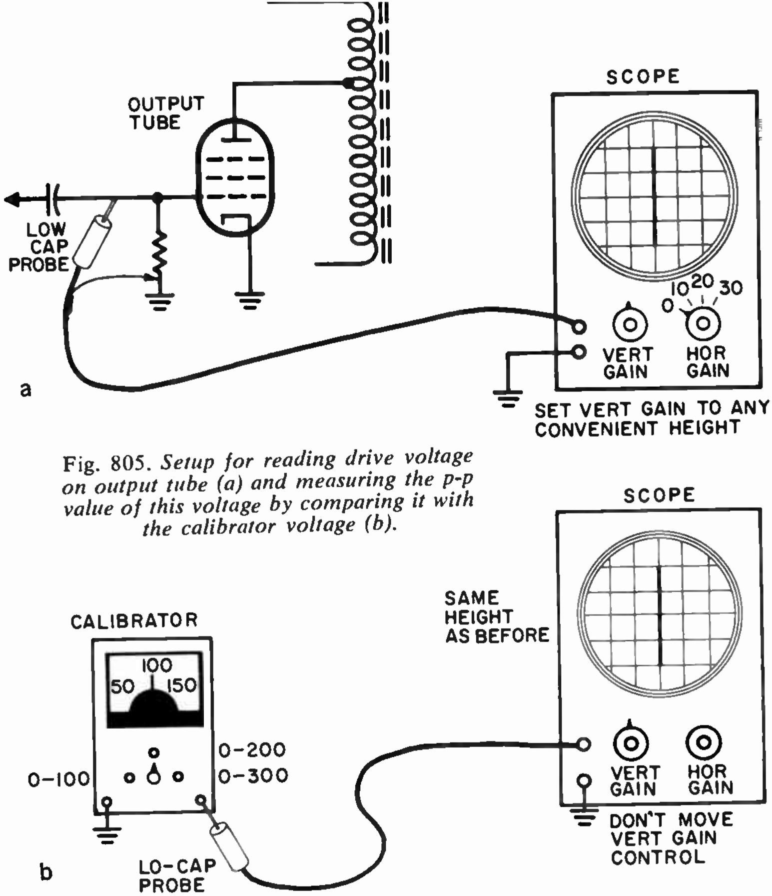


Fig. 805. *Setup for reading drive voltage on output tube (a) and measuring the p-p value of this voltage by comparing it with the calibrator voltage (b).*

is go, the horizontal oscillator is in good shape, and you can go on to the next test. This test should take less than 1 minute to make at the bench, and will give you a lot of info.

Frequency

The next thing to check is the oscillator frequency. Pick up a comparison waveform from the video amplifier, and set up the scope for two or three cycles. Now put the scope probe on the oscillator output, and set the hold control to make the same number of cycles, and you're on frequency. This is *go.*

Horizontal afc tests

We check this circuit *second,* because the oscillator has to be working before we can check it! Best way: short out the afc first and check the oscillator all by itself. If the oscillator suddenly jumps off frequency when the afc is put back in the circuit, then the trouble is obvious–the afc is bad!

To check afc action, try the operation of the hold controls, if these are in the afc circuit. If you can't get the picture to hold, then check the parts in the afc. There are only a few; leaky capacitors, drifted or open resistors, or defective diodes will account for practically all of the afc troubles. If these parts check OK, then measure the p-p voltage and waveforms of the various pulses, sawtooth and sync, around the circuit. The correct waveforms will be shown on the schematic diagram, with their frequency and p-p voltages.

Incidentally, if the output stage is not working–no light on the screen and no high voltage–don't bother checking the afc! Because most of the pulses come from the flyback, you'd better go on and get this working first! If not, your pulses won't be of the right amplitude, etc., and you'll be wasting time. Best way, in these cases, is to leave the afc shorted out, and go on to the flyback and output circuits. Once these are working, you can correct any troubles in the afc, etc.

Horizontal output tube

Now we come to the most important single tube in the whole circuit–the horizontal output tube. He's the Big Boy; all of the whole circuit revolves around him. Directly or indirectly, he furnishes the push for everything else, even in some circuits, the plate voltage for the oscillator (through the boost voltage)! Normally, this tube will dissipate more power than any other tube in the set. By taking certain measurements around this circuit, we can tell what's going on in several others.

We make the same tests as before: grid drive signal, operating voltages, plus the cathode current. We've just checked the grid drive. Now check the supply voltages to be sure that they're normal. Next, measure the voltages on the tube. We check the dc voltage developed by grid current, using a vtvm, as a quick check on grid drive. Since we deliberately drive this tube far into grid current, we can measure the voltage developed by this current flowing through the grid resistor, to get an idea of how things are going. This will not be the same as the p-p signal voltage, of course: it is the dc voltage developed across the grid resistor. Typical values are −45 volts dc for a 160-volt p-p signal. This varies with the grid current and the size of the grid resistor, of course.

You can measure the drive voltage fairly accurately without a scope, if you want to. Connect an accurate 1-megohm resistor in series with a microammeter, and disconnect the grid resistor. Connect this combination in place of the grid resistor, and note the current, in microamperes. This is very close to the actual p-p voltage. We use a 1-meg resistor to simplify the math. Current (I) through a resistor (R) equals voltage (E). So, our formula comes out E (grid voltage) = I (grid current in microamperes: I $\times$ 10^{-6}) multiplied by R (grid resistor, ohms $\times$ 10^{6}). The exponents will cancel, and we get plain old E = IR.

We can measure the screen grid voltage at the tube socket, to be sure that it is correct but *do not measure the plate voltage on the plate itself*. If the tube is working, there are high-voltage rf pulses of several thousand volts. This will arc over and probably ruin your voltmeter or vtvm, if you try it. Anyhow, we don't have to. We can simply measure the voltage at the B-plus terminal of the flyback—the bottom of the primary winding. Actually, this is always the boost voltage, but it gives us the voltage which is being applied to the plate, and that's all we need to know, at this time.

We're handling *power* in this circuit. Up to now, and in all other stages of the TV set (except the audio output tube), we are using voltage. Now we're getting into power, so we must find out if the circuit is handling it properly. When we say power, we immediately run into *current* measurements: power is voltage times current, E $\times$ I. We mentioned this briefly in the chapter before this that we measure the cathode *current* of the output tube, to be sure that it is within safe operating limits. Now let's see how and why we have to do it.

Operating tests on horizontal output tube

The best and most reliable test in any circuit is actual operation. An old ad used to tell about the "Old Professor's famous test for whiskey—pour some in a glass and drink it!" Same here: the best way to see how this stage is working is to turn it on and see what we get *out of it!* If we don't get normal output, we must find out *why*. You have to be thoroughly familiar with this circuit, so that you can spot abnormal operating conditions immediately and cure them.

A car's engine has to have gas, oil and water before it can run; this tube has to have grid drive, screen voltage and B-plus before it can run. Of course, without gas (B-plus) the engine isn't even going to start. If we try to run it without oil or water, what's going to happen? It's going to overheat! Same here; if we run with too little grid drive (oil) our tube gets too hot. Too little water (screen-grid voltage), and we get the same thing. We have a very good indicator in the cathode current. By measuring this, we can tell immediately what's happening, and whether the tube is running within safe limits or not. Fortunately, there are lots of testers we can use to tell us this.

The simplest is the break-in tube-base adapter. We pull the tube, insert the adapter and place the tube in the adapter. A 0–500 dc milliammeter is now connected in series with the cathode. It will read the total plate and screen grid current, since this *is* the cathode current. If you want to be nasty nice about it, you can subtract the *grid* current, since this is also part of it, but this amounts to only about 75–100 microamperes. Our total current is going to be between 75 and 200 ma, so this isn't going to throw us off too much!

Tube testing with cathode-current readings

Don't bother testing horizontal output tubes in a tube checker. You'll be wasting time; no commercial tube tester loads these tubes heavily enough to give a valid test. We are using the same tests used in radio transmitter work: we provide the proper operating conditions, grid drive, voltages, etc., and measure the cathode current to see that the tube is capable of putting out the right amount of power. If we find a tube which has current readings lower than normal, this means one of two things: either the supply voltage, the B-plus, is below normal, or the tube is weak. Its cathode has aged to the point where it can't emit enough electrons to supply the right amount of current. Either fault can be checked very quickly: the B-plus can be measured, since the correct voltage is given on the schematic, and the tube can be replaced by another. If the current of the new tube comes up to normal, without changing anything else in the circuit, then the original tube is definitely weak.

There is *one* condition which can cause low current; this is overdrive on the grid. However, in such cases, you'll have other symptoms to point to the trouble. For one, the p-p drive voltage will be far above normal for this set. For another, you'll have light on the screen, and the raster will show the give-away clue—the drive line in the center of the screen. *Quickest check:* simply reduce the drive by adjusting the drive trimmer. If the current comes up and the drive line disappears, that was it. You'll soon learn to spot this one; it's easy.

Too high current readings: overloads

Now we get into one of the more common troubles: too much current being drawn. This always means trouble, so never overlook it. If you find the cathode current too high, stop right there and find the trouble and fix it before you go on to any further tests. You may fix the whole trouble by doing this. Now, let's see what can cause this.

One simple trouble is too low drive signal. You can measure this in any of the ways previously given. Another quick check is to substitute a drive signal from a special tester or from a working

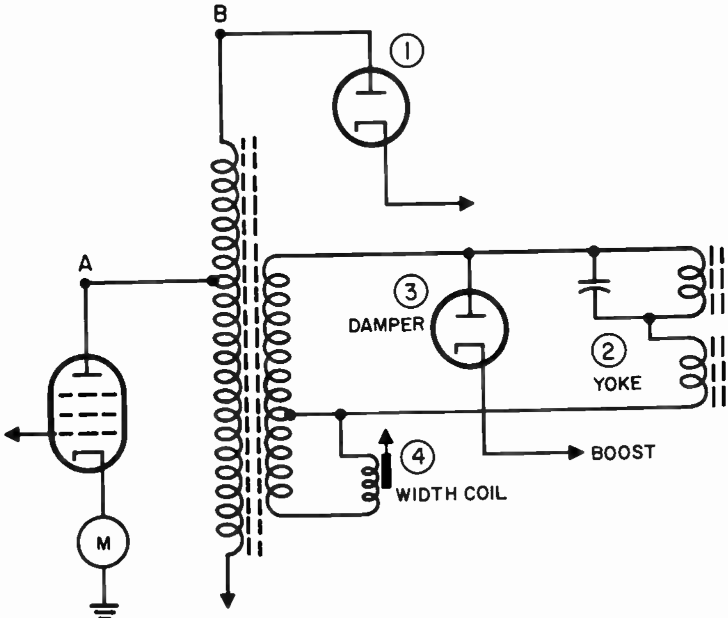


Fig. 806. *Horizontal output tube and flyback transformer showing the various loads which they supply.*

TV set. By applying a known-good drive signal to the tube, you'll be able to tell very quickly whether or not this is the main cause of the trouble. Incidentally, during all of these tests, put the milliammeter in series with the cathode and *leave it there*. This should be the last thing removed, so that you're sure that the tube isn't being overloaded.

The other thing that can cause current overload, of course, is a short or leakage somewhere in the load circuit, the flyback or yoke or damper, etc. Look at Fig. 806. Here, we have a power tube (A) driving a load through a transformer (B). Normally, it will draw a certain amount of current, which will read on the meter (M). Anything that happens in the transformer *or* the load will increase this current. How can we find out just which one of the various 'loads' (1, 2, 3 or 4) is responsible for the trouble? Disconnect them!

If we had a short in a B-plus feed line in the set, we'd go through the whole line with an ohmmeter, disconnecting each circuit until we found the one which allowed the resistance to come back up to normal. Right? We do the same thing here. Of course, the current will drop to below normal with the loads removed. For example, let's take a tube whose normal maximum plate and screen current should never be higher than 100 ma. We're reading about 140 ma, which is far too much. NO-GO. Disconnect the yoke. If it was shorted, the current will drop to about 40 ma. If disconnecting the yoke makes only a small difference, we take off something else. Try the width coil. If it's shorted, the current will come back to normal when it is disconnected. Same with the damper tube, or the high-voltage rectifier.

Suppose we've taken off all these loads, and we *still* have too much current. (Normal current here ought to be somewhere around 30–40 ma.) What's wrong? Well, what's left? The flyback transformer! There is probably a shorted turn in one of the windings. Incidentally, this shorted turn doesn't have to be in the primary either. A shorted turn anywhere in the transformer will cause an overload. A single shorted turn closely coupled to a transformer will represent a very low impedance load. The current induced in it will keep building up until something burns up, since it has no place to go except around in a closed loop! So, if we have definitely removed *all* loads from the flyback and we still read too much current, the flyback is definitely bad and must be replaced.

You see, an ideal transformer, running with no load, dissipates no power at all. A power transformer can be connected across the ac line, and it will read no watts at all, for there is no load on it. We use this as a test to find out if a power transformer has an internal short. We're using it here: if we go back down to normal plate current, 30–40 ma or below, with the open transformer, then the transformer must be good. If we still read 75–100 ma with no loads on the transformer, then the transformer itself must be causing the overload and the only way it can is by being shorted internally.

You should use other tests whenever the replacement of a major component is involved: yoke, flyback, etc. Always cross-check. If all tests give the same results, you're pretty safe in going ahead with the replacement. If even one of the tests shows the transformer to be good, look out! You may be getting double-crossed by some circuit peculiarity! We'll give you these other tests; there are a lot of them.

Flyback testing is an art in itself, because of the circuits used. So, let's go on through the rest of the tests, and then go into flyback testing all by itself. For a while, we're going to assume that the flyback is good.

Yoke testing

A deflection yoke is a simple sort of thing, not hard to find troubles in. There are only two windings, a small capacitor and maybe a resistor. (This refers to only the horizontal yoke windings, of course.) Let's see what kind of troubles a deflection yoke can cause.

There are only two defects we can have: open or shorted windings, plus a shorted capacitor, which will give us the same thing as a shorted winding. Once in a while you'll find a shorted yoke that will show the typical keystone raster shape. This won't happen too often with shorts in the horizontal yoke, however. Why? Because the yoke circuit is tuned to the flyback, remember? This is the *source* of the flyback pulse, which does the most toward generating the high voltage. Troubles in the yoke usually result in a complete loss of the raster, because they upset the efficiency of the yoke-damper circuit so badly. We lose not only the high voltage but the boost, thus cutting down the plate voltage of the output tube.

This is one symptom, the loss of boost voltage. If your voltage measurements show nothing but B-plus voltage on both plate and cathode of the damper tube, you have no boost at all. Check the yoke. This is about the easiest part in the circuit to check, outside of the tubes! Easy way: disconnect the yoke and measure the dc resistance of each half. If there is a fairly big difference, it's probably bad. However, there's an easier way, really. The dc resistances are often very low, especially in the low-inductance types. So, you may not be able to 'see' a short in one half.

For a positive check, substitute another yoke. Use a replacement yoke with approximately the same inductance in the horizontal windings (the vertical windings have nothing to do with this test.) Leave the original yoke on the tube, and disconnect the wiring, at the chassis; it's easier. Most of the time, you'll find this connected to the flyback. If the yoke has a center tap, disconnect it, too. Now, using temporary leads, clip the test winding between the yoke terminals, on the flyback. Connect a dc voltmeter, on the 0–1,000-volt scale, to the boost terminal on the flyback *Alternative:* connect a high-voltage probe to the HV connector. However, the boost is easier to get at.

Turn the set on. If the original yoke is defective, the test yoke will bring the boost and the high voltage back up. If the original yoke is still on the tube, you'll get a very bright vertical line on the face of the CRT, which tells you that high voltage is present. Don't leave this on too long unless you turn the brightness down. You can burn a stripe on the phosphor this way.

Several testers have variable inductances built in. These can be connected in place of a suspected yoke. The inductance can then be varied to find out if the flyback and other parts are good.

This test, by the way, can be made in the customer's home without too much trouble. If it shows that the yoke is definitely bad, a new yoke can be installed without hauling the whole set to the shop, in most cases. Later sets have the picture tube supported at the front, with the yoke merely clamped to the neck; very simple to replace.

Yoke replacement

When you replace a yoke, be sure to match three things on the original: the deflection angle, and the inductance of both horizontal and vertical windings. Yoke[illegible] very definite deflection angle, and they are *not* interchangeable, as a rule. In most cases, an exact-duplicate yoke will be available from any one of the major transformer manufacturers. When you connect the new yoke, trace out the two windings.

Never replace a yoke using either the wire colors or terminal numbering as a guide! These can be entirely different, even in some yokes marked exact duplicates, even if the new yoke comes from the set manufacturer! (Production changes, etc.) So, find the lead which goes to the hot side of the horizontal winding, and connect it to the right terminal on the flyback, and so on. In most yokes, you'll find an instruction sheet packed with the unit, giving the location of windings and terminals.

It is always a good idea to replace the balancing capacitor whenever a yoke is changed. Use the same value, or the value recommended by the yoke manufacturer for this particular yoke. If you find any traces of yoke ringing, the capacitor value may be

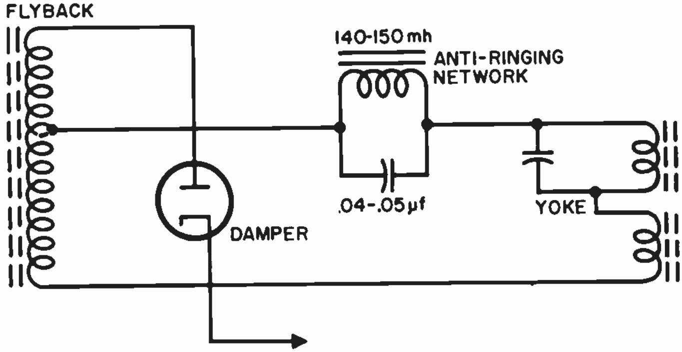


Fig. 807. *Anti-ringing network which can be added to solve ringing problems.*

changed, to eliminate it. As a last resort, if you get a stubborn ringing condition, you can connect an anti-ringing network between the hot side of the yoke and the flyback.

Anti-ringing networks are very simple; they're parallel-resonant circuits tuned to the right frequency (Fig. 807). If you get into deep trouble, you can even use an adjustable inductance and tune these circuits for maximum effect on the ringing. However, they're not necessary in most cases.

Yoke center tap

In some sets, you'll find a third wire coming from the horizontal yoke. This will be the yoke center tap. It is connected to a corresponding center-tap terminal on the flyback (Fig. 808). Unless this is provided in the original flyback, you can't use it! Many replacement flybacks, however, include this center-tap connection, and the original yoke can be changed to use it. When the center tap is used, the balancing capacitor is removed. The use of a center-tap connection usually takes out all possibility of ringing trouble, since the yoke's two halves are then perfectly balanced and won't ring at all.

Stuck yoke

Now and then, you'll find a yoke which is very tightly stuck to the neck of the tube due to old age, etc. This can be a problem, in yoke or picture-tube replacement! You'd better not take a hammer to it; you may loosen up the wrong thing. More gentle ways are indicated.

If the yoke is defective, it can be torn apart and removed. Take off the retaining strap, a thin sheet-metal band around the core.

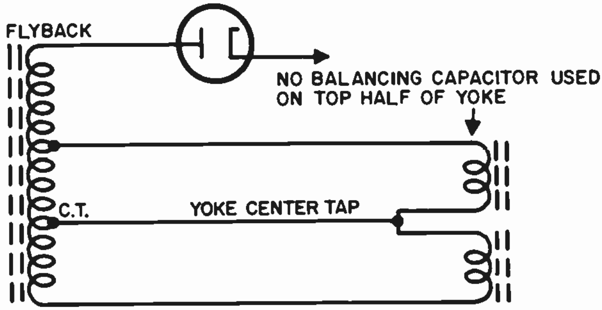


Fig. 808. *Center-tapped yoke circuit does not use balancing capacitor. Refer also to Fig. 630.*

Remove the core, which is in sections. Gently pry off the vertical windings, which will be on the sides; clip the wires and discard them. The horizontal (inner) windings will be exposed. You can very gently pry these off one at a time, or spray some kind of solvent, such as acetone, into the yoke, to soften the old varnish or cement which has stuck it. Use common sense! *Don't* try to pry the yoke loose by jamming a heavy screwdriver between it and the fragile glass neck of the picture tube!

There is another way to do this, somewhat slower but just as effective. Heat the old yoke to soften the cement and so expand it slightly. The best way to do this is to connect it in series with a light bulb and connect the whole thing across the ac line (Fig. 809). You can adjust the amount of heat by using different sized bulbs. A 25-watt bulb gives very little heat, a 100 or 150 watt quite a bit. The heat does not come from the bulb, directly, but is generated inside the yoke windings by the current: the windings are resistive, and cause a loss, thus generating heat. A 100-watt lamp will usually loosen the yoke in about 15–20 minutes, without harming it at all. This is ideal when the yoke must be used on the new picture tube!

Yoke connections

If you accidentally get the yoke connections reversed when replacing, you'll get some funny-looking pictures! If the vertical windings are reversed, the picture will be upside down. If the horizontal windings are reversed, the picture will be backward or inside-out. Also, since the balancing capacitor will now be connected across the wrong half of the winding, you'll probably have

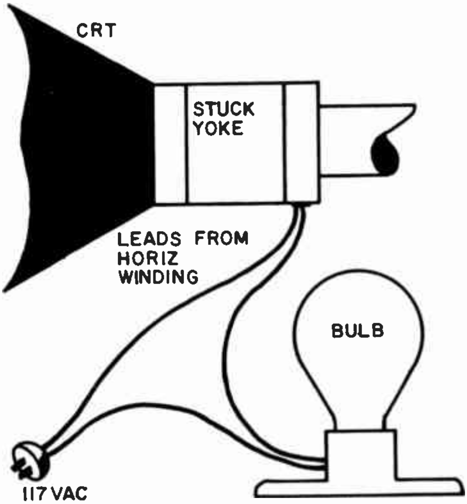


Fig. 809. *Current through the yoke is limited by the resistance of the lamp in series with it. Larger bulb, more heat. A light coating of silicone grease on tube neck will reduce possibility of future sticking.*

very severe ringing. Best check: put a picture on the screen, and wait for some printed words like a title or commercial. These will tell you very quickly if things are in good shape. A TV pattern generator, which actually gives you a picture on the screen, will do the same thing; most of the test slides used have some sort of lettering on them.

Damper boost troubles

While we're still in the neighborhood, let's take up troubles in the damper circuit. This means, most of the time, boost voltage troubles. We mentioned the main cause just now—yoke troubles. However, now and then other causes show up. About the most common among these will be capacitors. If the boost capacitor opens up, you'll lose the boost voltage entirely. If substituting the yoke fails to bring the boost back, check this capacitor. It's usually easier to substitute a yoke than to disconnect this capacitor; that's why we recommend that first!

Many circuits use a large electrolytic boost filter capacitor. This will be about a 10-μf electrolytic, and always of the non-polarized type (Fig. 810). There is often another capacitor, about 0.1 μf 600 volts, paper, across the same circuits. The main purpose of these capacitors is to clean up the boost voltage, to filter out the high-voltage spikes coming from the horizontal output circuits. In this way, the boost voltage can be used to drive the vertical output stage, horizontal oscillator stage and other circuits in the receiver.

The electrolytics sometimes open. When they do, you'll see weaving and bending of the picture, and usually a very severe horizontal instability. More common, however, is a very slight leakage. Since they work under a pretty high voltage, this results in internal arcing. You'll see small black or white horizontal streaks and flashes in the picture, depending on how severe the internal arcing in the capacitor is. Many technicians have a habit of suspecting this capacitor when *anything* unusual shows up in the horizontal output stage, and they're usually right! For a quick check, disconnect it and connect a standard polarized electrolytic across the circuit, with the positive to boost. Since, in normal operation, the highest positive voltage is on the boost side, this will work very well long enough to make this test anyhow. If this stops the flashing and streaking, replace the old one with a new nonpolarized type. This must be a nonpolarized type, because when the set is turned on, B-plus is applied to the *negative* side of the capacitor. This means that a standard capacitor is actually connected backward, and would break down very soon. When the damper tube has warmed up, boost voltage appears, and the capacitor has positive voltage on the boost-side plate. During warmup time, though, it is reversed. In emergencies, two 20 μf polarized electrolytic capacitors can be used as replacements. Connect their negative terminals together. This makes the two look like a nonpolarized 10 μf capacitor.

Width and linearity coils

The most common troubles found in width and linearity coils are the same: shorts. Under certain conditions, these coils can overheat. If left this way long enough, their windings will short to the iron core, which is always grounded. You can detect this, aside from overload symptoms in the output tube's cathode current, by the burned, blackened appearance of the coils. Check them with an ohmmeter or, better still, disconnect them and check the circuit

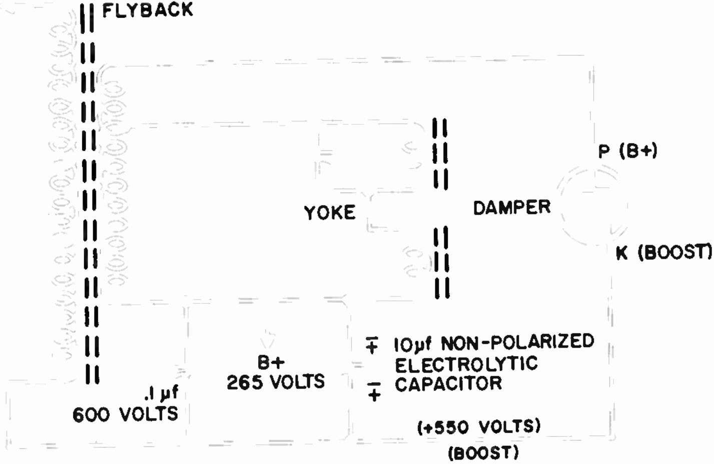


Fig. 810. *The .1 µf capacitor is more efficient at the high frequencies, the 10-µf electrolytic at the low. Both are needed for best boost filtering.*

response, as we outlined a moment ago. Width coils, being in shunt with a portion of the flyback, can be left disconnected without bothering anything. Linearity coils, since they are always in series with the boost, may be shorted out or replaced with a temporary substitute, which is better. Capacitors on the load side (away from the damper tube) of the linearity coil can short out and cause the coil to burn out.

Flyback testing

As Mr. Kipling says, "There are nine-and-sixty ways of constructing tribal lays, and each and every one of 'em is *right!*" There may not be 69 ways of testing flybacks, but each and every one of 'em is valuable. We can use any information we can get, in this situation. We have to make up our minds about the condition of the most expensive part in the set, besides the picture tube; this involves quite a bit of work, and we don't want to waste that, either. It is much cheaper to make an extra test or two, to be absolutely sure, than it is to replace a flyback, and then find out that it was something else after all!

Testing *thoroughly* won't take up a lot of time, either. You'll find, as you get a little experience, that you can make any of these tests in 1 or 2 minutes. So you can well afford to make extra tests to save the possible loss of an hour or more of time! Let's go over all of the possible checks and measurements you can make in this circuit.

Ohmmeter tests

Simplest of all: check the resistance of the flyback against the values given on the schematic. Don't bother with very small differences, say 1 or 2 ohms. These are probably meaningless. If the flyback has been replaced, forget the resistance test! Fig. 811 shows what I mean. All of these flybacks are "exact duplicates" but notice the difference in dc resistance. This is mostly due to different wire size.

Look for open windings and for big variations in resistance. If the high-voltage winding should be 400 ohms and reads 200, then that's probably bad. You'll have about 10% tolerance, normally. Other tests can be used to confirm suspicions you may have, of any given winding.

Q measurement

One good way of checking flyback windings for suspected shorts is by measuring the Q. This is the figure of merit, the ratio between resistance and reactance. If there is a shorted turn anywhere in the flyback, the Q is going away down, taking the efficiency with it. Special testers can measure this. These have an oscillator operating at about the horizontal frequency, with a meter connected in the circuit somewhere. To make this test, the instrument is set so that the meter indicates a certain amount of oscillation. Then the flyback or yoke is connected across the circuit.

If it is good—that is, if the Q is still very high, as it must be in order to work properly—then the oscillator won't be loaded down. The meter reading will stay high. If there's a shorted turn somewhere, this lowers the Q, the circuit is loaded, and the meter reading falls. The meter scale is calibrated in BAD-?-GOOD, like a tube-tester's English-reading scale.

Signal substitution

One of the best ways of testing this circuit is signal substitution. We've spoken before of breaking the circuit up into sections. Dealing with the circuit as a whole, if we can break it up into smaller pieces and drive each piece by itself, we can tell what is going on. So we use substitute signals.

We can remove the output tube and feed a high-level driving signal through the flyback all by itself, from a special tester. If

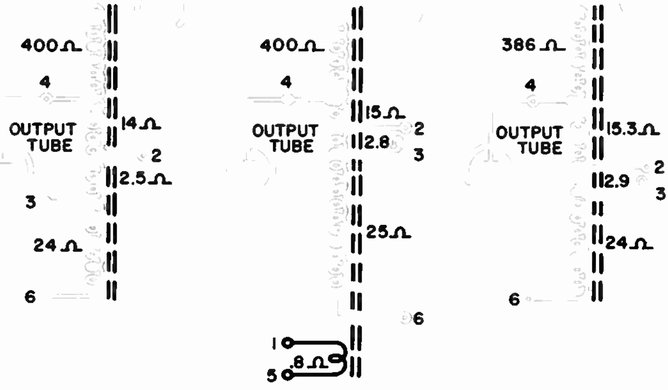


Fig. 811. *Original and "exact duplicate" replacement flybacks showing different values of resistance. Multiple taps are often found on replacement type transformers.*

this brings the high voltage to normal and boost voltage to normal, and gives us plenty of sweep width (GO, in other words), we know that the flyback, yoke, high-voltage rectifier, damper and boost circuit are OK. If it does *not,* then we don't have to waste time checking the oscillator or output tube circuits. We know there is trouble somewhere after the output tube—flyback, yoke, etc.—and we go directly into that circuit with our component testers: ohmmeter, flyback tester, etc.

Suppose we do not get the proper results (NO-GO) from this test. Now we must check individual parts to find out why not. Ohmmeter tests show that we have continuity in all places where it should be. So we check the flyback; disconnect all loads, such as the high-voltage rectifier, width coil and yoke, and take a Q measurement. If this shows us that the flyback is apparently shorted, we take it completely out of the circuit and repeat the test. If *this* shows shorted, we can feel fairly sure that the flyback *is* bad.

If the flyback shows OK on a Q measurement, then the short must be external or intermittent. (There will be two kinds of shorts to cause any overload: external and internal. What we have to do is separate them!) To find which of the external loads is causing trouble, we disconnect them, one at a time, and recheck by applying the substitute driving signal. For instance, if the yoke is shorted, when it's taken out of the circuit, the high voltage will come back up, not all the way, but increase. Boost will still be down, because boost comes from the yoke. Here, we should connect a substitute yoke; if this brings the HV and boost back to normal, then we have found the trouble. Boost is measured on a voltmeter. Easiest way to check the high voltage is to look for the bright vertical line on the face of the picture tube.

If this test shows the flyback and yoke to be OK, then we replace the output tube and check its circuits. Easiest way: break the cathode circuit and hook our 0–500 dc milliammeter in series. Then apply a substitute grid-drive signal to the control grid. If this gives us normal output (GO), then we go back and check the horizontal oscillator circuits. These have been covered in detail in earlier chapters.

So there you are. These tests are aimed specifically at just one thing—checking the flyback to be sure that it is bad before you replace it. They should be applied in cases where there is a distinct possibility that the flyback is faulty: where there is no high voltage, no sweep or very little sweep, and no boost or rf output at the high-voltage rectifier plate.

I'd recommend applying them in this order: First, drive the flyback alone with a substitute signal. If this is NO-GO, then disconnect the loads from the flyback and apply Q-measurement and continuity tests. If the results of all three point to a bad flyback, then replace it.

Flyback replacement

Since we've made up our minds that the flyback is definitely bad, we'll have to find a suitable replacement. This isn't the problem that it once was. In the early days, the only way to get a replacement flyback was to order it from the set manufacturer. Now several large companies are making very high quality replacement flybacks, yokes and all other sweep-circuit parts. Some of these are actually of higher quality than the originals!

Our replacement flyback should be an exact duplicate of the original, physically and electrically. The electrical characteristics are the most important, of course; we can deal with minor differences in mounting, etc. An exact duplicate will have the terminals numbered in the same order, making it a lot easier to install! Precaution: if possible, leave the old flyback on the chassis until you're ready to install the new one. If not, make a rough sketch of the connections on a piece of paper, and tie this to the set. Note such things as color of wire, "heavy red wire," "thin green wire," etc. and their positions. All this takes only a minute and saves a lot of time when you go back to a set after waiting a day or two to get the new flyback.

Many manufacturers issue yearly catalogs with complete listings of TV receivers. These give the original manufacturer's part number plus the number of the part recommended as a suitable replacement. These catalogs are very useful in other ways, too. They can be used to pin down unknown models of TV sets by checking part numbers all the way across.

Well-planned service data give part numbers, dc resistance and recommended replacements for almost all sets. They may also include terminal-board data for replacement transformers, a very valuable feature!

In addition to these helps, transformer makers pack complete instruction sheets with each flyback. A drawing of the terminal board is shown, with numbers, so that you can find the location of each terminal. Wire colors and other information can be noted on this sheet when the old flyback is removed.

In some of the earlier sets which were notorious for short flyback life, you'll find a slight variation in replacement flybacks. The root of this problem is a slight mistake in the original engineering: the flyback was underrated for the load it had to carry! Consequently, it went out in a short time. Some of the major transformer makers have designed heavy-duty replacement flybacks for these sets for longer life. They will be found in the catalogs. Many are in the form of a kit including the new flyback, width and linearity coils and sometimes the yoke. Using such replacements in these sets gives much better performance and a lot longer flyback life. The physical mounting is often identical to that of the original.

Flyback tests, after replacement

There is one thing you *must* do: After replacing a flyback, be *very sure* that you have found and corrected the trouble which caused the flyback to burn out in the first place! This means making tests to be certain that the new flyback is not overloaded.

After all connections are made, hook the milliammeter in the output tube cathode. Turn the set on, but keep your hand on the switch! Watch that cathode current: if it rises above normal, shut that switch and check back to see what's wrong. This does not mean too much, of course; it could be due to an incorrect setting of the linearity coil, etc. A short-term overload won't do any damage, say for 5 minutes, while your testing. However, before this set is returned to the owner, be sure that the loading is normal.

The careful technician will always "cook" a set on the bench, under more or less continuous observation, for at least 2 hours after a flyback replacement. This needn't interfere with other work. The set can be pushed to one end of the bench, and you can go on working on other sets while watching the screen out of the corner of your eye. If anything goes wrong, you'll notice it immediately. If you don't happen to have the picture tube with the set, leave the meter in the cathode circuit but place it where you can check it easily now and then.

Watch out for overheating, current above normal, or any signs of arcing or flashover on the screen. On the meter, the needle should remain very steady. Any sign of jitter or unsteadiness in the cathode current should be investigated and cured before the set's returned to the customer.

Chapter 9

Dogs and Intermittents

NOW, WE COME TO THE 'DOGS', THE ONES NOBODY CAN FIX. THERE are several breeds, but here's a controversial statement—none is hard to repair! Not if you use the right methods and common sense! Why? Because there are only a couple of little things wrong with 'em. There's an old saying: "Anybody can find the trouble if it's smoking!" So, the cause is something that everyone has overlooked. When you find it and make a permanent repair, your reputation will go up like an Atlas-Agena!

Now, what is the best way to start? The first thing to do is make a test. Any test; makes no difference. Find out *something* about this set, and then use that as a starting point.

Example: See if there is any high voltage. Check for rf at the HV rectifier plate. If it's there, go on toward the picture tube and see why you don't have HV. If it isn't, go back and find out why not. A 'negative' result on a test is just as valuable as a positive one; you get some information. If it's GO, then go on to the next stage. If it's NO-GO, turn back toward the oscillator, and work your way through the circuit until you find something that isn't right, and fix it. It's as simple as that.

Troubleshooting chart for horizontal sweep stages

While there may be a few cases that aren't shown in Fig. 901, I think we got most of them. To use this, find your particular symptom at the left, and follow the arrows until you find something to test! If you get a 'GO', turn back and follow the next 'NO-GO' triangle (arrow). This is nothing but a graphical presentation of the stuff we've been telling you about all through the book.

Clyde the clipper

There *is* one type of job that won't respond to standard servicing procedure. This is the set that has paid a visit to another "service technician." He knows little about TV, but does have a sharp pair of diagonal cutters! His method of 'servicing' is to clip parts, 'test' them, then stick them back wherever the remaining leads will reach! It doesn't make any difference if this is where they were or not, that's where they go!

There is only one way to deal with a 'butchered' set like this. You'll have to make a part-by-part check of the whole circuit to find not only the original part failure, but the damage that he has caused.

Start with the plate-drive; lift the plate cap, and connect a tester to see if the flyback, yoke and damper circuits are OK. If not, trace the complete circuit to be sure all wires are in the right place. Fortunately, most of these thugs are pretty sloppy 'solderers'. If you see a blobby joint, check it and all the circuits around it, to be sure that they're connected properly.

You'll need complete service data. Put the schematic on the bench alongside the set. Check off each part with a very light pencil 'tick' as you find it. This sounds like a 3-day job, but it isn't. There are only about 35—40 parts, counting everything, in the whole horizontal sweep circuit! Most will be easy to find and check. By using substitute signal tests, you can 'clear' whole stages at one time. Thus, if you can drive the flyback alone with a plate drive signal, and get HV, sweep and boost, then you've eliminated that whole circuit as OK, and you can go back to the oscillator and afc.

Wrong parts: resistors, capacitors, etc.

Watch for wrong parts! Clyde can't read color codes; in fact, sometimes I doubt if he can read, period. Nothing he likes better than mixing colors on resistors. So, if you think you see a 3.3-ohm orange-orange-gold resistor, look to be sure that it isn't a 330-ohm orange-orange-brown!

To sum up on 'dog-training' procedures: Start anywhere in the circuit and check both ways. Break the circuit into sections and check each until you know it's working. Use any test you want: voltage and current measurements, sub-tests, etc. After you have finished with one section, mark it OK, then go on to another. Final hint: in the sets where 'everything is OK but it still won't work', you've probably got an open electrolytic filter somewhere,

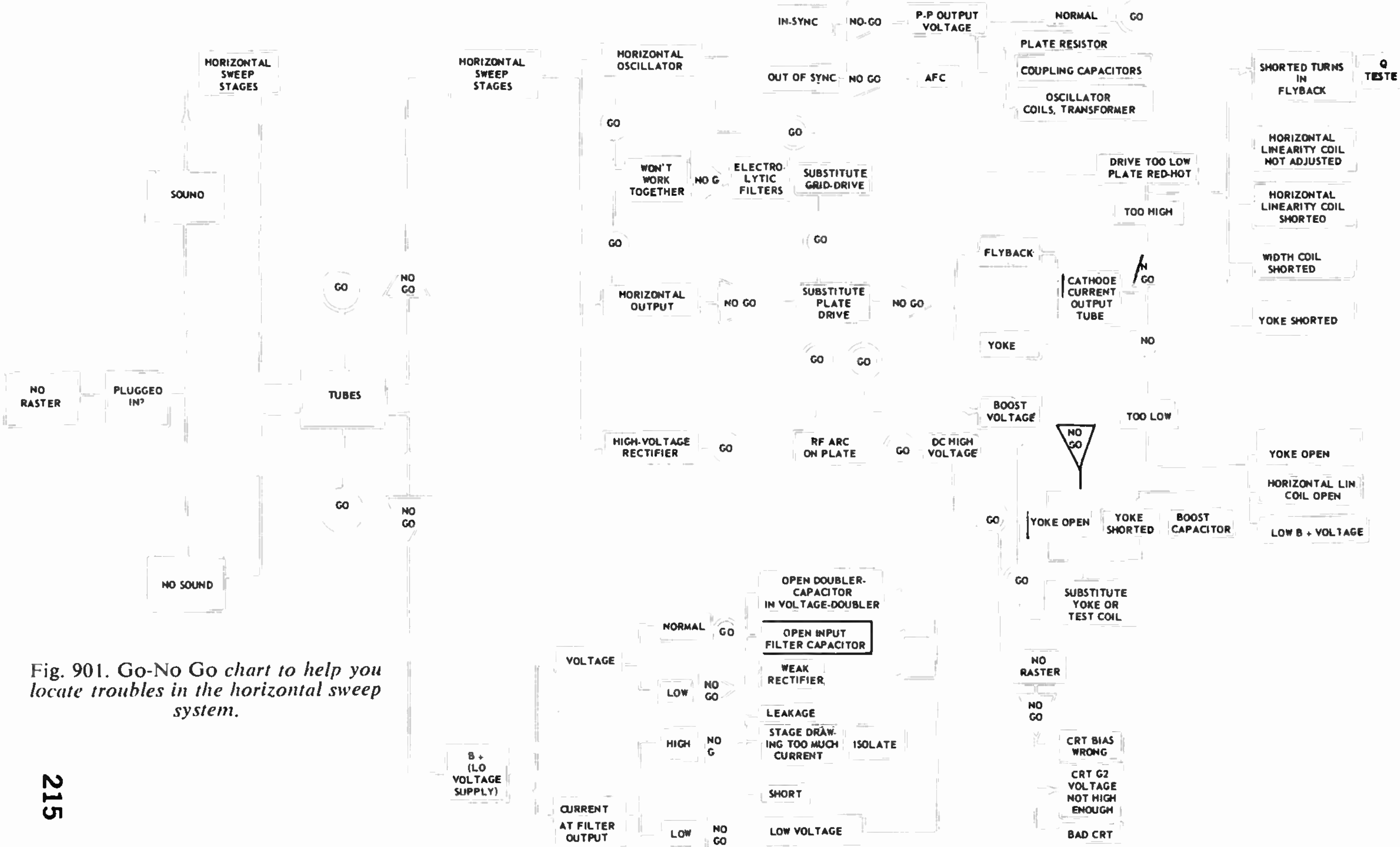


Fig. 901. Go-No Go *chart to help you locate troubles in the horizontal sweep system.*

even as far back as the input filter capacitor in the B-plus supply! So, strip 'em down to the bare essentials, make those work, and go on to the next one. When you run across something that could be the trouble, stop and fix it.

The intermittent

Now we come to the most annoying breed of dog possible: the intermittent. These work fine for any length of time, from ten minutes to ten days, then suddenly go out. Incidentally, we're going to confine ourselves here to intermittents in the horizontal sweep circuit, and those in other circuits which affect the sweep. They can cut out in a number of ways. This is a valuable clue; the way it acts when it does go out. The typical tough dog intermittent won't go out while you're watching it. So, you have to get your first bits of information from the owner.

Remember now, he doesn't know too much about TV. (If he did, he'd fix it himself!) So, you're going to have to phrase your questions carefully. Here are some suggestions, aimed at getting the most information in the least time:

1. How long does it take to cut out?
    a. Does it cut out after it has been playing for some time, or does it refuse to come on when turned on?
    b. If it cuts out after playing for some time, how long?
2. Does the screen stay lighted, or go dark?
3. If it goes dark, can you hear a pop, crack or frying noise?
4. After it goes out, can you smell something burning, like varnish?
5. After it went out, did you look in the back of the set to see if the tubes were still lit? Was the pilot light on (if any)?

This last is a very important question. Before leaving the home with the 'intermittent' set, check the line cord, wall receptacle, the interlock on the TV chassis, and the switch. Many an intermittent has been traced to a loose connection on the line cord or interlock socket! If this has been loose for some time, you'll find the contact pins on the chassis socket burned off to thin charred spikes! Don't move anything until you give this part a checkout. Shake the line cord, and be sure that the back is tightly fastened to the cabinet so that it holds the plug firmly in the interlock socket.

Now, with the answers to these questions we've at least got something to go on. The typical intermittent displays all the lovable characteristics of the 'tooth that quits hurting when you get to the dentist'! In other words, you can set it up on the bench and it'll play for days and days! So, we've got to have *some* idea of what kind of trouble to look for, and where to begin. This we get from the owner's answers to the test questions.

From the answers to the questions, you can get an idea of *about* where the trouble is.

Example: Set plays for 5 minutes, then the screen goes dark; sound OK. Definitely in the horizontal sweep circuit *somewhere*. Possibilities: intermittent tube, resistor or capacitor, or even intermittent contact in tube socket. Most likely cause; thermal. Something is getting hot, expanding and causing trouble.

Example: Set refuses to come on. Sound normal, no light on screen for several minutes, then lights up suddenly. Plays normally afterward. Possibilities: weak horizontal oscillator tube, which refuses to start oscillating until the set is well warmed up. Resistor in supply circuits increased in value, lowering plate voltage on horizontal oscillator to make it 'marginal' in operation. Open cathode-tab in tube. Cathode completely open until tube has heated thoroughly; thermal expansion closes circuit and tab welds temporarily. Weak low-voltage rectifiers; not so prevalent in sets using semiconductor rectifiers, but still possible.

Example: Set plays for several minutes then falls out of sync. Possibilities: same type of troubles, only in horizontal afc or oscillator circuits. Second possibility: sync tubes, lowering amplitude of horizontal sync. Does set lose vertical sync at the same time? If so, look in circuits working with both syncs: sync amplifier, sync separator, video amplifier, etc.

On the 'slow-heaters', which take up to 5 minutes to come on with sound coming on normally in less than 30 seconds, check the picture tube. An aging CRT can cause this symptom. If the screen lights up very gradually, and the other symptoms are present, suspect the picture tube; check it to make sure. A filament brightener will stop this for an unknown length of time.

Time-constants

You can get some valuable information from the time constant of the set; how long it takes to go out after it's turned on. Remember these are *not* definite, just helpful.

1 to 2 minutes—tubes. Tubes heat in approximately 15 seconds. If there are leakages or shorts they will show up inside of the first 5 minutes. Exception: tubes with small grid emission. These usually start showing troubles (picture weaving, bending, clipping, etc.) inside of the first 5 minutes, but may take 10 or 15 minutes to go bad.

Check in a good grid-emission tube tester to make sure. Easy check; replace all tubes in suspected circuits.

3-5 minutes – leaky capacitors; couplers, bypasses, etc. These begin to show up as soon as the stage gets into 'full operation'. Electrolytic filter capacitors sometimes fall within these limits, too. It takes about this time for gas to form inside a defective capacitor under load, and cause troubles; loosening of connector-tabs, etc.

5-10 minutes – resistors. If a carbon resistor is drifting in value, it usually takes about this length of time to show up. In most cases, these resistors are not being heated by an overload of current but by natural heating of the chassis. It takes the average chassis about this long, or sometimes even longer, to get hot all over.

Making an intermittent show up on the bench

Always take an intermittent to the shop. Several reasons for this. The most important one is the superior working conditions there, plus the easing of the pressure! So, you can take your time and be thorough. Before you take any intermittent set back as 'cured', be sure that it is! Don't be afraid to repeat a test, and especially, put the bad part back in and see if you can get the identical symptoms to show up! Sometimes you won't be able to but you will in most of them.

Our biggest trouble is going to be getting the thing to act up on the bench as it did at home. We have to see the trouble before we can make any kind of start at fixing it. This may seem impossible in some cases, but it isn't. There are several ways we can do it.

Cooking

The easiest way is to put the set on the bench and let it play until it goes out. You can go on with other work, keeping an eye on this one. If the trouble doesn't appear, then take more drastic measures. There are ways that can *make* the trouble show up.

Heating

The majority of intermittents seem to be 'thermal', associated with the heating of the chassis or parts. So, once we get some idea as to the general area of the trouble (that is, oscillator, output, flyback, yoke, HV rectifier, etc., from the symptoms and the owner's descriptions), we can apply localized heat to speed it up. Thus, if the oscillator seems to be the trouble, falling out of sync after about 15 minutes, this could be due to a drifting resistor. So, we set the chassis up to make a picture, then apply heat to each resistor in the circuit. Hold the tip of a soldering iron beside each one, watching the picture. There will be about 8 or 9 resistors in the whole circuit: of these, only about half will affect the operating frequency. So, heat these first. Leave the iron on each one until it smokes slightly, too hot to touch with a fingertip. This won't hurt a good resistor, but it will cause a bad one to show up. To verify this, disconnect the resistor, hook an ohmmeter across it, and reheat it. You'll soon see that this is causing a drastic change in value, if it is bad.

Same thing applies to capacitors, especially to small ceramic and mica capacitors. Heat can cause them to develop leakage and high resistance joints where the leads are soldered to the ends of the foils. So, don't overlook them when you're heating parts.

In printed circuit chassis, heating will cause hairline breaks in the wiring to open. If the symptom is intermittent, and hard to pin down because it shows up for short periods, try applying heat to the whole area. A standard 250-300 watt heat lamp, in a flexible gooseneck desk lamp, is ideal for this purpose, as you can see in Fig. 902. To concentrate the heat in a small area, wrap the bulb with aluminum foil, leaving a small round hole where you want the heat. You can heat an area as small as 1 or 2 square inches with this method. Good advice dep't: don't set this up and go away and forget it! You'll not only burn out the heat lamp, but you can melt the whole chassis in about 15 minutes! (And don't ask me how I know; just believe me!)

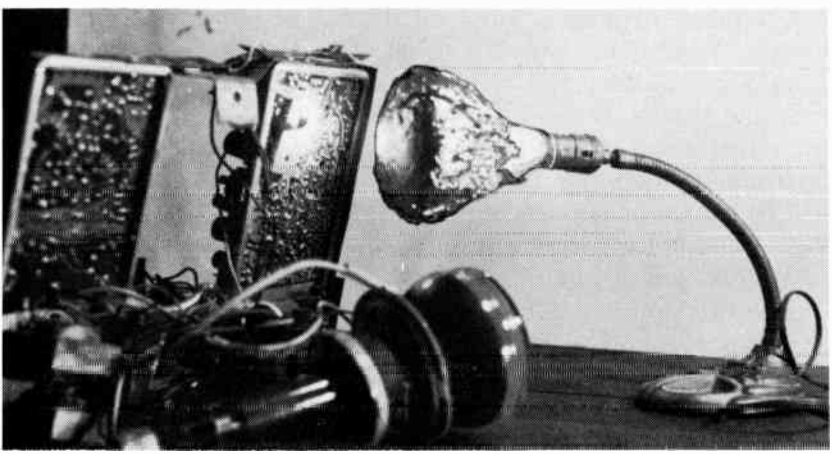


Fig. 902. *Standard 250-watt heat lamp can be used to apply localized hot spot to any area of the chassis.*

The typical symptom of hairline breaks in PC boards is a sudden stoppage after enough time to heat the board. If you can pin it down to a small area, it's often a time-saver to go ahead and resolder *all* of the joints there. This will take only a few minutes; just melt and let cool. If you suspect the wiring, run a thin string of solder along each 'wire': this will bridge hairline breaks and cure them.

You can often pin down hairline breaks in PC conductors with a short test lead, equipped with a pair of needle-point test prods. Use this to 'jump' each suspected conductor, pushing the sharp points into the solder at each end. If the circuit suddenly starts working again, you can make a permanent repair by shunting the broken conductor with a piece of insulated hookup wire, soldering it at each end. The bad 'wire' can be pulled off or left in place; it really doesn't matter.

The typical 'clue' to such a thermal intermittent is this: the set will cut out in the cabinet, but will play indefinitely out of the cabinet on the bench. (It's cooler.) So, to simulate the same heating condition, cover the chassis with a cloth; an old piece of blanket, or a cardboard box. Anything that will cut off the normal flow of cooling air. A cardboard box is very handy. Get one big enough to drop over the whole chassis, and cut a hole in it so that you can see the screen, to tell when the thing cuts out. If the intermittent affects the sound, leave the speaker connected, playing softly so that you can hear it and know when it stops.

One typical cause for this condition is shown in Fig. 903. This is a terminal strip on a 'hand-wired' chassis, but any of them can have it. The 'villain' here is a string of solder which has run down from a connection, and is within a few thousandths of an inch from the chassis. When the chassis heats, thermal expansion forces the solder down until it touches the chassis, and you've got a nice intermittent! Look for these. They aren't easy to see because they will be hidden under bunches of parts. Jarring the chassis, or probing around in the wiring with some kind of insulated tool will often make this kind of trouble show up.

An old nylon tuning-tool is a good thing for this. Make a small slot in one end. This can be slipped over the leads of capacitors and resistors, and used to 'wiggle' them back and forth to show up loose solder joints, intermittent connections inside capacitors, and similar troubles. There are 'soldering-aid' tools available, with the slots, but these are metallic, and you'll have to be careful punching around in a hot chassis with them.

Cooling

Newton said, "For every action, there is an equal and opposite reaction." We use this to fly rockets, and we can use it to find intermittents! Sometimes, our intermittent isn't due to "heat expansion", but to "cold contraction". In testing, this can get bothersome: once the chassis is warm, it takes quite a lot of time to get it to cool off enough for the trouble to show up.

As usual, though, we have our ways. If your shop is air-conditioned, try putting the chassis directly in front of the cold air outlet. More effective, and a lot easier, is localized cooling of suspected parts. You can get spray-can packaged "coolant" at radio-TV supply houses. Like all liquefied gases, this gets very cold when liberated. So, it can be sprayed directly on resistors, capacitors, and even tubes, to cool them off one at a time. A small nozzle allows cooling of only one resistor at a time if necessary. In emergencies, you can even use spray-cleaner, of the kind used to clean tuners and controls! This also cools things off, and has the added advantage of cleaning them at the same time! As a final resort, you may have to do what one irritated technician did: he stuck the whole set in his deep-freeze and really 'cooled it'! PS: he found the trouble, too!

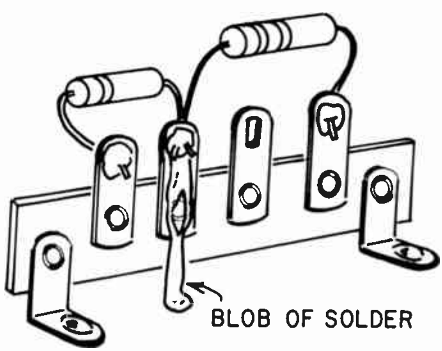


Fig. 903. *Heat causes solder string to touch chassis producing hard-to-find intermittent.*

Monitoring

One of the easiest ways of catching an intermittent is 'monitoring'. By this, I mean connecting some kind of indicator to the set so you can see just what is happening when the trouble shows up. For instance, you could make a setup something like this, and get a clue to the location of the trouble on almost any intermittent: Scope probe, clipped to wiring or parts near but not touching the output tube grid (set the gain to give yourself a display of 2 or 3 cycles at any convenient height); voltmeter (dc) connected to boost-voltage circuit anywhere except on the damper tube socket;

milliammeter (dc) in the cathode of the horizontal output tube; neon light indicator clipped to the plate lead of the HV rectifier; HV probe connected to the HV connector on the picture tube.

Any or all of these can be used simultaneously. Notice that they have the necessary characteristics of all intermittent-monitoring test equipment; they're connected to the circuit in ways which won't disturb it! We want to leave things exactly as they are, so that we don't inadvertently cure the intermittent by adding capacitance, closing a bad connection, and so on.

Now, when something happens, you can get an idea of about where the defect is. Let's say that the grid drive signal stayed where it had been, but the cathode current suddenly jumped far above normal, and the boost voltage dropped to zero. We know right away that we can eliminate the oscillator as a possible trouble source. This is an intermittent short somewhere in the flyback-yoke-damper circuit. Note: when we speak of the boost 'going to zero', we do not mean actually returning to zero voltage with respect to ground. We mean that it will drop back to the B-plus value, whatever this is. This means that there is no boost action. The damper tube will conduct continuously because it has B-plus on its plate, and we'll read B-plus voltage on both plate and cathode.

So, in such a case, we should turn the set off, and check something in that circuit: measure the resistance of the yoke, check the Q of the flyback: anything that will give us a chance of eliminating some part so that we can narrow down our list of suspects. We might disconnect the yoke and substitute either a yoke from a tester, or the horizontal winding from another yoke. Then, the test is repeated. If it goes out again, then we have cleared the original yoke of suspicion. Notice that we get some good out of every test. Even if we only clear one capacitor from suspicion, we've gained that much!

Substituting high voltage from an operating set is often valuable. With a known-good HV supply you can often see from the reaction of the raster what's happening. For instance, if the yoke does have an intermittent short, this would cause the set's own high voltage to go down. With substitute HV we'd see the characteristic keystoning, and make a dive for that yoke right away!

On a really tough intermittent, substitution is the best way to get information. For instance, we can set up a plate-drive check, locking the picture in by feeding a signal into the set which is supplying the drive and then watch. If the trouble shows up, we will have cleared the flyback, yoke, damper and quite a few other circuits, all at one fell swoop. Next, we can go back and drive the output tube in the intermittent with a grid-drive signal from our test-set. We can even go back far enough to use horizontal sync from the test set, if we want to. However, this usually isn't necessary. Just don't overlook any possibilities of getting information by substituting a known-good quantity: plate or grid drive, high voltage, even, in some cases, B-plus or boost voltage! If you suspect the B-supply to a given stage of acting up, lift the supply end of the resistor which feeds that circuit, and tie it into a point in the test set's B-plus line with the right voltage, and test away! This is very good for checking suspected intermittent filtering, since the test set (we hope) does have good filter capacitors.

Gadgets

There are innumerable helpful gadgets you can use. If you want to monitor the cathode current of a set suspected of an intermittent short in the flyback or yoke but, don't want to leave your expensive vom tied up, try this. Use the regular test adapter to break the cathode circuit, and connect a standard pilot light in series with it. Fig. 904 shows how this is done. If you want to,

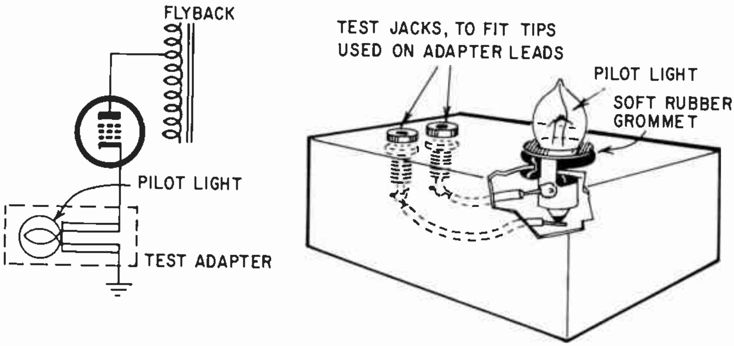


Fig. 904. *Simple gadget to "help you keep an eye on" cathode current of horizontal output tube. A pair of pilot lamp sockets, one for bayonet base and the other for screw base, connected in parallel, will enable you to use all the bulbs described in the text.*

you can mount a pilot light in a small metal utility box, by drilling a small hole in it and putting a soft rubber grommet in the hole. This will hold the bulb of the pilot light. The light is connected to a pair of pin-jacks, of the same type as those used on your regular meter. Of course, you can mount the pilot light socket permanently on the box to make it easier to change lamps.

By choosing the right type lamp, you can measure any desired current, with surprising accuracy. For example, to check output tubes that draw about 100 ma use a #40 (screw-base) or #47 (bayonet base) lamp. These take 150 ma for full brilliance. If we are drawing 100 ma they'll light up to a bright yellow. If a short develops in the circuit, the current may increase to as high as 200 ma. This will cause the lamp to flare to a bright bluish white, and may even burn it out. In any case you'll know *something* has happened! (Incidentally, a dime's worth of flash from a pilot light is a lot cheaper than $45 worth of the same from your vom!) Also, if something happens that causes the current to fall, loss of B-plus for instance, the lamp promptly goes out.

You can mount such a tester on your 'regular' end of the bench, where you can see it easily, and run wires so that the set being cooked can sit down at the other end of the bench out of the way. For checking tubes with 200-ma ratings, use a #46 (screw) or #44 (bayonet) lamp. Same effect; almost normal brilliance on normal load and a flare-up on overloads. You can use pilot lights in place of a fuse, by mounting a socket on a blown fuse of the right size. Currents up to 500 ma can be measured with the same ease, by choosing the right pilot lamp.

Voltage variation

High line voltage is often the cause of many 'mysterious' flash-overs, arcing, and assorted breakdowns of parts, after the set has has been checked out in the shop. Because of the voltage multiplication, especially in power-transformer sets where 110 volts from the line are 'transformed' into as much as 400 volts of 'B-plus', you can see what an increase in line voltage of 10 volts would cause! Parts would be overloaded and the high voltage circuits could go so high that they would arc over, etc.

Summation

You *can* fix any intermittent, with patience, skill, a thorough knowledge of the circuit, plus the right test equipment. This can be standard testers, or home-made, such as the adapters and junk TV we have mentioned. The results you get are going to depend not so much on the actual readings on the test equipment, but on your *interpretation* of them. Anybody can stick a prod in a set and make a meter reading; it takes a skilled technician to know what that meter reading means!

Printed in the United States of America