

**How To Test...**  
**Almost Everything Electronic**

by  
**Jack Darr**

**\$5.65**  
(In the U.S.)

# How To Test... Almost Everything Electronic

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Jack Darr



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## INTRODUCTION

In electronics, we work with things that we can neither hear, see, touch, nor taste. Electrical voltage, current, and resistance—these are “invisible” to our senses. A possible exception is high voltage. If we get an unwary fingertip into that, we can definitely *feel* it! However, that would be doing it the hard way. To learn what’s going on in our circuits, we use test equipment—special apparatus designed to give us visible or aural indications of what’s there and what it’s doing.

Test instruments are amazingly versatile. They will literally do anything, if we know how to use them, how they work, and what their *limitations* are. It is just as important to know what a test instrument *can’t* do as to know what it can. All instruments will make the tests for which they were designed; most will make many other tests as well, if we know how the instruments work and how to take advantage of their readings to indicate the presence or absence of other quantities.

That’s what this book is about—electronic tests and measurements, how to make them with all kinds of electronic test equipment, and how to *interpret* the results. Interpretation is the most important point of the whole process. It requires a full knowledge of the test equipment *and* the circuits in which we’re taking the readings.

We’ll begin with the fundamentals. You may be familiar with these, but read the material anyway. You never can tell when you’ll run into something new, or handy, that you hadn’t thought of before. This happens to me often.

There are three basic groups of measurements: quantity — meaning voltage, current, and resistance, plus capacitance and inductance; output — meaning the normal output of a certain unit, stage, or device; and fi-

nally, quality—which answers the question, “Are the output and operation of this device up to normal?” All of our test methods are combinations of these measurements, used as steps of a logical test sequence. If we use the right methods and equipment and a *logical* sequence of tests, we’ll get the results much sooner. For example, in testing a given stage, our first test should be qualitative: “Is the stage putting out the right amount and kind of signal?” If not, then we test for quantities: the correct and proper operating voltages and currents. When we find something off-value in one of these, then we test for the quality of the parts supplying the voltage and current to that stage. We find the defective one, replace it, and the trouble is fixed.

Dc voltage measurements are probably the most common tests on all kinds of electronic apparatus. Why? Simply because they are the fastest, easiest, and the most meaningful. By using them, we can get the maximum amount of information in a minimum amount of time. We don’t have to break the circuit; we simply connect one lead of our voltmeter to a common or reference point and then check for the presence or absence of proper voltages with the other lead.

By the correct interpretation of dc voltage readings in a given circuit, we can tell if the circuit is drawing the proper current. In some cases, we can tell whether there is a short circuit to ground, and so on.

How can we check current by taking a *voltage* reading? By noting the voltage present at a given point in the circuit. In almost every case, the current will have to go through at least one resistor to reach the test point. By noting whether the voltage at the test point is high, low, or normal, we can tell if the correct amount of current is flowing through the resistor. We’ll go into more detail as we go along through the various tests for tubes, transistors, and all kinds of devices.

All voltage readings—in fact, *all* instrument readings of any kind—are comparisons. The value we read must be compared against a standard before we can tell whether our test reading is high, low, or okay. For example, if we put a voltmeter on the plate of a tube and read 100 volts, this means absolutely nothing! If the standard value, given on the schematic diagram, says that this tube should have 200 volts, then we have learned something useful.

Experience is often very helpful. If we know the circuit of a typical TV set, for example, we already have a good idea of what voltages to expect on various other circuits. If we find that the plate voltage of a resistance-coupled amplifier tube is too high, we know the tube isn’t drawing enough current. The tube could be weak, or the load resistor could have changed in value, or the grid bias could be too far negative.

Fundamentals. If the collector voltage of a transistor output stage of an auto radio is too low, we know that the collector current is too low. All this is "straight Ohm's law"; current and voltage always have the same relation to each other no matter what kind of circuit you find them in. The most important difference between the tube and transistor circuits is in the *size* of the voltages and currents: tubes use high voltages and low currents; transistors use low voltages and high currents. But in every case, we can get our first clue to the cause of a trouble by taking a set of voltage readings.

An important part of making tests is *accuracy*. Our test equipment must be within a certain range of accuracy with respect to the standard. However, there are a lot of cases where absolute accuracy is not as important as many people think. In tube circuits, for instance, plate voltages have a wide tolerance: often as high as  $\pm 10\%$ . This means that a tube requiring 100 volts on the plate can have any value between 90 and 110 volts and still be okay. In transistor circuits, however, where we may find such a voltage reading as "base bias with respect to emitter, 0.4 volt," our accuracy must be considerably better. In this circuit, a voltage change of only 0.1 volt can cut off a transistor completely. So, we must know when to strive for extreme accuracy and when not to bother. This will be covered as we go through the various test procedures.

There are many shortcuts, combinations of instruments, etc., that we can use to test any quantity—even those that are apparently not in the range of such equipment. We'll give you as many of these as are appropriate. There will be others that you can work out for yourself. A great many of these are tests that can be made with such complex and expensive equipment as a pilot lamp, a neon lamp or a dc voltmeter!

Jack Darr



## Section I

### Power Supplies and DC Voltage Tests

#### 1-1. DC VOLTAGE MEASUREMENTS

To measure dc voltage, we use a dc voltmeter. This sounds a little obvious, but there are several different types of voltmeters, and there are also circuits where we must use the right type if our test readings are to match the standard. The first of the two major types is the “straight” dc voltmeter, as found in the typical volt-ohm-milliammeter (vom). It consists of a d’Arsonval movement (basically a milli- or microammeter) with resistance in series to give it the proper range. The other major type, of course, is the vacuum-tube voltmeter (vtvm) or its transistorized counterpart, which uses an amplifier to drive the meter movement.

In the first type, the meter movement and its series resistance are hooked directly across the circuit under test. In the second, a very large voltage-divider resistor is hooked across the circuit; the meter is driven by a dc amplifier whose input is tapped down on this voltage divider to obtain the desired range. Each type of meter has its uses, advantages, and disadvantages.

When it comes to using voltmeters, the most important difference between the two types is in their input resistances, since the input resistance sometimes affects the voltage reading you will get. The 1,000-ohms-per-volt meter—a typical “straight” voltmeter—has a basic 0–1-mA movement. With this movement, the meter—that is, the movement plus the series resistance—must offer a total resistance of 1,000 ohms for every volt of the full-scale range we want to be able to read. Such a meter, set to a 10-volt (full-scale) range, would have a total resistance of only 10,000 ohms; on a 200-volt range, it would have a resistance of 200,000 ohms. The 20,000-ohms-per-volt meter—another “straight”

voltmeter—uses a much more sensitive 50- $\mu$ A movement. With this meter, the 200-volt range has a total resistance of 4 million ohms (4 meg).

The usual vacuum-tube voltmeter uses an input voltage divider whose total resistance is 11 megohms. Some recent instruments have up to 16 megohms input resistance. This resistance remains the same for every voltage range the meter may have.

In power supplies, batteries, and other low-impedance, high-current circuits, the meter resistance—whether high or low—will not affect the circuit under test. If the voltage to be read has an ample current reserve, the type of meter used has nothing at all to do with it. They will all read the same.

On the other hand, in very high-impedance circuits—such as the plate circuit of a tube where the plate load resistance may be up to, say, 1 megohm—meter resistance can make a lot of difference! Let's take a tube with a rated plate voltage of 50 volts, which is supplied from a 150-volt source through a 1-meg resistor. Ohm's law says that this means a normal plate current of .0001 amp, or 100  $\mu$ A.

If we try to read the plate voltage with a 1,000-ohms-per-volt meter, on a 50-volt scale, our total meter resistance will be 50,000 ohms. Placing this low resistance across the tube results in a shunting effect; current through the plate load resistor will increase because it now has a 50,000-ohm path from plate to ground. Since it doesn't take very much current through the 1-meg resistance between the plate and B+ to give a terrific voltage drop, the indicated plate voltage will probably be close to zero!

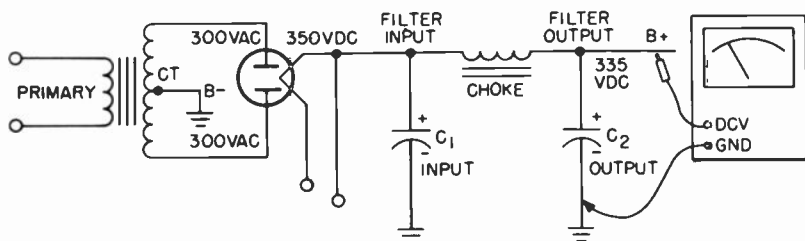
If we use a 20,000-ohms-per-volt meter on a 50-volt scale, our meter resistance will be 1 megohm. Putting this in parallel with the tube, we'd read about three-fourths of the actual voltage, or about 37.5 volts. Still not close enough, *unless* we do some mental arithmetic and consider the voltage drop *caused by the voltmeter*.

However, if we hook a vacuum-tube voltmeter with an input resistance of 16 megohms across the tube, things will look better. Now, with the shunt resistance through the meter much higher than the effective resistance of the tube, we'd read much closer to the actual value. In fact, since most voltage readings in such circuits are now made with vtvm's at the factory, we'd probably read 50 volts.

When testing a circuit, look at the little box in the lower corner of the schematic diagram to see which type of meter was used in taking the standard test-voltage readings. In some of the older sets, you'll find that a 20,000-ohms-per-volt meter *was* used—in which case, if you use a vtvm, all voltages will *seem* high! So, to get an accurate voltage reading, we must always know the test conditions and the type of instrument used to make the standard readings.

## 1-2. THE FULL-WAVE POWER SUPPLY

Here is a full-wave, vacuum-tube rectifier power supply with a power transformer. This circuit is used in many TV, PA, and radio circuits.



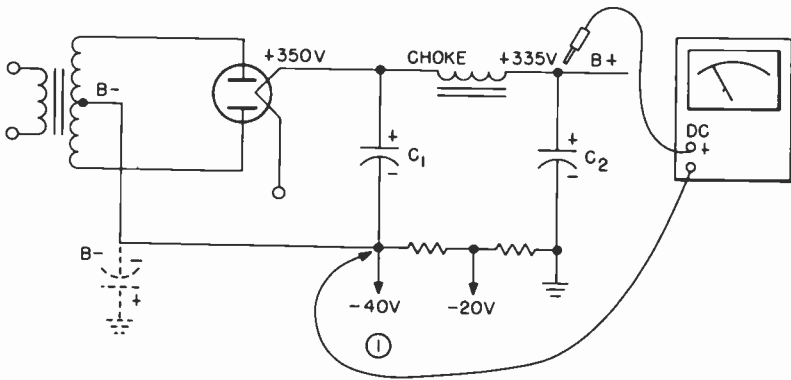
Let's look at the ac/dc voltage relations in it. To read the supply voltage for the TV or amplifier—or the “load,” from now on—we put the positive prod of the voltmeter on the filter output, which is one terminal of the choke. Set the meter to a scale that will show *more* than the voltage you expect to read. In typical TV circuits, this will be between 300 and 500 volts. So, start with the meter on a 0–500-volt dc scale.

Notice one odd thing: while we are putting in 300 volts ac at the rectifier plates, we're getting out 350 volts dc at the rectifier cathode. Are we getting something for nothing? No. This apparent voltage increase is due to a difference in the way the voltmeter reads ac and dc. Ac voltage is read as an *effective* or *rms* (root-mean-square) which is only 0.707 of the actual peak or maximum voltage in the waveform. (Conversely, the peak value is 1.414 times the rms value.) By rectifying the ac voltage, we get a series of dc pulses that reach the *peak* value of the input voltage. Here, this would be  $300 \times 1.414$  or about 420 volts.

When we feed this pulsating dc voltage to the input filter capacitor C1, a big electrolytic, we charge the capacitor to the peak voltage, less the “tube drop”; with 5U4's, etc., this drop is about 50 volts. We are drawing current out of the power-supply circuit to feed the load; this drops the voltage a little more, and we wind up with about 350 volts dc at the filter input. Drawing the load current through the filter choke gives us a small voltage drop, so we read about 335 volts dc at the filter output. In some circuits, you'll find resistors used in place of the choke. The higher dc resistance makes the drop within the filter higher, so you'll get a lower voltage at the filter output.

### 1-3. FULL-WAVE POWER SUPPLY WITH FLOATING B—

This circuit is exactly the same as the one in Unit 1-1 so far as the transformer, etc., are concerned; but notice that the center tap of the power transformer secondary does not go directly to ground, but through a pair of resistors. Since all of the load current flows through these resistors, a voltage drop will develop across them, and this will make B— negative with respect to *ground*.

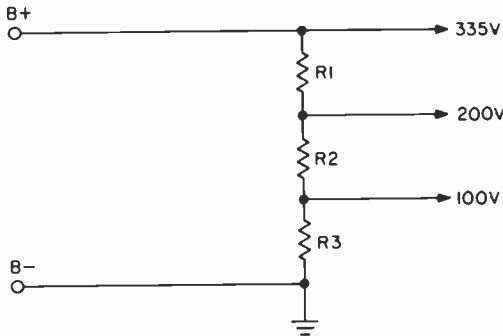


If we take our B+ voltage measurement as we did in Unit 1-1—ground to B+—we'll get the B+ voltage of 335 volts, *less* the value of the highest negative voltage. So, at the filter output, we'll read  $335 - 40$ , or 295 volts, to ground. To read the *total* B+ voltage, which is the same as before, we could hook the voltmeter prods as shown in the figure above—negative to B—, positive to B+. However, in almost all cases, we take these readings to ground, as a positive and a negative voltage, and then add them up in our heads. The voltages will be shown on the service data as so many volts positive (+) and so many volts negative (—), and this is really all we need to check.

There is one thing you must watch in this circuit. When replacing filter capacitors, notice that the negative terminal of the *input* filter does *not* go to ground as before, but goes to the B— point. This is necessary to get proper filtering.

## 1-4. POWER SUPPLIES WITH VOLTAGE DIVIDERS : I

In actual circuits, we need to divide the B+ voltage to get the proper values on the different circuits. So, we use a circuit that for some odd reason is called a voltage divider. Such a circuit is shown in the figure. We have the B+ voltage from the full-wave power supply just discussed, so all we need to do is make the + and - connections to the divider.



When we hook the series of resistors across the supply, we'll get a small, constant current flow in the resistors. This bleeder current helps to stabilize the voltage by furnishing a constant load on the supply. We can take off any voltage we need, by tapping down on the voltage divider.

You'll find a lot of variation in resistance values used in voltage dividers, but the total will probably be somewhere around 40–50,000 ohms. The total resistance is chosen so that the bleeder current will not be too high, which could overload the power supply. The values of the individual resistors are chosen to divide the total voltage as desired.

The resistors can be checked by reading the voltages at the taps, and vice versa. Here, the B- is grounded, so we'd put the negative prod of the voltmeter to ground, then read the voltages at the taps. For instance, we might get something like this: The 335-volt tap reads 345 volts; the 200-volt tap reads 210 volts; the 100-volt tap reads zero. What's the trouble? R2 is open. How do we know? Because of the characteristics of the readings; note that the taps that still read voltage have higher readings than normal. This means that part of the normal load has been lost. The bleeder current has also ceased, since the circuit from B+ to ground is open, and this raises the voltages still more. Double-check by turning the set off and reading the resistance of R2 with the ohmmeter.

## 1-5. POWER SUPPLIES WITH VOLTAGE DIVIDERS : II

Now let's see what happens if we find *almost* the same symptoms as in the preceding unit. Suppose the 335-volt tap reads 320 volts; the 200-volt tap reads 180 volts; and the 100-volt tap reads zero again. Note that these voltages are now lower than normal. You'll notice another typical symptom, too—especially if you touch the resistors—R1 and R2 are now very hot, and R3 is cold.

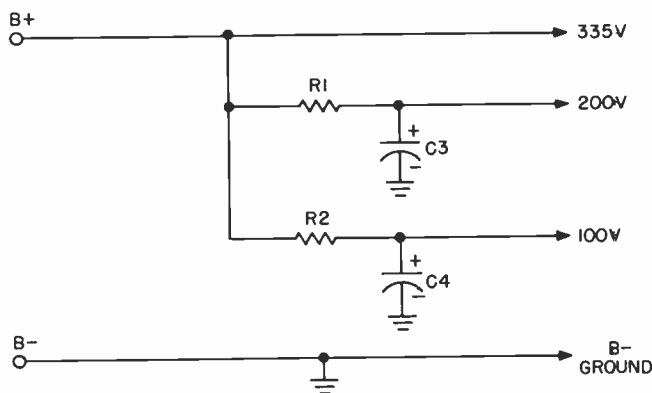
If we turn the set off and take resistance readings, we'll find that all of the resistors themselves are correct. However, when we read the resistance from the 100-volt tap to ground, we find a zero reading. There is the trouble! There are always bypass and filter capacitors farther in the circuit and one of these has shorted out.

The key clues, besides the overheating of the other resistors, are the low voltages. When the capacitor shorted, it took R3 out of the circuit completely. So, we have that much less resistance from B+ to ground. This means that the bleeder current will go up, and the total voltage will go down. In a great many cases, you'll find that this kind of overload will be enough to burn out R1 or R2. So, if you find an open resistor at any point in a voltage divider circuit, check on its *load* side (the end away from the source of voltage) to make sure that there is no short circuit there that could burn out a newly installed resistor.

## 1-6. POWER SUPPLIES WITH DROPPING RESISTORS

The figure shows the equivalent of the previous circuits, but with the resistors arranged a little differently. Here, we have individual resistors connected into each voltage-supply circuit. The end result is the same—each circuit gets its proper voltage. But we don't have the multiple-tapped voltage divider resistors. There is no bleeder current in such a circuit, of course.

The dropping resistors are chosen so that their values will give the correct voltage to each circuit when the current in that circuit is normal. This feature gives us a very good clue when there's trouble. If the voltage on any tap is low or high, then we should check that circuit first, to see why. The rest of the voltages won't be affected as much, but will be changed to some extent.



First check the supply voltage (this rule holds true for all power-supply troubleshooting). If we don't have the right supply voltage, none of the other voltage measurements will mean a thing. We can use some of the same obvious clues that we found before. For example, if we see some of the dropping resistors are very hot, and the supply voltage is low, we know immediately that there's a short circuit somewhere.

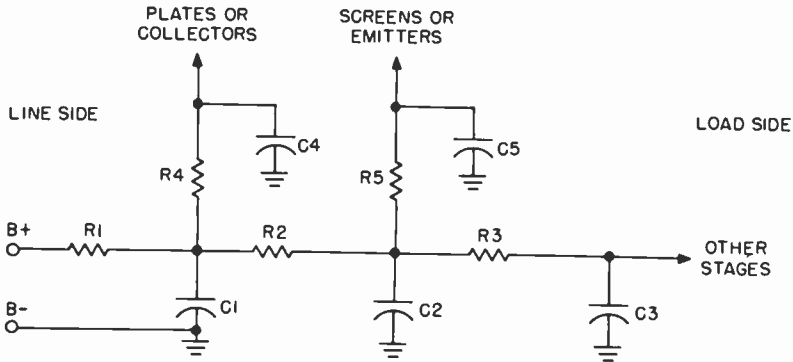
If the supply voltage is low, but there are no signs of overheating, then we look for something that is weak—an old rectifier tube, an open input filter capacitor, a weak selenium rectifier, or anything that would reduce the ability of the power supply to deliver the right amount of current.

These same tests apply to all circuits: First check the supply voltage, then the individual tap voltages. In the circuit shown, a short in one load circuit will kill the voltage at that tap, but won't make the others drop as much as before. For example, if we have a short in C3, the 200-volt line will read zero, the 335- and 100-volt lines will go down by about 10%. The key clue will be R1; it will be very hot. If the short has existed long enough to cause R1 to burn out, then the 200-volt line will read zero, but the other voltages will be above normal because of the loss of the normal load current in the 200-volt line.

Many sets use this circuit. The average dropping resistor will be a 2-watt carbon type. If it's been overheated, you'll notice a decided change in its appearance. The case will be darkened, and the color-coding paint will have changed color because of the heat. The red bands, if there are any, are particularly valuable as indicators. They are the first to show a change of color from overheating and they usually turn a dark brown. Any resistor that shows signs of overheating should be checked. In fact, it's a good idea to replace it on general principles; the overloading may have changed the resistance value.

## 1-7. POWER SUPPLY CIRCUITS WITH BRANCHES

Here's a power-distribution circuit found in all kinds of electronic equipment using tubes or transistors. The main differences between the tube and transistor circuits are in the values of the resistors and the voltages; voltages range from 30 to 40 volts for transistors and up to 300 or 400 volts for tubes.



In the figure, the supply point (B+) is again at the left-hand side. B- is ground. The current goes through R1, then branches through R2 and R4; the current through R3 goes on to other circuits. Each junction point is bypassed by a capacitor; this is absolutely necessary to keep the rf impedance of the power supply very low. Since this distribution circuit is common to all stages, we must prevent any interaction between the various circuits. If we don't, we'll get feedback, and the equipment will oscillate.

The capacitors are the most common cause of voltage troubles. If any one of them shorts out, it will kill all voltages past the point where it is connected in the circuit. However, there's a quick and easy way to find a shorted capacitor.

Here B+ is the supply side or line side of the network. The right-hand side of the circuit is the load side—the stages that need the voltage. If we know where the current is coming from and what it goes through on the way, we can tell what's wrong when it doesn't get to where it should!

For instance, if C2 shorts out, we'll read zero voltage at the junction of R2, R3, and R5. Clue No. 1: Voltage is present at the junction of R1, R2, and R4, but it isn't as high as it should be. Clue No. 2 is easy to spot: R2 is probably getting very hot. R3 and R5 are cold. So, we look on the load side of R2 for the short. The current must go through the last



hot resistor in the circuit before it gets to the short. Turning the power off and taking an ohmmeter reading, we find zero resistance to ground; such a reading is always wrong in a voltage supply circuit, so we've found the trouble. To confirm this diagnosis, disconnect C2 and check it. The short disappears from the resistor network, and C2 shows a high leakage or short.

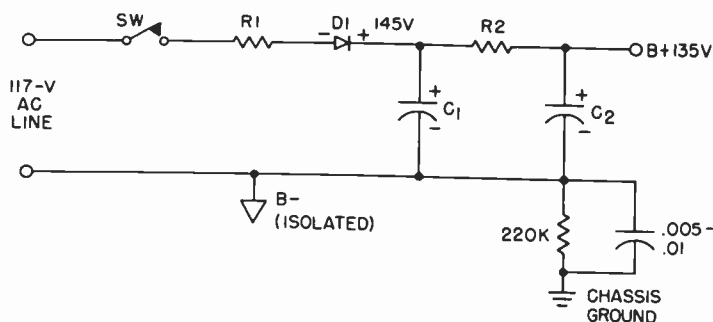
When you're hunting for a short in the power supply, start at the power supply (B+) and go from there toward the loads. Remember this procedure, because it's always the easiest way to find the cause of the trouble. Use the schematic diagram. Trace the power-supply circuits to each stage through the dropping resistors, past any bypass capacitors that could short out, until you get to the point where you found no voltage.

In a transformer-powered circuit, you'll find normal resistances of about 20,000 ohms to ground. This is mainly the leakage resistance of the electrolytic filter capacitors. In silicon-rectifier or voltage-doubler circuits, you may have to disconnect the rectifiers; they offer a very low back resistance, which can falsely indicate a short circuit.

Another quick check is to disconnect some of the loads and see what happens. If the supply voltage suddenly jumps back to normal, the last load disconnected could be the trouble spot. Also, you can make mental additions of the various dropping resistors in the circuit by checking their values on the schematic; take resistance readings at each end of the circuit, and compare. In the circuit shown, for instance, if all resistors were 1,000 ohms, and C1 was shorted, you'd read 1,000 ohms to ground from B+, and 2,000 ohms to ground from the load end of R3 (R2 + R3).

## 1-8. THE SIMPLE TRANSFORMERLESS POWER SUPPLY

Many types of equipment now use transformerless power supplies, for economy's sake. Instead of stepping up the ac voltage with a transformer, we apply the line voltage directly to a rectifier, at the standard value of 117 volts rms. Actual line voltage may vary, of course; but most equipment is designed to work, as stated on the rating-plate, at "105-120 volts ac."



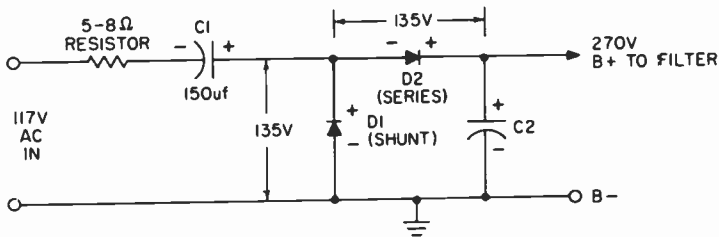
The figure shows the simplest possible circuit—a half-wave rectifier and filter circuit (the filter is the same as before, if you'll notice). Here again, we find the dc voltage higher than the ac input. With 117-volt ac input, we'll read about 145 volts at the rectifier and about 135 volts at the filter output. The input capacitor, C1, will be a big electrolytic, usually from 60 to 100  $\mu$ F. A resistor of about 1,500 ohms is used as a choke.

Notice one important thing about this and all "line-connected" circuits. We can't use the chassis as our B— any more; if we did, this would mean that it *could* be connected to the hot side of the ac line, if the line plug were plugged in "wrong." This would be very dangerous to the user. So, we isolate B— from the chassis; this B— point is shown by the hollow-triangle symbol. This point is usually returned to the chassis through an RC network consisting of a large-value resistor shunted by a bypass capacitor. The chassis-ground symbol is the same as usual.

To measure dc voltages in this circuit, we must take the readings between B+ and B—; measurements between B+ and chassis won't be accurate, because of the large series resistor. One fast way to find the negative terminal is to put the voltmeter negative prod on the negative terminal of the electrolytic capacitor. In can-type electrolytics, with one exception, the can is always negative. In cardboard-tube types, the black wire will be the negative if standard color coding is used.

## 1-9. THE HALF-WAVE VOLTAGE DOUBLER

The 135 volts from a simple transformerless power supply isn't high enough for TV circuits, so we need a circuit that will give us a higher voltage. Such a circuit is the voltage doubler shown below. There are several types of voltage-doubler circuits, but this is the most popular, probably because it's the simplest. It is called a half-wave voltage doubler, because it uses each half of the incoming line voltage to charge a separate capacitor; the two capacitors are then discharged in such a way that the voltages add up. This is the basis of all voltage-doubling circuits.



Although they tell us that an electrolytic capacitor should never be connected to the ac line, here we seem to have one hooked right to it: C1 is in series with the ac input. However, if we follow the return circuit, we can see that the capacitor is never subjected to a true alternating voltage. On the first half-cycle of voltage, the polarity is such that D1 is conducting. Current flows into C1, then out through D1, which is the "shunt" rectifier, and back to the other side of the ac line (note that this is a unidirectional current). When we say that current flows through C1, we mean only this one-direction *charging* current. Such a current flows in all capacitors while they are charging to an applied voltage.

Now, C1 is charged to about 135 volts, and during the next half-cycle of line voltage has such a polarity that D1 is not conducting, but D2 is. So, the current from the line flows on through D2 and charges C2; at the same time, C1 *discharges* through the same circuit, and its voltage is added to the charge on C2; since the polarity is the same (positive with respect to B-), C2 charges up to double the line voltage and we get about 270 volts instead of the 135 we got in the ordinary half-wave rectifier circuit.

The voltages here are read to an isolated B- point, as shown. The most important thing to look for in voltage readings here is balance. If both rectifiers and both capacitors are good, you will be able to read the dc voltages as shown: 135 volts across D1, from B- to the center tap of the two rectifiers, and an equal 135 volts directly across D2, from

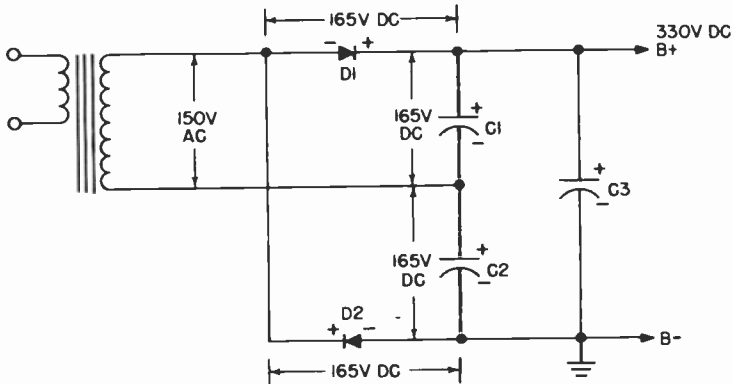
center-tap (place the negative meter prod here) to positive or B+. If you read 135 volts across one rectifier and only about 80 volts across the other, the chances are that the "low" rectifier is faulty.

If the input capacitor loses capacitance or opens, the dc voltage will drop to less than half normal or disappear entirely. If C2 opens or loses capacitance, the dc voltage will drop quite a bit, and there will be a great increase in the hum level. The small resistor seen in the ac input is called a surge resistor and is a fusible type; although it is a wirewound resistor of about 4–5-watt rating, it is designed to act as a fuse. If something shorts out in the power supply, it will open and prevent further damage. (A good quick-check for this resistor, in actual circuits, is to carefully feel it after the set has been on for a minute or two. If it's warm, it's okay. If it's "stone cold," it is very apt to have been blown.)

This is the instance we mentioned in an earlier unit where the can or negative terminal of an electrolytic capacitor is *not* B—. Notice from the circuit that *both* sides of C1 are "hot" with respect to the chassis, B—, and practically everything else! Because of the pulse nature of the current and voltage across C1, it is very difficult to check this capacitor with a voltmeter. The symptom of an open C1 is a large drop in B+ voltage; the quickest test for this condition is to shunt a known-good electrolytic capacitor of about the same size across it. Hook your dc voltmeter to the output with test clips, note the reading, and then shunt the test capacitor across C1; if the dc voltage jumps up to normal, replace C1. You don't have to use the same size capacitor for *testing*. If you replace a capacitor, always use exactly the same size; but any size capacitor will do for a quick test. If C1 is 150  $\mu$ F, as many are, you can shunt, say, an 80- $\mu$ F unit across it; a very definite rise in the dc voltage indicates that the original capacitor is bad.

## 1-10. THE FULL-WAVE VOLTAGE DOUBLER

The full-wave doubler is the original voltage-doubler circuit. It was used with special dual-diode vacuum tubes in old radios, and is now found in quite a few circuits with selenium or silicon rectifiers as shown here. To make the circuit easier to read, we've shown it fed by an isolated transformer secondary winding—a circuit that you'll find in actual equipment in many cases. In a few cases, this circuit is used without the isolation transformer—not too many, though, because the floating center tap makes it hard to handle with respect to the rest of the circuits.



It works like this: On the first half-cycle of voltage from the ac supply, D1 conducts and charges C1, just as in the half-wave rectifier circuit. Since D2 is reverse biased during this time, it does nothing. On the next half-cycle, the polarity reverses; D2 conducts and charges C2, and D1 is cut off. Now, we have two big electrolytic capacitors; each one is charged to 165 volts dc, and they are connected in series. So, we can take the “added” voltages off and feed them to the filter as the sum, or 330 volts dc. The action of this circuit depends on the alternate-charging and series-discharging of these two capacitors. This is the basis of all voltage-doubling circuits, but it is not so apparent in the others. Here, you can see the two separate capacitors.

Tests are the same as in the half-wave circuit. Read the dc voltage across each rectifier, watching your voltmeter polarity; this reading should be 165 volts dc on each one. The same goes for capacitors C1 and C2: the voltages must be equal, because the capacitors should be the same size. The dc output voltage is the sum of the voltages across the two capacitors. C3 is the filter capacitor.

If one of the doubler capacitors should lose capacitance or open, the

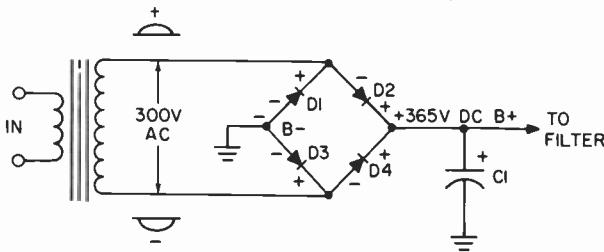
circuit will not balance and the output voltage will drop quite a bit. The same thing happens if one of the rectifiers goes bad. As we said, the doubler capacitors must match; you'll find sizes from 40 up to perhaps 200  $\mu\text{F}$  used here. The size of the doubler capacitors affects the developed dc voltage. As a rule, the bigger the doubler capacitors, the higher the dc voltage, because larger capacitors will hold more charge.

The filter capacitor, C3, has nothing to do with the doubling action; the doubler capacitors have very little to do with the filtering. So, if you have a bad hum, with almost normal output dc voltage, the filter capacitor is weak. If you have some hum and the voltage is low (more than 25%), one of the doubler capacitors has probably gone weak or almost open.

In the isolated circuit shown here, the B— point can be grounded to the chassis. In line-connected circuits without any isolation, both the capacitor center tap and B— must be isolated from the chassis, as in the half-wave circuit. This can be confusing when you are taking dc voltage readings, so watch out. Always connect the negative prod of the voltmeter to the negative terminal of the filter capacitor, not to one of the doublers, unless you are *sure* that you are on the negative terminal of C2.

## 1-11. THE FULL-WAVE BRIDGE RECTIFIER

Here's a circuit you'll find used in color TV, two-way FM transmitter-receiver power supplies, and many others, including low-voltage supplies for ac power of transistorized equipment. It's a full-wave bridge rectifier. It has many advantages. Notice that the isolation transformer needs no center tap. So, the full secondary voltage is available at the rectifier output, rather than half of it, as in the center-tapped full-wave rectifiers seen before. This saves both size and cost in the power transformer. The circuit can be made fully isolated, and B— will usually be the chassis.



It works like this. On one half-cycle, one end of the secondary winding will be positive, the other end negative. Current will flow through D1 and D4 to the load and ground, respectively (in the same direction with respect to the load), while the other two rectifiers have reversed polarity and will not conduct. On the next half-cycle, D1 and D4 will be reverse biased and cut off, and current will flow through D2 and D3. So, we use both halves of the cycle, as in the full-wave circuit shown earlier.

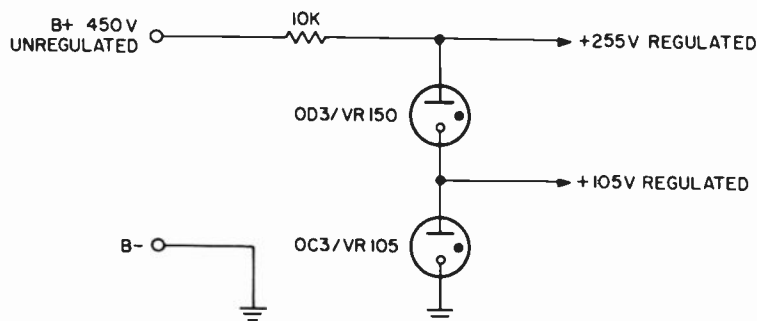
One advantage of the bridge circuit is that there are always two rectifiers in series across the total ac voltage of the secondary. Thus, for a given output voltage, the individual rectifiers have a lower peak voltage applied to them than in other circuits. This gives them longer life expectancy, allows the use of lower ratings, etc. The ripple frequency is 120 Hz, as in other full-wave circuits.

When making replacements, look for the identification on the rectifier. Notice that there are two positives hooked together, and two negatives. These are always B+ and B—, respectively. Each end of the transformer winding always gets one positive and one negative and it doesn't matter which of these is which. In some circuits, you may find bias resistors connected between B— and chassis ground. These work in exactly the same way as in the previous full-wave circuits.

The dc output voltage here is related to the ac input voltage as it is in the full-wave tube-type rectifier circuit, except that in the bridge circuit the entire secondary voltage of the transformer is the ac input. If we have a 300-volt rms ac supply to the bridge, we will read the same proportion of increase as before; so, we get about 365 volts dc at the filter input, read between B+ and ground or B— in the circuit shown. This dc voltage is developed by charging C1, the input filter capacitor, to the peak voltage of the rectified ac output, just as in all other rectifier circuits. If the output voltage is low, this capacitor should be checked first. Once again, hook the dc voltmeter to B+, and then shunt a good electrolytic capacitor across C1. If C1 is low in capacitance, you'll see the voltage jump back up toward normal. If C1 is completely open, your dc voltage will probably read about 40% to 50% of normal, or even less, depending on the load current being drawn.

## 1-12. VOLTAGE REGULATORS — TUBE TYPES

We often need dc voltages that will stay constant: to stabilize critical circuits, hold gain constant, serve as reference voltages, and so on. So, we regulate. In vacuum-tube circuits, we use special voltage-regulator tubes. These are gas-filled; by the use of different electrode spacing, types of gas, etc., they can be made to have different output voltages. The common values are 90, 105, and 150 volts.



A series dropping resistor is connected to the B+ supply voltage, and the tube is connected from this point directly to ground. If the supply voltage rises, the tube conducts more current; this increases the voltage drop across the series resistor, so that the voltage drop across the tube stays almost the same as before. If the voltage falls too low, of course, the tube has no control (it usually goes out—that is, stops glowing).

In this circuit, taken from an oscilloscope, a type OD3 (old designation, VR-150) and OC3 (VR-105) have been hooked in series to give a total of 255 volts dc. A 105-volt tap comes off the OC3 for another circuit.

A voltage-regulator tube can be used as an indicator of the presence of B+ voltage. Just look to see whether it is glowing. Some glow blue, others have an orange tint, depending on the gas used. If the regulator tube is glowing, B+ is definitely there, and probably okay. Lack of glow means that the tube is defective or that there is no B+ voltage, usually the latter.

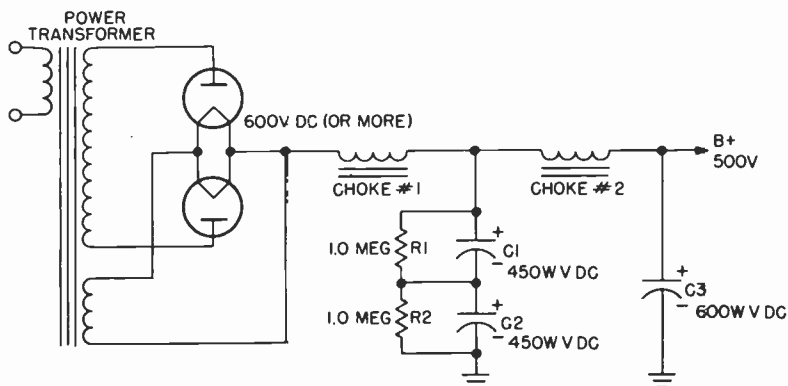
If there's a short in one of the circuits fed by a regulator tube, the overload may drop the voltage below the level at which the tube is supposed to regulate—105 volts in the case of the 105-volt OC3—and the tube will go out. If the dropping resistor increases in value, or if the supply voltage drops below the value needed to fire the regulator tube initially (133 volts dc, minimum, for the OC3) there will be no glow.

Voltage-regulator tubes very seldom, if ever, short out as others do, because of their construction. However, if you suspect that one has, simply pull the tube and recheck voltages.



## 1-13. ELECTROLYTIC CAPACITORS IN SERIES FOR HIGHER WORKING VOLTAGE

Here's a circuit you'll find now and then in high-powered amplifiers, and in a few transmitters. The figure shows the basic schematic. Notice that the filter circuit has a choke input for better voltage regulation. This cuts down on the peak voltage, but helps to hold the output voltage much steadier.



In this circuit, we're getting into B+ voltages that are above the normal working voltage of electrolytic capacitors. The average TV filter capacitor will be rated at about 450 working volts, with a 550-volt peak surge rating. This means that the capacitor should withstand 450 volts—at turn-on, for example—without blowing out. This peak rating shouldn't be exceeded or even reached, for more than about 15 to 20 seconds. The working-voltage rating, for the best results and longest life, shouldn't even be met. A 450-volt capacitor, for example, shouldn't be used in circuits with steady or normal voltages of more than about 400 volts, and this is cutting it a little close; personally, I like to have at least 100 volts of safety factor. A 450-volt capacitor working at about 350 volts is about normal in the average well-built TV set or amplifier.

However, there are times when we simply must have an electrolytic that will hold a higher voltage. So, we simply put a couple of capacitors in series. This works just as with paper capacitors; we wind up with half the capacitance and twice the voltage rating.

We see this scheme used in the figure. Here, C1 and C2 are 450-volt capacitors (900 volts total) and big enough so that the resultant capacitance is enough to give adequate filtering. In a typical commercial circuit, a pair of 100- $\mu$ F capacitors is used, giving 50  $\mu$ F at 900 volts. One

thing must be remembered whenever such units are replaced: for best results, the two capacitors must be of *exactly the same value*. If you use 100- $\mu$ F and a 60- $\mu$ F in series, the smaller capacitor will assume a greater percentage of the total voltage, and probably blow! So, if you have to replace one capacitor of a pair like this, always use an exact duplicate. Actually, if one shorts out, I replace *both*, because the remaining capacitor has been severely overloaded and could fail in service soon.

The 1-meg resistors hooked across the capacitors are necessary to equalize the voltages. They take no perceptible current from the circuit because they are so big. If you want to figure it out, they will draw 1 mA of current for each 1,000 volts across 1 meg! So, if we had 600 volts here, and 2 meg, our total current would be 0.3 mA (not enough to make the power transformer run hot!).

Quick-check in this circuit: Read the dc resistance from B+ to ground, at the rectifier cathodes or filaments. If you read 1 meg, one of the filters is *shorted*. (You're reading a short through one and a 1-meg resistance across the good one.) The normal reading, of course, would be 2 meg or less, depending on your ohmmeter polarity. You'll read a certain amount of leakage resistance through the electrolytics, of course. You must disconnect all loads—including voltage dividers and bleeder resistors, if any—for this test to have any meaning.

## 1-14. AC POWER SUPPLIES FOR TRANSISTORIZED EQUIPMENT

Up to this point, we've talked about power supplies for vacuum-tube equipment. Now, let's see what the differences are between these circuits and ac power supplies used with transistorized equipment. Ready? *There are no differences*. The same basic circuits are used in both types of equipment. There *are* differences in the values of voltage and current, however. Tube supplies use high voltages and low currents; transistor supplies use low voltages and high currents. If a TV supply has 350 volts output at 250 mA, it draws 87.5 watts. A transistor amplifier power supply with a —25-volt output at 3.5 amps also draws 87.5 watts. There is no difference in the *power* supplied; only the values of voltage and current are different. As long as their product stays the same, the output power is the same.

In one respect, we need different test equipment for transistor circuits. In tube circuits we measure high voltages; in transistor circuits we must

measure very small voltages—a tenth of a volt or so. With tubes, voltage *tolerances* can be very high. If the rated plate voltage of a tube is 100 volts, in a great many cases it can vary from 90 to 110 volts, without making a lot of difference in the output of the tube. (In some circuits, you'll find tolerances as high as 20% or even 25%.) So, our dc voltmeter can have a fairly large error before it makes any difference in a tube circuit.

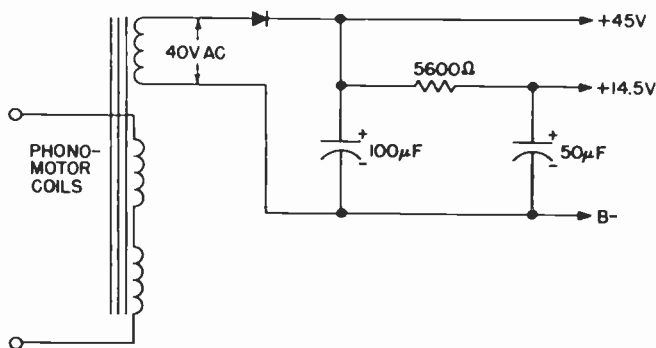
Transistor voltages are more critical for two reasons. One, we're working with tenths of a volt; and two, tolerances are much tighter than with tubes. In the bias voltage reading of a typical transistor amplifier, you may find such values as these: base, 0.4 volt; emitter, 0.6 volt—giving a 0.2-volt difference. Trying to read that on a 5-volt range (the lowest on many vom's) is demanding a great deal from an instrument whose accuracy at *full scale* may be no better than 5%. In the lowest quarter of the scale, it may be considerably poorer. A good vom for this kind of work should have a 2.5-volt (or lower) low range with at least 20,000-ohms-per-volt sensitivity and 2% full-scale accuracy.

Changes of a fraction of 1 volt can come from a variation in the supply voltage. We find voltage-regulated power supplies quite often in better transistor equipment. Like tube circuits, the cheaper transistor units simply use "straight" power supplies and depend on the regulation of the power line to keep them within limits. However, even under the best circumstances, the ac line voltage varies constantly, as its load changes. The use of some kind of voltage regulation makes transistor equipment work much better. Batteries, of course, furnish a steady source of power. In high-quality equipment, such as laboratory-type transistorized voltmeters you'll find the *battery* supply going through a voltage regulator!

Transistors are far more sensitive to hum than tubes. Transistors operate on very small voltage changes—which cause very large current changes for a given power output in watts. Since hum is always a voltage phenomenon, we really have to lean over backward to make sure we have taken out every last bit of hum and ripple in the power supplies. You'll see some highly specialized circuits in the next few pages that have done this. Voltage regulation serves a dual purpose here; since hum is voltage variation, we'll automatically take out the hum if we use a regulator that holds the voltage absolutely constant.

## 1-15. POWER SUPPLY FROM A TRANSFORMER WINDING ON A PHONO MOTOR

Here's a power-supply circuit that you'll find on many small phonographs with transistor amplifiers. The novelty is in the use of a separate winding on the phonograph motor, making the motor serve as a power transformer as well. Transistors need low voltages but high currents. So, using a power transformer to obtain a suitable supply voltage is much better than the only other method: a dropping resistor in series with the ac line. With a dropping resistor, heavy current changes that occur in transistor circuits would cause the supply voltage to change as well, upsetting the circuits.

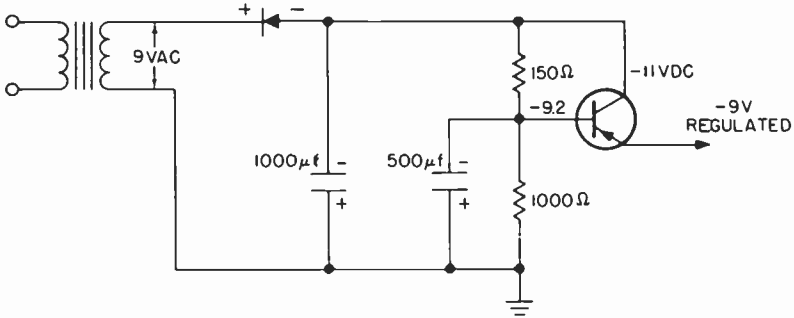


In this circuit, a simple half-wave rectifier is used. In others you may find full-wave rectifiers, bridge rectifiers, and so on. They all work on the same principle as the power supplies discussed earlier.

In a variation of this circuit, used with small one-tube phonograph amplifiers, the filament of the tube is connected in series with the phono motor. The motor, of course, must be specially wound to work on the lower voltage. A typical example of such a circuit uses a 25-volt tube in series with a 92-volt motor;  $92 + 25 = 117$  volts ac, so the combination can be connected directly across the line. You can always tell by its behavior when this circuit is used; if the tube blows out, the motor stops!

## 1-16. A TRANSISTORIZED CAPACITANCE MULTIPLIER

Transistor circuits need very good power-supply filtering. Also, they need very good voltage regulation, which is another way of saying the same thing. Very large capacitors help stabilize supply voltages; their charge furnishes extra current when sudden peaks occur in the load current, holding the voltage steady. Even with the large capacitances used in transistor circuits, we can always use more. The figure shows a voltage regulator called a capacitance multiplier because of its effect.



The load current from the power supply flows from the collector to the emitter of the transistor, just exactly as in the voltage-regulator circuits. We control the transistor's resistance with its base bias. We can make the resistance higher for low currents, and lower for high currents, thus holding the output voltage steady.

Notice the voltage divider connected between the -11-volt supply and ground. The transistor base is hooked to the junction of the two resistors. Under normal load, the base will have a certain voltage (-9.2 volts here) that will hold the emitter voltage constant at -9 volts. It does this by controlling collector-emitter current or, looking at it another way, by controlling the resistance of the transistor.

If the load current goes up, the bias changes in response. The higher current loads the power supply; the supply voltage drops. The voltage across the voltage divider drops, and the base bias drops with it. This change makes more current flow through the transistor (lowers the resistance); so, there is now a lower voltage drop across our variable resistor and the output voltage is held where it was. (This action takes a good while to describe, but it occurs in a split second.)

In effect, the circuit uses the 2-volt drop across the transistor as a reserve. When the supply voltage tends to go down, the circuit adds part of this reserve to the output voltage. The reverse is also true; if the supply

voltage tries to go up, the transistor takes on a larger surplus.

Why call this circuit a capacitance multiplier? Because of its effect. If we had a very large capacitor across the power-supply output, it would hold a quantity of electrical energy; from this reservoir it could release energy whenever needed to hold the output voltage constant. The capacitance-multiplier does the same thing with a smaller capacitor. The capacitance multiplication of a given transistor is related to its current gain: The higher the gain, the better the circuit will work. (Current gain is the ratio of a small change in base bias to the corresponding change in collector-emitter current.)

The base capacitor (500  $\mu$ F in the circuit shown) plays an important role. By holding a charge, it holds the base voltage as steady as possible. When the supply voltage drops, the base voltage would also drop if it weren't for this capacitor. It discharges part of its energy through the 1,000-ohm resistor, and the resulting voltage drop opposes the supply-voltage drop and holds the base at the normal voltage.

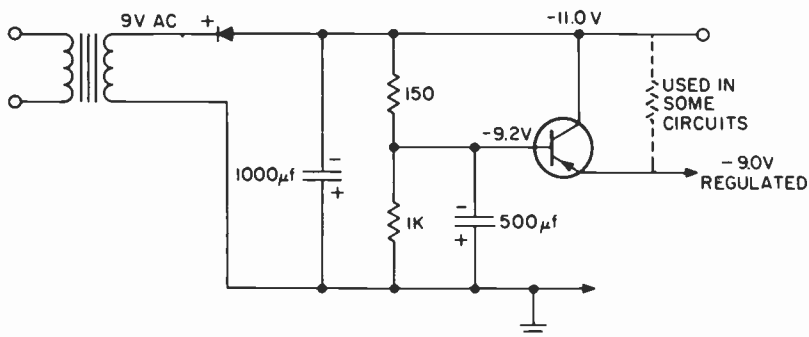
## 1-17. CHECKING CAPACITANCE MULTIPLIER CIRCUITS

To check a capacitance-multiplier operation, check all of the dc voltages and compare them with the values given on the schematic diagram. They should be very close. Be sure to check the ac input voltage to see that it is normal; most circuits are rated at 117 volts ac input. Vary the loading. In an audio amplifier, for example, turn the volume full up for maximum load and then all the way off. This variation should have no effect on the output voltage of the capacitance-multiplier circuit.

If the output voltage is low, disconnect the load. If the voltage jumps back up to above normal, there may be a heavy overload of current being drawn by the amplifier—more than the regular circuit can handle. The load current can be measured by putting a milliammeter in series with it at the voltage-regulator output. The proper value will be given on the schematic.

Check the dc voltage between collector and emitter of the regulator transistor. If this difference is very low, or zero, check the base voltage before you decide that the regulator transistor is shorted. If, in the circuit shown, the base should be down to about -8 volts instead of the nor-

mal  $-9.2$  volts, the transistor would be conducting as hard as it could in an effort to hold the voltage up. A wrong base voltage could result from changes in the values of the voltage-divider resistors, excessive leakage in the base electrolytic capacitor, etc.



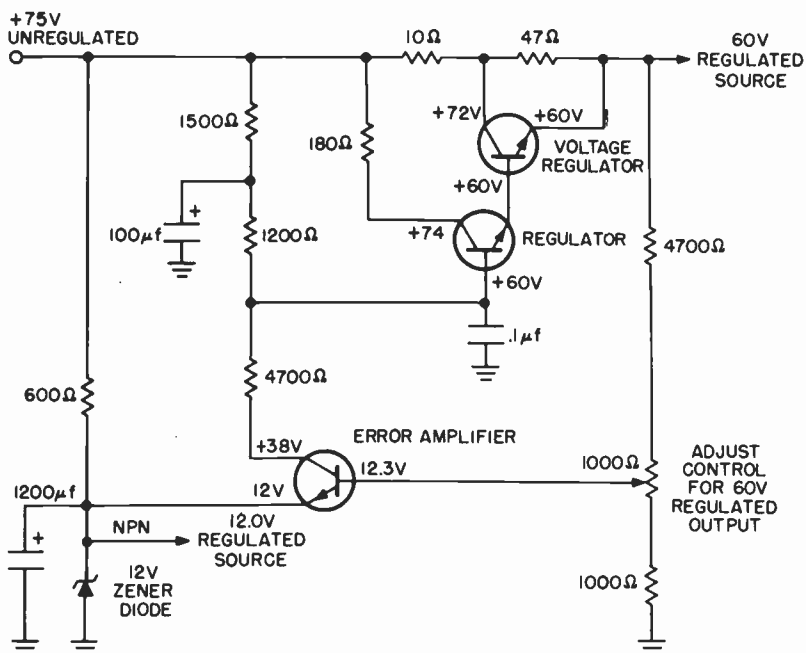
As usual, there is an alternate trouble that can show similar symptoms. Check the control transistor for shorts and leakage. If you're not certain, take it out and check it with an ohmmeter; all transistors should show the diode effect on each pair of elements. Also, check the schematic to see if there is a shunt resistor connected across the control transistor, as shown by the dotted lines. Such a resistor is used in some circuits to reduce the current loading on the transistor junction; it is a fairly low-value resistor, and of course would upset any in-circuit tests for back resistance between collector and emitter leads.

If the output voltage is low—say, by about half the normal voltage—check the input filter capacitor. If this capacitor is open, there will be no reservoir effect, and the output voltage will drop drastically. It is not a good idea to bridge capacitors for test in transistor circuits; the charging pulse can cause transients that can damage transistors. For safety, turn the set off, clip the test capacitor across the suspected unit, and then turn the set on again. With the instant warmup of all transistor circuits, you won't lose any time.

If you suspect the rectifier of being weak, use the same procedure. You can clip another rectifier across the original unit—watch the polarity—and turn the set back on. If this brings the voltage back up, replace the old rectifier. Silicon rectifiers will not get weak as seleniums do; they usually short out completely when they do fail. You may find one that is completely open, but not often.

## 1-20. A THREE-TRANSISTOR VOLTAGE REGULATOR FOR TRANSISTOR TV SETS

Transistor TV sets need very close regulation. The three-transistor circuit shown is used in one leading make. This regulator uses exactly the same principle as the single-transistor circuit, but is more elaborate. A pair of direct-coupled transistors is used as the regulator, controlled by an error amplifier. A 47-ohm resistor is shunted across the voltage-regulator transistor from the collector to emitter, to carry part of the load.



The error amplifier makes this circuit quite sensitive to small load-voltage variations. The base is connected to the slider of the voltage-adjust control, which is a part of the voltage divider across the output. In the emitter circuit, a 12-volt Zener diode clamps the voltage at this value and also provides a 12-volt regulated source for some of the TV circuits. The collector is supplied from the 75-volt line through the three resistors; it is also connected to the base of the lower transistor of the regulator. So, the collector voltage of the error amplifier sets the base voltage of the regulators.



If the load current goes up, the output voltage goes down—that is, more negative. The base of the error amplifier also goes more negative. This transistor is an npn unit, so the shift in base voltage changes the bias so that *less* current flows in the collector–emitter circuit. This circuit includes the three resistors from the 75-volt unregulated source. With a lower current flowing through these resistors, the collector voltage goes more positive; it rises. This makes the base of the lower control transistor more positive. It's another npn, so the positive-going base voltage makes it draw *more* collector current. This reaction in the lower transistor is transferred and amplified by the upper one; its collector–emitter current increases (or its resistance decreases) and more current is fed to the load circuits, making the voltage come back up again. If the opposite happens and the load decreases, making the output voltage go up, just repeat all of this, but reverse the polarity of each reaction.

This regulator is adjustable. Using a Variac or adjustable transformer, set the ac input at exactly 120 volts, and connect an accurate dc voltmeter across the 60-volt regulated output. With the TV set tuned to a station, adjust the voltage control to make the dc meter read exactly 60 volts, and that's all there is to it. To check operation of the regulator, vary the input ac voltage up and down 5 to 8 volts from the 120-volt level. The dc output voltage should stay at 60 volts.

If this test shows too much variation, check the dc voltages on all three transistors. See that the collector voltage of the error amplifier changes as the voltage-adjust control is moved. If it doesn't, go back and check the base voltage of this transistor to see if it is changing. Make the regular tests for leaky or shorted transistors.

Normal drop between the collector and emitter of the (upper) regulator transistor is 15 volts; if this is too low, or if there's no drop at all (output voltage too high), this transistor may be shorted. Since these are large transistors, and bolted in, they're not hard to remove for testing. When you return them, be sure to get all of the insulating washers, etc., in the right places!

## 1-21. TRANSISTORIZED DC-TO-DC CONVERTERS

Now we come to a different type of transistor circuit. We've been discussing circuits where the ac supplies the power for the transistors. Now we're going to make the transistors convert dc to ac and then change the ac back to dc at a higher voltage. This is a circuit you won't often see. It's used mostly in middle-aged two-way FM transmitter power supplies and in auto radios built during the transitional period before they went all-transistor.

In the original auto-radio power supply, a vibrator interrupted the dc in the primary of a transformer so that we could step up the voltage to the 200 volts or so needed for the plates of the tubes. The transistor version does the same thing; it supplies an ac voltage for the primary. We can step it up, rectify it, and come out with a high dc voltage. Transistors produce ac by oscillating. The alternating current in an oscillator circuit is a good substitute for the interrupted dc from a vibrator (it's also quieter).

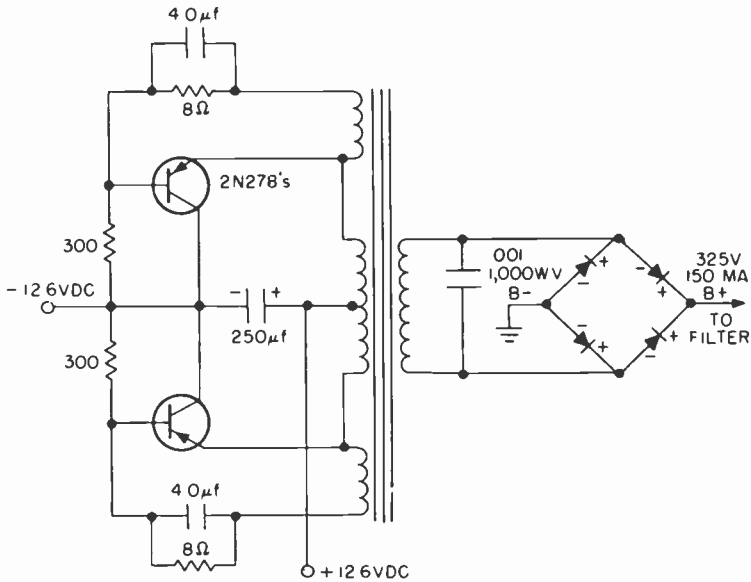
These circuits are usually called dc-to-dc converters when the output is a high-voltage dc. However, there is another popular application; we leave off the rectifier and filters and come out with ac. By making the output 117 volts at 60 Hz, we can use ac equipment in cars, etc. Such dc-to-ac circuits are usually called inverters or dc/ac converters.

The figure shows a typical dc-to-dc circuit; it could be a transmitter power supply, a supply for a tube-type PA system, etc. The same principle is used in all such circuits. A transistor, or pair of transistors, is connected to the primary of the transformer. Feedback windings make the transistors oscillate. (This is a blocking-oscillator circuit, but other types can be used.)

These oscillators are often run at frequencies above 60 Hz. The higher the frequency we use, the smaller the transformer can be. Power-line transformers must work on 60-Hz ac; vibrators run at about 115 Hz. We can make transistor circuits run wherever we want, though. Motorola, in some of its two-way radio power supplies, uses a frequency of about 400 Hz, and others have used frequencies up into the thousands of Hz. (These supplies sound peculiar to an old-timer when a filter capacitor opens up. He's used to hearing a low 60-Hz hum, and a high-pitched howl can startle him.) With high-operating frequency, filter capacitors can also be much smaller for the same filtering efficiency. These characteristics make this circuit ideal for use in mobile and airborne equipment.

The output of the oscillator is a pretty good square wave. This is highly efficient and also fairly easy to filter into a good dc. Bridge rectifiers are commonly used, with standard pi-type filter circuits.

The figure shows a typical dc-to-dc circuit with a common-collector connection.



## 1-22. TESTING DC-TO-DC CONVERTERS

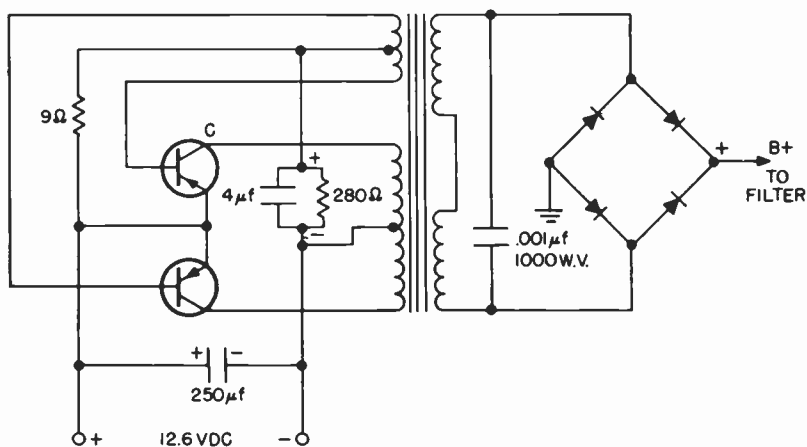
In actual use, the dc-to-dc converter has been a remarkably trouble-free circuit. Some have been known to run for five years or more without ever giving trouble. However, they're simple to test. The dc output voltage should be measured first. This must be read under full normal load, of course, as in all other cases. If the converter is used in a radio transmitter, the voltage should be measured with the transmitter keyed on and tuned for full rf output.

If the dc output is low, check the dc input voltage first. In mobile units, make this check in the vehicle with the engine running. Many cases of false trouble have been traced to simple dropping-off of the vehicle's battery after a long test under power. If the engine is running at a fast idle, the charging system will keep the voltage up to normal as when the vehicle is in actual service. Incidentally, on a 12-volt system, this voltage should read almost 14 volts. Running the engine can make a big difference in the

rf power output of a transmitter: It has been known to bring rf power from 35 watts to the full-rated 50-watt output.

The ac voltage output from the transformer can be measured if you suspect the rectifiers of being weak. However, since this is a square wave, your rectifier-type ac voltmeter will not read the true value because it's calibrated on a sine wave. If it reads about 300 volts ac, that's probably good enough. If so, then the trouble must be rectifiers or filters because the transistors are definitely in oscillation.

If the transistors are not oscillating, check all parts. Since there are only five or six it won't take long. The figure shows a common-emitter oscillator circuit similar to the one shown in the preceding unit, but with a slightly different hookup. It works exactly the same.



If either of the 4-μF capacitors in the feedback circuits is open, the oscillator will not work at all, or not at the right frequency. If it is trying to run, there will be some ac in the secondary, but not at the right frequency, so the output will be very low.

The output waveform should be in a pretty good square wave, and it *must* be balanced. If it shows a decided imbalance, look out: This means that one of the transistors is not conducting as heavily as it should. Possible causes are leaky capacitors, leakage in the transistor itself, or an off-value resistor.

The circuits shown use pnp transistors. Npn's will do the same job, but the voltages will be reversed in polarity.

## 1-23. HOW TO READ BATTERY VOLTAGES CORRECTLY

Until now, this section has dealt with reading dc voltages in ac-powered supplies. However, we shouldn't forget the old original source of power—batteries. A tremendous amount of battery-powered electronic equipment is in use today, so we must know how to check batteries correctly.

There's only one accurate way to read the voltage of a battery—under full load. This is easy; just turn the equipment on before taking a reading! Practically all batteries recover some voltage when the load is taken off. So, if we want to know what voltage is present under actual operating conditions, check it with the equipment on and the batteries under load.

Even a dead dry-cell battery will read almost full normal voltage if you check it with a dc vtvm, which places practically no load on the battery at all. When current is drawn from such a battery, the voltage drops to practically nothing. A brand-new standard dry cell will read about 1.64 volts. This will drop to about 1.4 volts after an hour or so of use, and then gradually drop off as the active materials of the battery are used up. When a cell reaches a load voltage of 1.1, it is considered "dead." Early battery radios were designed for a cutoff of 1.1 volts per cell; transistor radios may work a little past this point, but the volume will be fairly low.

Incidentally, dry batteries are figured at 1.5 volts per cell; so, a 9 volt battery would be made up of 6 cells at 1.5 volts apiece. So, cutoff voltage for a 9-volt battery would be 6.6 volts under full load, and so on.

Special battery testers can be obtained. Such a tester is nothing more than a dc voltmeter combined with a shunt resistor to draw current from the battery being tested. A battery tester might be useful at times, but it is certainly simple to just turn the equipment on and read the battery voltage with an ordinary voltmeter.

In auto radios and other equipment used in cars, the power comes from the car's storage battery. Older cars have 6-volt systems, and most newer cars have 12-volt systems. The 6-volt type actually reads 6.3 volts if the battery is fully charged, and the 12-volt system, 12.6 volts.

If the engine is running, the generator or alternator should be feeding current into the battery to keep it charged; the system voltage will therefore go up. The upper voltage limit is controlled by the car's voltage regulator. With the engine running at a fast idle, the voltage shouldn't go above about 14 volts or so. If the voltage regulator isn't set properly, the voltage can go higher than this and cause damage to transistors, especially the high-power output types used in car radios now. If the system checks higher than 14 volts with the engine running, have the voltage regulator adjusted by a competent mechanic.

## Section 2

### Current Tests

#### 2-1. CURRENT MEASUREMENTS: INTRODUCTION

Current measurements aren't as simple to make as voltage measurements. We have to put the meter *in* the circuit instead of touching across it, and this takes more time. Also, we have to be very careful—if we pick the wrong current range, or short the load to ground accidentally, we can blow a meter very quickly. For this reason, many technicians are reluctant to use current tests. However, current measurements can give a great deal of information about a circuit in a short time, and that's what we must have. With reasonable care, there is no more risk of meter damage in this test than in any other kind of test.

We can make the job of getting the meter into the circuit much easier with some special equipment. Test adapters of various kinds let us take current measurements by "plugging in," without unsoldering wires. Some types of adapters can be bought ready-built, but you may have to make up a few types. They're well worth the little time it takes, in terms of bench time saved.

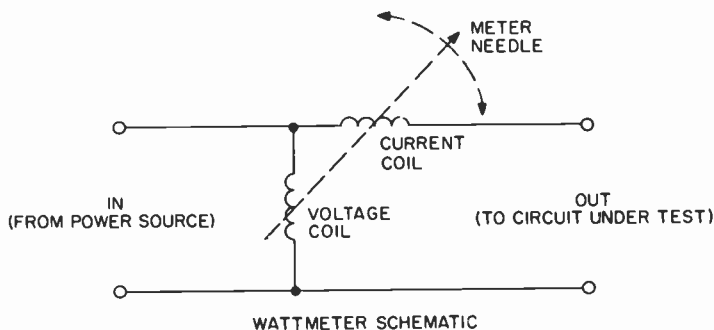
Reading the *input current* drawn by any electrical apparatus can tell you the total wattage being consumed; simply multiply the current by the applied voltage. The actual wattage consumed is a valuable piece of information, since the rated wattage is almost always given in the service data for the apparatus. If a device is taking more power than it should, there is definitely something wrong—a leakage, a short circuit in the power supply, etc. By measuring input current, we can, for example, check a power transformer for an internal short; such a check can save up to an hour in this case, perhaps more in others.

The input-current test works on ac and dc equipment, all the way from a tiny transistor radio up to a 5,000-watt transmitter. Current measurements within a circuit are essential in transmitter testing and in all kinds of high-power work such as PA systems, high-power amplifiers, etc. In high-power transistor amplifiers, a current measurement will tell you if transistors are leaky, indicate whether bias voltages are correct, and give you other useful information.

## Power Measurements

If a TV set, amplifier, etc., becomes too hot as it plays, we need to know whether it is actually drawing too much power and, if so, why. The input wattage of any piece of ac-powered equipment is a very good clue to what's going on. A check of the actual power being consumed can be used to pin down a short or leakage in the power-supply circuits, or even an open circuit—one that isn't drawing as much power as it should.

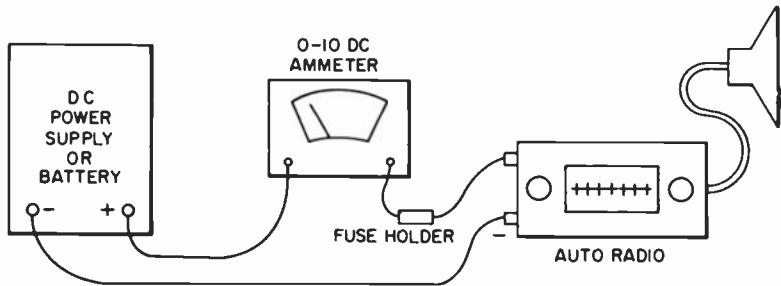
The watt is a unit of power which is always a *product*—volts multiplied by amps. So, an ordinary voltmeter or ammeter will not read power. We have to take simultaneous voltage and current readings and then do the arithmetic. There are wattmeters that will do this for us. They're actually combination volt-ammeters, having a current coil in series with the line and a voltage coil across it. Both coils affect the position of the meter needle: the amount of deflection depends on the product of the currents in the two coils, so the scale can be calibrated directly in watts (see the figure).



There are many uses for this instrument. However, wattmeters are not commonly found in service shops, since they are fairly expensive. We'll show you some shortcut tests that give the same information, but use more common test equipment. Any of the wattage tests we'll discuss can be made accurately with the three substitute testers described in a later unit.

## 2-2. MEASURING THE DC DRAIN OF AN AUTO RADIO

Measuring the current drain of an auto radio is about the simplest current test. All you need is a 0–10-amp dc ammeter. This is connected into one of the power-supply leads to the auto radio, as shown. The rated current drain for the set will be given in the service data.



For older tube sets with vibrators, current often runs as high as 8 to 12 amps. The early hybrid models, using low-voltage tubes for the early stages and transistors in the output stage, draw about 1 to 1.5 amp at 12 volts. All-transistor sets take even less.

If you use an ac-powered bench supply for operating auto radios for test, this will probably have a dc voltmeter and an ammeter built in. If not, your vom can probably be used for the ammeter; such meters usually have a dc range of 10 amps or so, which is ample for most auto radios. Be sure that the supply *voltage* is set to the stated level, because this affects the current drawn and the wattage.

If the tone of an auto radio is not as good as it should be, and the current is either more or less than the rated value, check the bias on the output transistor(s), since the output stage causes the heaviest current drain in the whole set.



## 2-3. DC CURRENT MEASUREMENTS IN TRANSISTOR PORTABLE RADIOS

Current measurements are invaluable in servicing small transistor radios, particularly the subminiature types. Because of their small size, it's hard to get into these circuits. So, we take current readings, which we can do from the outside, and get all the information we can before we start taking things apart.

Practically all of the bench power supplies used for testing these radios have a dc milliammeter as well as a dc voltmeter. If yours doesn't have one, you can always use the 0-25- or 0-50-mA range of the vom, as in Fig. 1.

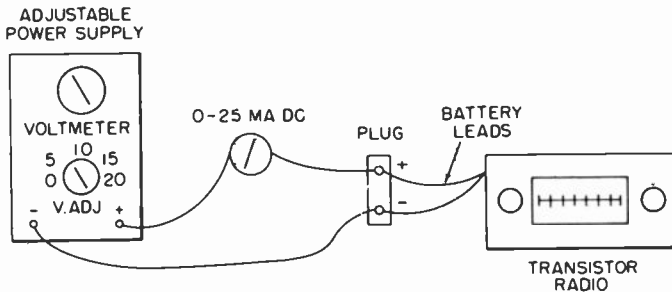


Figure 1

It will speed up the work if you make a set of connector harnesses. Take the battery terminals from a dead battery and solder a set of test leads to them, watching polarity. Now, when a radio using this size battery is being worked on, you simply snap on the connector. It's handy to have a harness for each of the common size battery sizes.

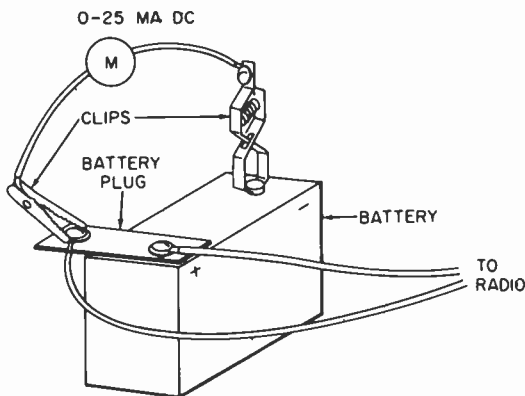


Figure 2

A set of test leads with alligator clips is very useful. For example, you can use them to connect a milliammeter in series with the radio battery by turning the battery plug sidewise and clipping on as in Fig. 2.

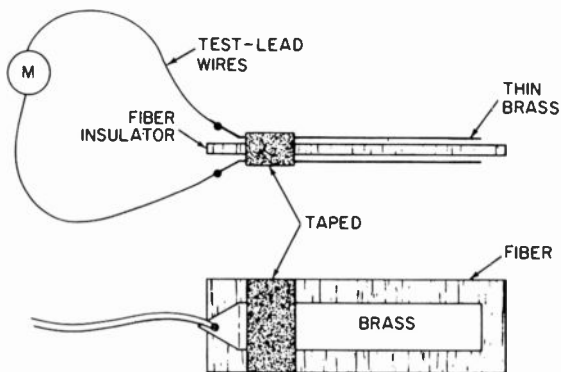


Figure 3

If the radio uses penlight batteries in holders, you can get the meter into the circuit with an adapter like the one in Fig. 3. Get a strip of heavy insulating paper, such as the fish paper used in electrical work, about one-half inch wide and two to three inches long. Cement a thin strip of brass (shimstock) to each side, and solder test leads to the ends of the strips. Be sure the brass strips are cut a little smaller than the insulator. To use this adapter, insert it between any two batteries in the string and connect the test leads to the milliammeter. It's easy to get the adapter in place if you lift the ends of two of the batteries, put the adapter between them, and then push them back into the holders.

Check the service data to make sure what the current drain should be. In a typical six-transistor portable, it may run less than 10 mA at minimum volume, and about 15–20 mA at full volume. Maximum current depends on how much audio power output the set has.

There are many uses for the input-current test besides checking bias, battery life, etc. You can even use it as an alignment indicator! The total current drain of a transistor radio depends on the audio output; if we use an audio-modulated signal for alignment work, the current drain will be directly proportional to the amount of audio signal. So, we feed in an i.f. or rf signal and tune for maximum current. The volume control can be set to give a convenient amount of current. This setting and that of the rf signal generator output shouldn't be changed during alignment unless the signal becomes too high and threatens to overload the receiver or cause clipping.

## 2-4. TESTING POWER TRANSFORMERS FOR INTERNAL SHORTS

We find many sets with hot power transformers. They may be smelling bad, have tar running out, etc., and in general show all of the symptoms of being hopelessly burnt up. But are they? The big question is always this: "Is the transformer broken down internally, or is the overheating due to a short in the load circuits?" In all cases, we must know if the transformer itself is bad before we can make any estimate on the job. So, we check it first.

Remove the rectifier tube, or disconnect the silicon rectifiers, etc. In a few sets, you can do this by pulling the B+ fuse. In any case, be sure that the rectifiers are completely disconnected from the power-transformer secondary. Now, open the filament circuit by disconnecting one wire from the power transformer. You could pull all tubes, but that takes longer. If the filament circuit is center-tapped, you'll have to open both supply wires. In all tests, make sure there is no load on the power transformer.

Plug the primary of the power transformer into the wattmeter and turn it on. If the transformer is *not* internally shorted, you'll see a very small kick of the meter needle as the magnetic fields build up, and then the reading will fall back to almost zero. This reading, usually 2–3 watts at most, is the "iron loss" and is normal. If there is a shorted turn anywhere in the transformer, however, you'll see the wattmeter needle come up to 25 or 30 watts. If the short is in one of the high-current windings, you'll see a full-scale, needle-slamming reading. This means that the transformer is *definitely* bad. Recheck to make sure that all loads have been disconnected. (Even two pilot lights can show a reading of about 5 watts!)

There is also a no-instruments-at-all test you can make for a power transformer. Hook up the transformer with no load on it, and leave it on for 5 to 10 minutes. If the transformer gets too hot, it's bad. A good transformer will get just barely warm, running no-load. A badly shorted one will heat up and smoke.

## 2-5. SUBSTITUTE POWER TESTERS

Let's discuss the kind of equipment we can substitute for a wattmeter to get the same results. Since we must have a "volts times amps" reading, we're going to have to do our own arithmetic. The ac line voltage is usually specified as being 117 volts rms, but let's use 120 volts—it's such a nice round figure. Besides, the usual line voltage is nearer to 120 than to 117 anyway. If we know the line voltage, we can measure the current and get watts by multiplying.

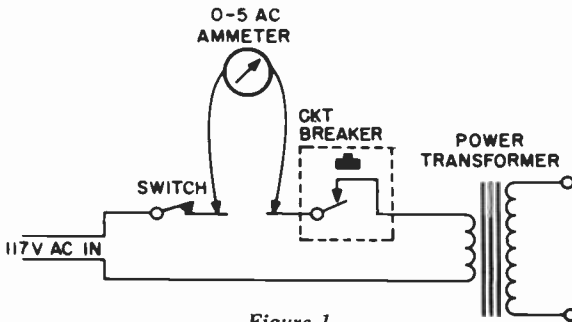


Figure 1

A 0-5 amp ac meter in series with the input, as in Fig. 1, will give us this reading. For example, if the rating plate of the equipment under test reads 240 watts, our current should measure 2 amps. You can use a 0-5 ac ammeter of the panel-meter type for such measurements. Also, an adapter is available that makes a clamp-on ammeter out of a pocket vom. It has a current transformer made so that the core can be opened up and clamped around either one of the ac wires. When the adapter is in place, the meter reads ac current on the ac volts scale (Fig. 2). If you have one of these adapters, be sure to place the clamp-on core around only one of the wires; if both wires get inside it, you won't get any reading. On TV sets, you can usually get at one wire at the ac interlock, at a wire going to the switch, etc.

You've seen that we can read current, multiply it by line voltage, and end up with the wattage. But ac ammeters aren't common in service shops either; let's figure out another way to measure power. We can use an ac voltmeter, from the vom. Get a fairly accurate 1-ohm resistor; the standard 5- or 10-watt wirewound types are an "automatic" Ohm's-law computer. Using  $E = IR$ , Mr. Ohm said that for every ampere of current that flows through the resistor (which we deliberately made 1 ohm), we'll read 1 volt of drop across it. So, we can read our ac voltmeter as an ac ammeter. In a 240-watt circuit, we'd read 2 volts (and therefore

2 amps) and get the same result as before (Fig. 3).

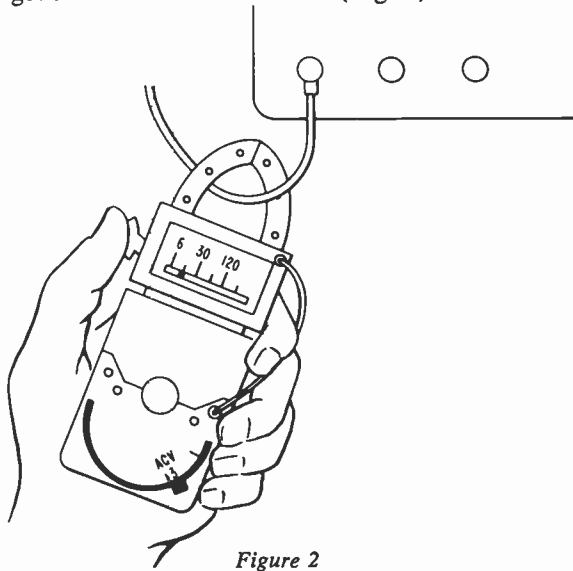


Figure 2

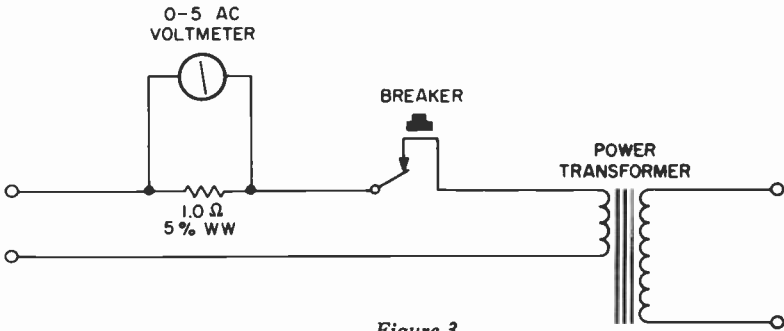


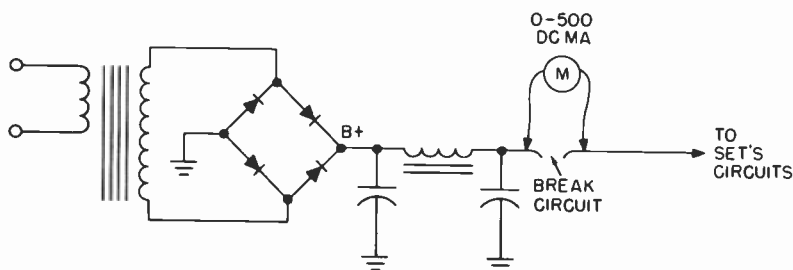
Figure 3

The method just described is a valuable test for sets using small circuit breakers in the primary of the power transformer. If the breaker kicks out at odd intervals, check to see whether it is due to an intermittent overload in the secondary circuits or to an intermittent *breaker*. The kickout value of current is always specified on the breaker itself; for example, a typical unit might be rated "hold 2.2 amps; open at 2.5 amps." If we read the actual current in the circuit and find that the breaker is kicking out at 2.2 amps, we replace the *breaker* and that usually fixes the trouble!

## 2-6. FINDING OVERLOADS IN B+ CIRCUITS AND POWER SUPPLIES

After clearing the power transformer from suspicion in a fuse-blowing or overheating problem, we can put the loads back on one at a time and find out which one is faulty. One good test is to leave the filaments open and hook up only the B+. Check input power again. If this shows more than 30 to 35 watts, look out! If the current drain is as much as 75 to 100 watts with only the B+ circuits hooked up; there is definitely a short circuit in one of the branches.

Leaving the filaments off will raise the B+ voltage by taking off the normal loading. This test also will often help to break down leaky parts and give us a nice, definite indication, such as a thin pillar of smoke rising from something. So use this test with care, and with one hand on the switch!



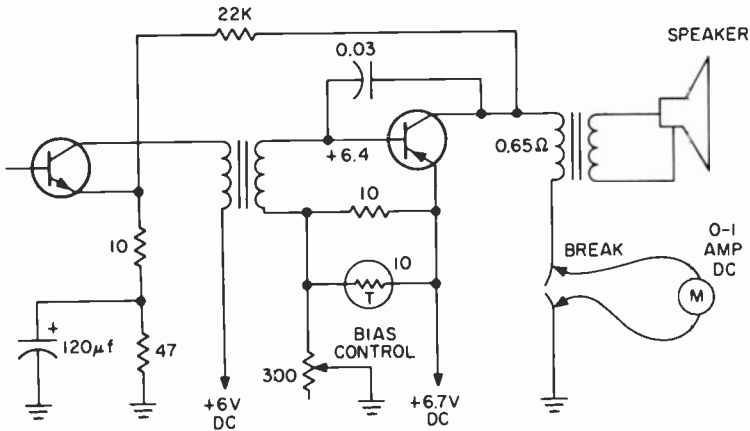
If the transformer and B+ filter circuits check okay, you can read the B+ current drain by hooking a 0-500 dc milliammeter into the B+ filter output, as in the figure. The normal current drain will always be given on the schematic; for example, 350 volts, 260 mA—and so on. If you get something like 300 volts at 290 mA, look out. Something is drawing more than its normal current.

The excessive current can be traced by voltage readings in individual circuits, especially if they have their own individual dropping resistors. Look for the resistor with the greatest percentage of drop. For instance, if you have taps for 350, 250, and 150 volts coming off the B+ filter output, and the 350- and 250-volt lines read about 10 volts low while the 150-volt line reads about 50 volts maximum, the trouble is in the 150-volt line. For a quick check, disconnect the 150-volt line and see whether the others jump back up to normal (or probably a little above, because of the reduced loading).

Having traced the trouble to a single circuit, you can chase down the short with an ohmmeter.

## 2-7. SETTING THE BIAS OF A POWER TRANSISTOR WITH A CURRENT METER

Transistor bias voltages are critical. A change of only a small fraction of a volt can cause a transistor to cut off completely or draw a very high current—often enough to overheat the junction and destroy the transistor. If you suspect that a power transistor is drawing too much current, the only way to check it is to insert an ammeter and read the current directly.



The figure shows how this is done on a typical single-transistor output stage. The bias is adjusted by means of a series resistor in the base return circuit. We open the bottom of the output transformer primary circuit, as shown, and insert a 0–1-amp dc meter. With this connection, we read the collector current; its value is determined by the base bias. (You can consider this as either a voltage bias or a current bias; the two are equivalent as far as we're concerned. If we change current, we change voltage, and vice versa, so don't be confused about it.)

The circuit shown happens to be from a 6.3-volt radio, and the power output is not very high. The rated values for this circuit are as shown, and the bias control should be adjusted to give a collector current of 550 to 600 mA (0.55 to 0.6 amp).

The collector goes directly to ground through the primary of the output transformer. This winding has a very low dc resistance; so, you can see that a dc voltage measurement here would be hard to read, unless we had a meter that would read millivolts! This explains why we take a *current* reading, which gets up into more readable values. The actual current will be different on other sets, but the principle is the same.

For a given auto radio, you'll find details on how to adjust the output

current in the service data. Check these before you make the test, because auto radios differ in current values. The current in a given circuit depends on the type of transistor used and how the circuit was designed. You need the exact value so that you can adjust for correct current in the set you are working on. The bias value sets the operating point of the transistor.

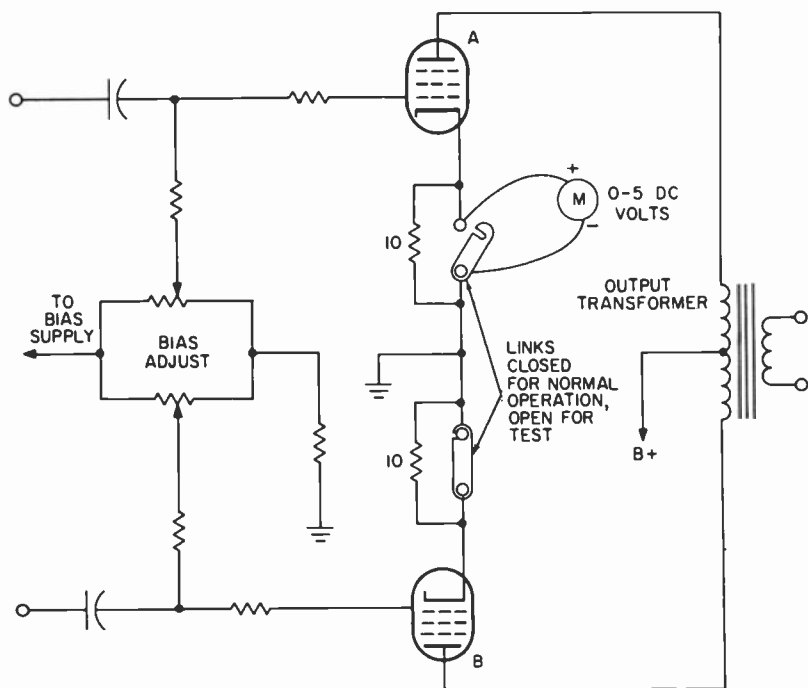
In two-transistor push-pull or output-transformerless circuits, correct collector current is especially important. Most of these circuits work in class B: one transistor amplifies the negative half of each cycle, the other the positive. If the bias isn't exactly right, we'll get what is called cross-over distortion at the point where one transistor stops conducting and the other starts. You can see this distortion with a scope; there will be a decided break or notch in the signal waveform where it crosses the zero line. Some sets use a combination bias; the output stage actually works in class A on small signals, shifting to class B on large ones. Bias is very important on these circuits. Combination-bias circuits are also found in hi-fi and stereo amplifiers, and are adjusted in exactly the same way as car-radio circuits.

## **2-8. USING CURRENT READINGS TO BALANCE HIGH-POWERED AUDIO STAGES**

Another case where current readings come in handy is in balancing plate currents in the output tubes in high-powered PA-system amplifiers. This should be done on amplifiers having 50 watts output or more. A typical circuit used in a 75-watt commercial amplifier is shown. Notice that there is a fixed bias supply, coming from a rectifier and filter in the main power supply. This bias supply will be about  $-75$  volts dc; it is fed to the control grids of the final amplifiers through a pair of variable resistors so that the two tubes can be balanced by changing the fixed bias.

We read the cathode current of each tube, which is the plate current at a lower-impedance (and lower-voltage) point. Although this is actually a current reading, we take it by connecting a small resistor in series with each cathode circuit and then reading the dc voltage drops across them with a voltmeter. (We'll use this particular trick often as we go along; the right resistance makes a sort of automatic Ohm's-law calculator.) By making the resistance a known even value, we can take a voltage reading across it and interpret the reading in terms of the current flowing





through the resistor. For instance, if we use a 10-ohm resistor, as this circuit does, we can say "Every 100 mA through the resistor causes a 1-volt drop"; thus a reading of 1.5 volts indicates a current of 150 mA, and so on.

In this application, a shorting link is connected across each resistor when the circuit is in normal use. To make the test, both links are opened. The negative lead of the voltmeter is hooked to ground, and the positive lead is moved from one cathode to the other. You'll find the exact value of current in the service data for each amplifier.

This test is usually made at low volume or with the gain all the way off. However, it can be used at a higher power level if you want to make a dynamic check for balance. The readings for the two tubes should be the same, within a small tolerance. If one is high, it can be brought down, or the other one brought up. Make the grid bias more negative to cut down current, or more positive to increase it. For high-level balance tests, a sine-wave signal from an audio generator must be used so that you have a fixed signal level at all times.

## Section 3

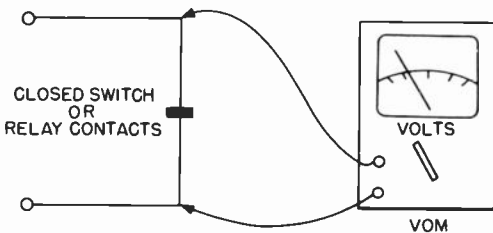
### VOM-VTVM Tests

#### 3-1. MEASURING CONTACT RESISTANCE WITH A VOM

Once in a while we have the problem of testing a switch or relay contact to see if it is actually making good contact. A bad contact can be annoying, especially if it happens to be intermittent. However, there is one positive test: checking the resistance of the contact by reading the voltage across it in actual use.

The contact resistance of a good switch should be zero, of course. There should be absolutely no voltage drop across the contacts under full normal load. If the contact surfaces become dirty or burnt, there will be resistance. Where there's resistance, there's heat, voltage drop, etc.

To check for contact resistance, set your voltmeter to the full line voltage of the circuit, and connect it directly across the contacts. The voltage may be either ac or dc; just set the meter to read the full voltage that the switch is breaking. With a sensitive meter, you'll see the full voltage across the open switch, even if the load circuits have fairly high resistance. Now, close the switch; the voltage should drop to zero. Turn the switch on and off several times to see if the voltage does drop to zero every time.



If there is any contact resistance, you'll see a small voltage reading when the contacts are closed. In most cases, this can be read with your initial meter setting. If you want to, turn the meter to a lower-voltage scale for a more accurate check, but be careful. The contact could be intermittent, and the resulting surge of voltage could damage the voltmeter unless it is a vtvm.

With the meter set on the full-line-voltage scale, you can tap the switch with the handle of a screwdriver to see if this makes any difference in the reading. It's a good idea to do this, before going to a lower voltage scale with a vom.

It takes only a very small voltage to show you that there is contact resistance. Even 0.5 volt means that there is some resistance between the contacts. This resistance will tend to increase in time, and the switch may eventually burn out. (Resistance makes heat; heat makes more resistance—It's a vicious circle!)

If the contacts are accessible, as in some relays, you can often clean them up with very fine sandpaper or crocus cloth and a contact-burnishing tool or even a piece of cardboard. After cleaning, check again for zero resistance and zero voltage drop.

### **3-2. MEASURING VOLTAGE DROP IN LONG BATTERY WIRES**

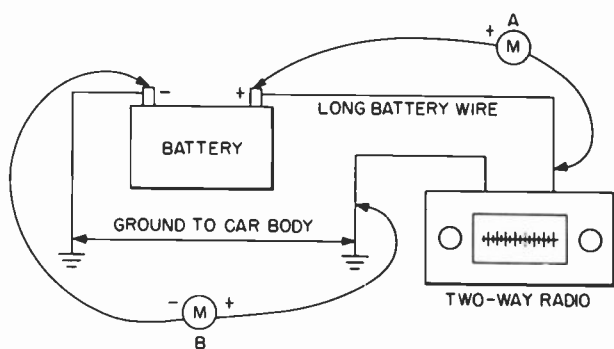
We can get into some mysterious troubles when there is too much voltage drop in the supply wires. Take a typical case; a two-way radio transceiver is mounted in the trunk of a car and connected to the car's battery by long wires. If these wires aren't heavy enough, or if there is contact resistance in a switch or relay, the radio supply will be low, and we'll have a mysteriously weak set.

The first step in such a case is to read the battery voltage at the radio power-supply plug. If the voltage is below normal, then go back to the battery itself and read its voltage. The radio must be turned on, of course, so we get a full-load reading; in most cases, it's desirable to key the transmitter to place maximum load on the power supply.

If the battery voltage is up to normal and we have a loss between the battery and the radio, the next step is to find out just what part of the supply circuit is guilty. We can do this by taking more voltage readings, this time across the wires themselves. You'll probably need an extension

lead for one of the voltmeter test leads because you'll have to take a reading between two points that are 18 to 20 feet apart! Don't worry about the long test lead. Because of the small current drawn by the voltmeter, voltage drop in the test leads will not affect the reading much.

Connect one test lead to the ungrounded post of the battery itself. If this is positive, as it is in most American cars, put the positive meter lead here. Make sure that you have a good, clean connection; a clip will be needed to hold the lead in place. Now put the other test lead on the positive (or hot) wire of the radio power-supply plug, as at A in the figure. Turn the radio on; there should be no voltage reading at all on the meter. Normally, you'll be able to see any significant voltage drop, since it must be from 1 to 3 volts to cause trouble.



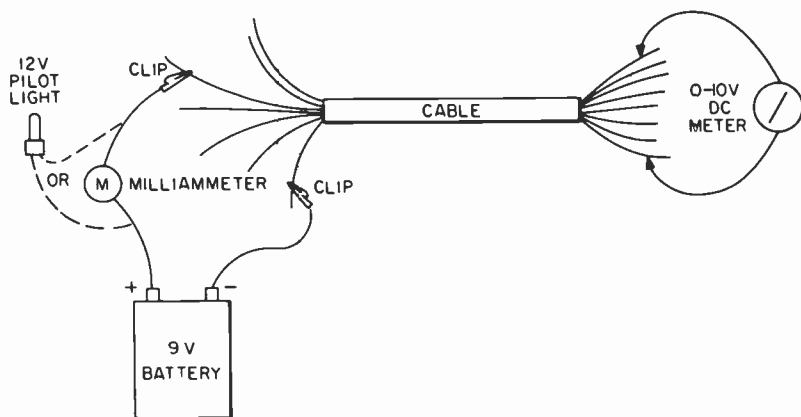
If you see no voltage drop on the positive or hot lead, put the negative lead of the voltmeter on the grounded battery post. Then take another reading, this time to the ground point in the car's trunk or at the ground lead of the power supply plug (B). Again, you should see no voltage drop. However, if the ground path is not perfect—if there are painted joints between this point and the battery ground—you *will* see some voltage.

By making these two tests, you can pin down the cause of any excessive voltage drop in the supply circuits. Don't forget that these wires also go through switches and relays, as well. To get away from possible voltage drops in automotive switches, most two-way radios and similar high-current equipment have relays that do the actual switching on or off; the car's ignition switch is used only to control this relay. Make sure the supply circuit does not go through the ignition switch itself. Such switches are too light for such service.

### 3-3. IDENTIFYING UNCODED WIRES IN MULTICONDUCTOR CABLES

Identifying the wires in a large group of non-color-coded wires is mighty difficult. You find this problem in intercommunication-system work, where some clod has run a bunch of assorted wires without color-coding or identifying them. What do you do?

Get a 9-volt battery and a connection strip. Solder a pair of short test leads to the strip, with alligator clips at each end of the leads. You can hook a milliammeter in series with one lead, or use a pilot light—a 12-volt type (see figure). Now, all you need is a 0–10-volt dc voltmeter and a set of wire tags—the numbered adhesive strips sold in radio stores just for this purpose.



The testing takes two men; one man could do it, but he'd run himself to death. Find the two ends of the cable you want to identify. Put one man with the battery at one end. Connect the battery to any two wires in the cable, and mark the negative wire No. 1 and the positive wire No. 2. At the other end of the cable, with your voltmeter, start checking between all possible pairs of wires for voltage. This is the hard part because you have so many possible combinations. If the wires have continuity, you'll eventually find the right pair. Mark the negative wire No. 1 and the positive wire No. 2. To signal the man at the other end, short the two wires together a couple of times. If he's using the pilot light, it will flash, indicating that you've found the first pair.

He leaves his negative clip connected to the same wire (No. 1) and moves the positive clip to any one of the others. You leave your negative clip attached and search with the positive one until you find the voltage on

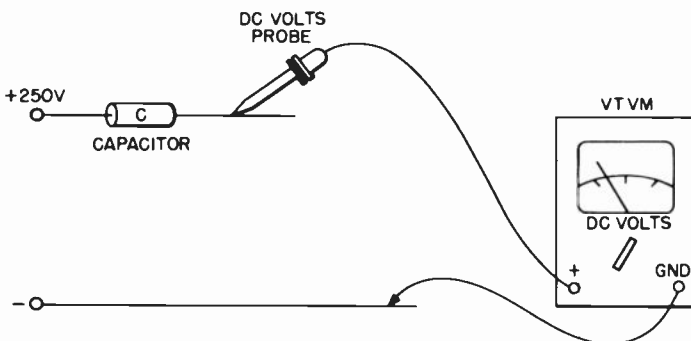
another wire. Mark this wire No. 3; then short it to No. 1 to flash the signal light. The other man should have marked his positive wire No. 3 while you were searching, so he now moves the clip.

This technique also serves as a good short or leakage test. Even after you locate the wire with voltage on it, go on and check all the wires. See if you get a voltage reading on any of the others. You shouldn't, unless there is water in the conduit, an accidental short, etc. If there is a short, this method will reveal it quickly. His light will burn the instant he connects to the shorted pair.

### 3-4. TESTING CAPACITOR LEAKAGE WITH A VTVM

In checking small capacitors, we need to find out if they are open, or leaking, or shorted. Because of the way such capacitors are built, it's almost impossible for them to change value. A  $.001\text{-}\mu\text{F}$  capacitor is likely to remain a  $.001\text{-}\mu\text{F}$  no matter what happens to it. So, we don't need a value check as with electrolytics, but we do need a condition test to tell us if the capacitor is able to do its work in the circuit. A leakage of as little as 200 to 300 megs in a high-impedance circuit can upset things considerably, so it's important to test for capacitor leakage when trouble occurs in these circuits.

A capacitor tester that has an insulation-resistance function is handy. This test can also be made with nothing but a vtvm. The figure shows how to do it. Disconnect the capacitor, and hook one end to the dc-volt probe of the vtvm. Now touch the other end to any convenient source



of B+ voltage. The actual voltage isn't too important, as long as it is about the same as, or higher than, the voltage applied to the capacitor in the circuit. About 200 to 250 volts is fine in most cases.

You'll see an initial kick of the voltmeter, caused by the charging current of the capacitor. If there is little leakage, this initial deflection will gradually ease off and the meter needle will go back to zero. The larger the capacitor value, the longer this takes. If you're in a hurry, you can touch the vtvm probe tip and ground with your fingers to discharge the capacitor faster.

Now, watch the meter needle. If it never reaches zero, or if it starts back up again after you have brought it to zero by touching the probe and ground as described, there is leakage in the capacitor. You're making a voltage divider that consists of the input resistance of the vtvm and the capacitor. Leakage current will give a voltage drop across the meter—and a voltage reading.

The actual voltage isn't too important; the fact that there is any voltage at all is what we're looking for. In coupling-capacitor circuits, even a 1-volt leakage can be too much! It will cause a leakage of positive voltage from the plate of one stage onto the grid of the next stage, canceling out part of the negative bias voltage and perhaps throwing the tube onto the wrong part of the curve and causing a severe distortion.

With transistors in similar circuits, capacitor leakage is even more important. It takes only a tiny fraction of a volt to make a transistor cut off or run wild. The latter can cause overheating and avalanching, and can destroy a transistor quickly.

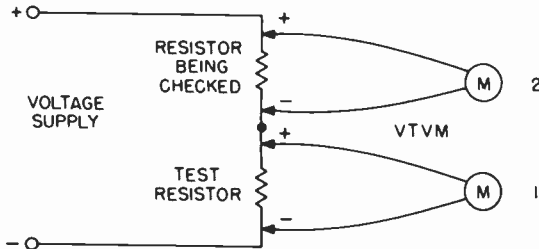
For best results, check any new capacitor before putting it into circuit. Such a check can save a lot of time if the new capacitor does happen to have a little leakage! We have a tendency to automatically assume that a new part is good. This isn't true in *all* cases; check first, and you'll be sure.

### 3-5. MEASURING VERY HIGH RESISTANCES

You may have occasion to check high-value resistors that are far beyond the range of your ohmmeter scales. There is a way to do this—in fact, there are several ways.

The easiest is with a resistor of the same value or as close as possible. If you don't have an exact duplicate, you can connect several resistors together temporarily to get the necessary value. For example, there's a bleeder resistor used in color TV focus-rectifier circuits—66 megs. To check one of these, first hook three 20-meg resistors and a 6-meg resistor in series; or use three 22-meg resistors; etc.

For the test, connect the combination in series with the suspected resistor and connect the whole string across a source of voltage. The B+ voltage of the TV set is handy, but you can use any voltage, even the ac line if you want. Take a voltage reading across one of the resistors, as shown, and note the reading. Next, check the voltage across the other resistor.



Because you have deliberately made a divide-by-two voltage divider, the two readings should be almost the same, if the resistor under test is okay. If the difference is not more than 10%, the resistor is probably good. (The amount of difference you should tolerate depends on the resistors used; if they are 5% resistors, then cut down your tolerance to this amount, and so on.)

If you don't have the right-value resistors, you can still use some that will make the total resistance of the voltage divider come out at a value that is easy to interpret. For example, with the 66-meg resistor, you could use a single 22-meg test resistor. Your whole circuit would then offer 88 megs ( $66 + 22$ ); your voltage reading across the 22-meg resistor would be one-fourth of the total voltage. If you used 200 volts, you'd read 50 volts across the 22 megs and 150 volts across the 66 megs.

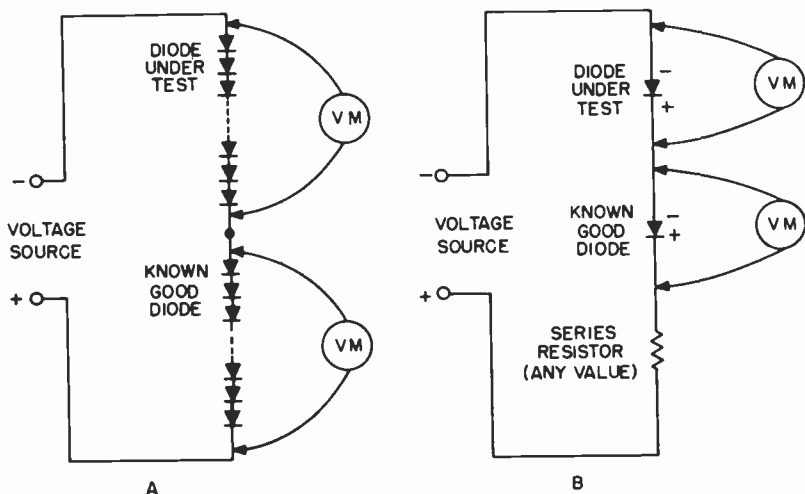
Note that this method—checking the voltage across each resistor in turn—takes the meter resistance out of the picture only if all resistors are equal. If you had to figure the actual voltage present across each resistor, you'd have to figure out the shunting effect of the meter resistance.



### 3-6. CHECKING DIODES BY THE BALANCE METHOD

You can use the method described for checking very high resistances to check diode back-resistance, if you want. Ordinary diodes, such as afc, video and sound detector, etc., can be checked with an ohmmeter, as will be shown in a later unit. However, if you run into special units, such as the high-voltage diode rectifiers used in focus and boosted-boost circuits in color TV sets, the ohmmeter simply won't reach the resistance range needed.

The duplicate-and-balance method shown in part A of the figure is the easiest. Connect the suspected unit in series with another one just like it, feed a voltage to the combination, and check for equal voltage drops across the two units.



You can also use this method for testing low-voltage diodes. This technique is useful for checking balance on afc diodes, ratio-detector diodes, and diodes used in any of the circuits of FM multiplex receivers and decoders. With these low-voltage units, connect the diodes in series and add a series resistor to keep the current within safe limits (see part B of the figure). Now hook a small test voltage across the combination and check the diode voltage drops for balance.

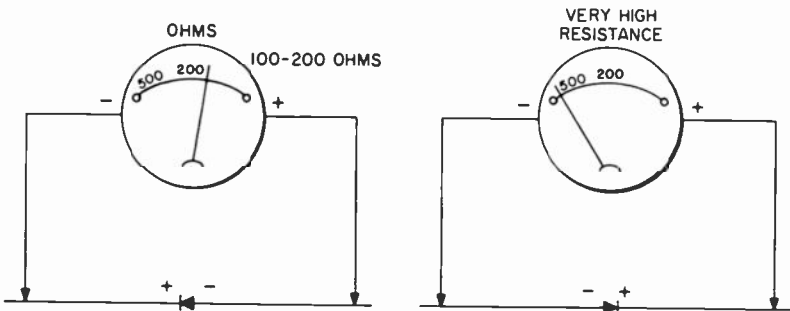
As a general rule, if any diode—from the 5,000-volt focus rectifiers down to one of the tiny video-detector diodes—is really bad, the defect will show up in the front-to-back resistance ratio, which can be measured by this test. You can feed an audio or rf signal across the combination and read the result with an oscilloscope or a good ac vtvm.

### 3-7. CHECKING VIDEO-DETECTOR DIODES WITH AN OHMMETER

The small video-detector or signal diodes can be checked very accurately with an ohmmeter. They'll show a small resistance in one direction and a very high one in the other, if they're in good shape. The actual resistance readings seem to depend on the battery voltage used in the ohmmeter. The forward resistance will vary with voltage and diode types, but will probably be in the neighborhood of 100—200 ohms. The back resistance, or resistance in the high-resistance direction, should read several hundred thousand ohms.

Practically all vtvm's use a low-voltage battery in the ohmmeter; the average voltage is about 3 volts. Most vom's use a 1.5-volt battery on the low-resistance ranges, but use up to 22.5 volts on the highest resistance scale in the megohm range. Diodes should be tested on low range—a scale of 0–2,000 or 0–5,000 ohms—because such a range will use a low-voltage battery.

Find out which of your ohmmeter prods is positive. All instruments we have checked, both vtvm and vom, had the positive side of the ohmmeter battery connected to the black prod. This could differ, of course, so check yours with another voltmeter to be sure. Then mark the positive prod with tape, etc. A voltmeter check will also tell you exactly what voltages are used in your ohmmeter on various ranges, and save your taking it apart to figure them out.

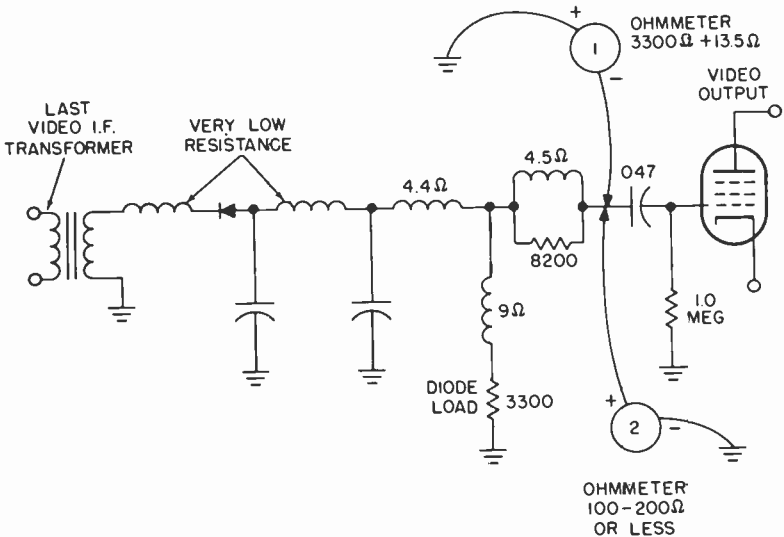


If the positive ohmmeter lead is placed on the cathode of the diode, and the negative on the anode, we get a high-resistance reading. Reverse the prods and we get a low-resistance reading. The ratio between the two should be very high for best performance in video detectors and similar circuits.

Actually, if we want to know if a diode is good, we don't have to bother with polarity. If we get a high resistance one way and a low resistance when the prods are reversed, the diode is okay. However, if we run across an unidentified diode or one so small that we can't tell what the markings are (not uncommon), we can use the ohmmeter to identify the elements. In the low-resistance direction, the positive ohmmeter prod will be connected to the anode (triangle) and the negative to the cathode (bar) of the diode.

### 3-8. CHECKING VIDEO-DETECTOR DIODES IN-CIRCUIT WITH AN OHMMETER

Whenever we run into a white-screen symptom in a TV, and the cause isn't an agc block or a dead i.f. tube, there is always a chance that it could be a bad video-detector diode. These diodes are usually covered up in a small can, and they shouldn't be unsoldered and resoldered too many times. We can make a definite and reliable test without moving a wire: The ohmmeter will tell us from outside whether the diode is good or bad.



The figure shows a typical video-detector circuit. The i.f. signal comes to the diode from a secondary winding on the last i.f. transformer; the

other end of the winding is grounded. (This is a series-diode detector, but shunt detectors can be checked in the same way.) The coils are peaking chokes, which give the circuit a wideband response, and the video-diode load resistor is the 3,300-ohm unit connected from the diode output circuit to ground.

To check the diode, we first hook the negative lead of our ohmmeter to the video coupling capacitor as shown. That way we can read the dc path through the peaking coils and diode to ground. The positive ohmmeter prod is connected to ground (1 in the figure). Now we are checking the diode in the high-resistance direction, so we should read nothing but the diode-load resistor plus the small resistance of the two peaking coils—actually, 3,318 ohms, but if we get 3,300 ohms, it's okay.

That's one check: Now, reverse the ohmmeter prods—positive to the coupling capacitor, negative to ground (2 in the figure)—and we're reading the diode in the low-resistance direction. Our path is through the low forward resistance of the diode, with the 3,300-ohm resistor in parallel, and we should get something like 150 ohms; a bit less or a bit more is fine, as long as we have a good, high ratio between the two readings.

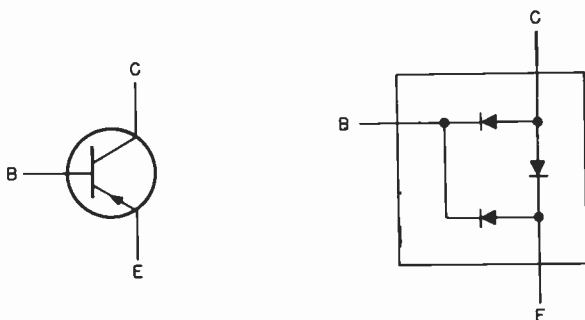
If the reading is infinity on both tests (no reading at all), the diode, or one of the peaking coils, is open. Doesn't matter which; you're going to have to take the circuit apart to find out which one and fix it. Check each of the coils for continuity before unsoldering the diode; such coils sometimes open because of corrosion on the fine wires. If you have a coil shunted with a resistor—such as the last coil in the circuit shown, which is shunted by 8.2K—the value of the reading may tell you which coil to suspect. For example, if you read  $8.2K + 3.3K$  from grid to ground, or in the high-resistance direction, you'd know the last coil was open, and check it first.

If the reading is the same in both directions, and very low, the diode is shorted. You can figure what the correct resistance of the circuit should be by totaling the resistances of the peaking coils and diode load resistor, etc. If you have any doubts, you can lift the ground end of the diode load resistor, thus eliminating the shunt path, and read only the diode's resistance.

In shunt detector circuits, where the diode is connected from the transformer output to ground, you can also trace the dc path for the ohmmeter reading and catch an open or shorted diode in the same way.

### 3-9. CHECKING TRANSISTORS WITH A VOM

The vom makes a pretty good transistor checker. Whether the transistor is shorted or open is what we usually want to know. This can be checked with an ohmmeter. The figure shows the basis of the test.



All good transistors will read as three diodes—base-emitter, base-collector, and collector-emitter—as shown. We need to find out if all three diodes are good. A good junction will read a high resistance in one direction and a low resistance in the other. The actual resistances will vary widely, depending on the battery voltage used in your ohmmeter, the type of transistor (silicon, germanium, etc.), and its rating. However, what we should look for is the ratio between the two readings for each diode; this ratio should be pretty high. Typical values might be 200 ohms in the forward direction, 50,000–75,000 ohms in the reverse.

Use the low-resistance scale on your ohmmeter, particularly in a vom. This scale usually has a low-voltage battery, 1.5–3 volts, and won't damage the transistor. The high-resistance (megohms) scale may use up to 22.5 volts, which could damage low-voltage transistors.

To check each diode, take one reading, then reverse the meter prods and read the resistance in the other direction. If the reading is the same in both directions, and usually pretty low (100 ohms or less), that junction is shorted. For a valid test, the transistor must be disconnected; there are often very low resistances, such as coils, low-value resistors, etc., connected across the junctions. If you get a reading of infinite resistance in both directions, the junction is open; this defect is fairly rare. If you read something like 100 ohms one way and only about 500 ohms the other way, the transistor is usually leaking across that junction, and should be replaced; a 5-to-1 ratio is too low.

### 3-10. VOLTAGE AND RESISTANCE TESTS

Voltage measurements in radio-TV work are helpful. They can also be misleading—that is, unless you know what you are reading, where you're reading it, what you're reading it with, and what the reading should be! As we have said, all tests are comparisons against a standard, and in the case of voltage measurements the standard is the operating voltages given on the schematic diagram.

In low-impedance circuits, such as the power supply, you can use any kind of voltmeter. The circuit can supply so much current that the type of meter used makes no difference. However, when we get farther along in a piece of equipment, into some of the high-impedance stages, things look a great deal different!

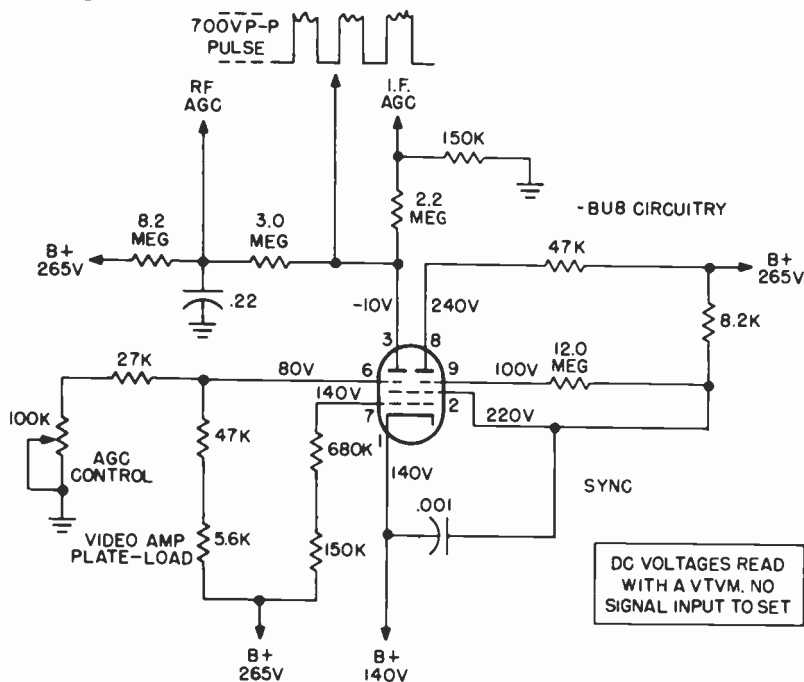


Figure 1

Fig. 1 shows a good example. This is one of the popular 'BU8 tube circuits, used in a great many TV sets as a sync separator and agc stage. Note the values of some of these resistors. In some cases, we may need to read a dc voltage through 10 or 12 megs. (We have deliberately left out all of the coupling capacitors, etc., that feed signals into this circuit, because what we are concerned with now is the dc voltage relationships

that exist in this type of circuit. However, as we'll see later, the signal makes a great deal of difference, not only in the output, but also in the dc voltages themselves.)

Now let's go. Yes, this *is* a complex circuit. But we can check it out rapidly if we know what we're looking for and the meaning of what we see. The diagram shows a set of voltages on the tube elements. Suppose we take a set of readings with a vom. They will all be different from the values called for on the schematic. Why? Because we didn't read the instructions, that's why. Look in the corner of the schematic; it says very plainly, "dc voltages read with a *vtvm*."

For instance, if we put a vom on a 0–100-volt scale (20,000 ohms per volt) and check pin 9, we won't read 100 volts as the schematic calls for. Why? Our meter resistance on this scale is  $20,000 \times 100 = 2$  megs. Look at the size of the dropping resistor. 12 megs! If we shunt only 2 megs from this point to ground, we're going to load down the circuit so that the voltage drop across the 12-meg resistor is far above normal. We'll read a "wrong" voltage and think that there is something wrong with the circuit!

If we use a *vtvm*, with an 11-meg input resistance, we'll get a reading that is closer to the actual voltage. In fact, we will be able to read the exact voltage shown on the schematic, because this is the type of meter originally used to read the voltage. So, all dc voltages should match those shown, *if* we use the type of meter specified on the schematic. Always check the little box in the corner of the diagram, because in some of the older sets you'll find that the voltages *were* read with a 20,000-ohms-per-volt vom! (In that case, your *vtvm* voltages should all read higher than normal.)

Some circuits will call for voltages that are far different from what you might expect at first glance. Notice, for example, that there is a total of 11.2 megs in series with the plate of the agc section of the tube, leading to the 265-volt B+. According to the schematic, however, the plate should read –10 volts. Why? Because there is a positive-going keying pulse fed to this plate at 700 volts p-p from the flyback. There are also resistors of 2.2 megs and 150K leading to ground in the i.f. agc circuit. The high pulse makes the tube conduct, and the plate-current flow through the load resistors makes that point negative when measured to ground. The positive voltage coming from the 265-volt line through the very large resistors bucks out or balances some of the negative voltage, and we wind up with the correct agc voltage. (Part of this circuit also serves as a delay for the rf agc, in case you're wondering.)

There's one other point that fools unwary technicians. The instructions

state clearly that these voltages were read with *no signal* applied to the set. Why? Well, if you check up on this circuit, you'll find that there is normally a video signal voltage applied to the *control grid*. This signal controls the conduction duration of the tube—the time when plate current is flowing. The tube is normally cut off by a high bias voltage, so it isn't drawing plate current at all. When a signal fed to the grid reaches a certain value, current starts to flow. This changes the voltages present, by a lot. Look at the monstrous resistors used; it takes only a few microamps of current to develop a large voltage across them.

Since we have no way of knowing what the actual signal input to the set would be, we take the only possible standard: no signal input at all. We're now taking our voltage readings under the same conditions they were taken under at the factory.

### Voltage-Resistance Circuit Analysis

What kind of troubles can we find in complex circuits by voltage and resistance measurements? Any and all kinds. In actual field servicing, operating voltages provide our best clue to trouble by *changing* from the normal, becoming either too low or too high.

Examples: If the plate voltage of a tube is too low, the tube is drawing too much plate current, or there is too much resistance in its plate supply path. If the plate voltage is too high, the tube may be weak (unable to draw normal plate current) or the plate supply path may have too little resistance. (Of course, there's always the grid bias to think of, too.)

So, whenever we find a tube with incorrect voltage on any of its elements, we check out that complete circuit to find out why. After the voltage analysis, we turn the set off and make a resistance check of all parts in the path in question, back to the supply point.

Suppose that either the 8.2-meg or the 3-meg resistor in Fig. 1 increased in value. This would reduce the positive voltage on the plate of the tube, making the plate go too far negative. This in turn would make the *agc* too negative, and the controlled stages would be cut off; we'd have an *agc* whiteout. If the 0.22- $\mu$ F bypass capacitor leaked, this would add a low-resistance shunt path at the junction of the two large resistors. Once again, we'd have too little positive voltage to balance the circuit, and the same symptoms—a whiteout.

How do we pin down the faulty part in such circuits? By measuring the values of *all* resistors in the path where the fault may be. If we had too much negative voltage at the *agc* plate, but the 265-volt supply checked



normal, and there was too much positive voltage at the junction of the 8.2- and 3-meg resistors, then we should suspect the 3-meg resistor of being open or greatly increased in value. If there was too little (or no) voltage at this junction, we could suspect the 8.2-meg resistor of being increased in value or open.

We cannot read the true values of these resistors in-circuit; there are too many shunt paths. To get a correct reading, we must open the circuit. Lift one end of a resistor before making any resistance measurements across it. To read the exact value of the 2.2-meg filter resistor from the plate to the i.f. agc, we would have to lift one end of the 150K shunt resistor to ground. If we didn't, we'd have at least two paths: one through the resistor and the 150K resistor to ground; the other, back through the big resistors to B+, which usually measures about 20,000 ohms to ground because of the leakage resistance of the electrolytic filter capacitors.

## Transistor Circuits

We've been talking about very high resistances and shunt paths in tube circuits. In transistor circuits, we have the same basic problem, but with very low resistances. Fig. 2 shows a typical class-A amplifier stage with an npn transistor. You might find such a stage in the preamplifier circuits of a hi-fi audio amplifier, etc.

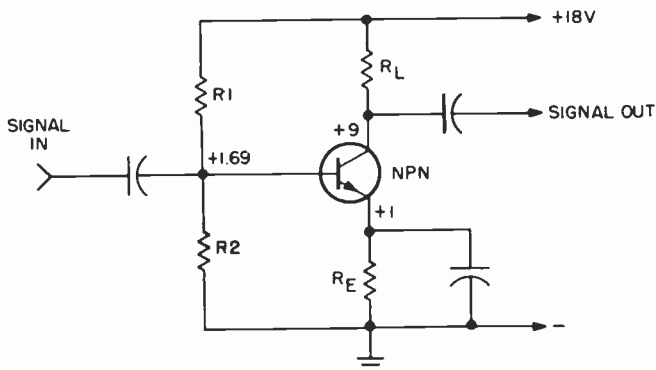


Figure 2

The signal here is developed across the load resistor  $R_L$ . This resistor is of such a size that half of the supply voltage will be dropped across it, and the plate current can swing above and below the operating point an equal amount; this is what makes it a class-A stage. With an 18-volt

supply, we have a 9-volt collector potential measured to ground. (If this were a pnp transistor, we'd have the same thing, but the collector voltage would be negative.)

Notice the voltage divider network, resistors R1 and R2. They are proportioned so that the base will have the right bias voltage for the type of transistor used—here, 0.69 volt. 0.69 volt? But the schematic says very plainly: 1.69 volts! Ah, yes. But, the emitter is 1 volt above ground. So, the actual base-emitter voltage is  $1.69 - 1.0 = 0.69$  volt.

In the tube circuit of Fig. 1, you recall that both grid and cathode of the tube read 140 volts from ground. What is the actual grid-cathode voltage? That's right:  $140 - 140 = 0$ ! In case you were wondering about the statement we made that the tube is normally cut off, look at pin 6. This pin is a second control grid in this type of tube, and actually has a -60-volt bias:  $80 - 140 = -60$ .

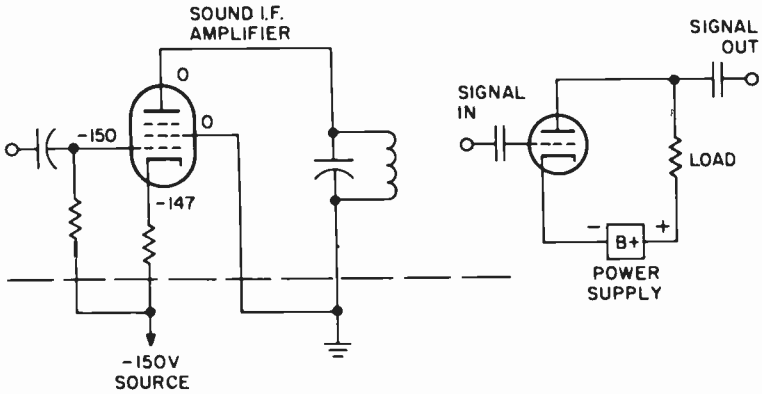
In circuits like this, we have shunt paths again. We can't read the resistance of either R1 or R2 correctly unless we open the circuit. The resistance of the base-emitter or base-collector junction is in parallel with them. So, we must take out the transistor or lift one end of the resistor to get a correct resistance reading. If the voltages are off value in such circuits, don't try to pin the trouble down by in-circuit tests with an ohmmeter. Break the circuit up into small sections and check each part by itself. Wrong bias on the base of the transistor could be caused by a shorted transistor or by incorrect values on R1, R2, or even  $R_E$ .

The voltage-resistance test sequence is probably the most useful in any kind of electronics work. Properly applied, it can give you a great deal of information in the least possible time. Use the wrong methods, and you'll lead yourself farther and farther away from the real trouble, hunting for nonexistent defects that aren't faults at all, but simply incorrect indications caused by the wrong test equipment!

In general, here's the test sequence: Find the defective stage by signal tests, then check its operating voltages. If any of these is off value, turn the set off and find the cause of the incorrect voltage by tracing the supply circuit back to its source. Measure all resistors in this path, including the resistance of coils, chokes and anything else that is a part of the dc path back to the supply. Learn to trace out a circuit and follow it back to the source of power, wherever it is. Start at this point, making sure that the *source* voltage is correct for the very first test. You would be surprised to know how many technicians overlook this obvious and extremely simple test! By beginning at the supply and following the circuit until you come to an abnormal indication, you can pin down the trouble in the least possible time.

### 3-11. VOLTAGE REFERENCE POINTS: THE GROUNDED PLATE

What would you think if you were reading dc voltages in a TV set and ran into something like the circuit shown? The first thing I'd do (did!) would be to see if I had reversed my meter prods. However, this is an actual circuit used in the sound i.f. of an old Emerson TV chassis. We include it to illustrate what you can run into now and then in real circuitry.

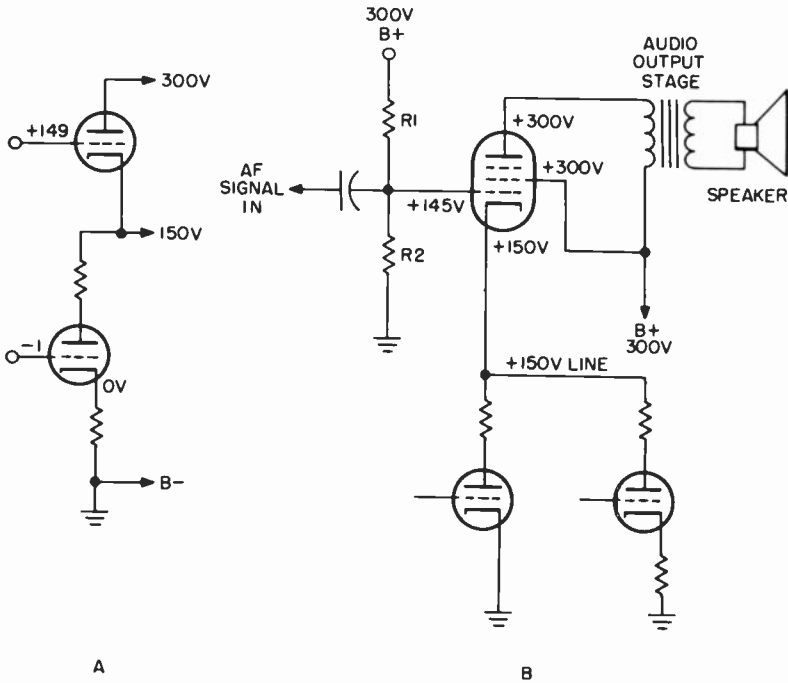


The circuit is perfectly normal, as far as operating voltages are concerned. The plate of the tube has the rated 150 volts on it, if we measure the plate voltage from the proper reference point—the tube's own cathode. Look at the smaller circuit in the figure; there is an amplifier tube, its load resistance, and the power supply. Note that this circuit has no connection to ground. If we measure the plate voltage from the cathode, we get a high positive voltage as we should. As far as the performance of the tube in amplifying a signal is concerned, we can attach a ground at any point and it'll make no difference.

You'll find this circuit most often in old sets, but that's not saying you will never see it used in newer ones. It is common in transistor circuitry, especially in the totem-pole or multiple-stacked direct-coupled circuits. Here, we must remember to use the proper reference point to get the exact voltage on any transistor (or tube). In the popular common-emitter circuit, the emitter is the reference point; base and collector voltages are measured with respect to the emitter. The bias on a transistor, of course, is the base-to-emitter voltage.

### 3-12. STACKED STAGES

Here's a circuit that has confused many technicians because of the unusual dc voltage relations. It's easy when you use the right reference point for each tube—the tube's own cathode, remember? The basic stack circuit is shown at A: Two identical tubes are hooked up in series. With 300 volts on the plate of the top one, and the same bias on both, they'll divide the voltage. Voltage readings to ground are shown.



The grids have a bias of  $-1$  volt each. Reading from ground, we have 150 volts on the cathode of the upper tube, and 149 volts on the grid;  $149 - 150 = -1$ . In actual circuits, a resistor network is used to set up this bias, but we have left it out so that you can see the basic circuit more easily. A bias of  $-1$  volt is also on the lower grid, with the cathode grounded.

Part B of the figure shows an actual circuit used in many TV sets. The audio output tube is the top one, and several other tubes are fed from the voltage developed at its cathode. Its grid bias is fixed—notice voltage divider R1 and R2 with the grid connected to the junction.

The audio tube is a power pentode, with a plate current of 40 to 50 mA. We can feed any other circuits we want to, as long as the total of their plate currents doesn't exceed this amount. Since these circuits are usually voltage amplifiers, sync separators, etc., they don't draw a lot of plate current, and many stages can be fed from this source. In common practice, the voltage supplied to these stages will be from 130 to 150 volts, and on many schematics the circuit carrying this voltage is called the 150-volt line.

Notice the similarity to the basic circuit of A. We have deliberately made the voltages the same. (Actually, we have left out the 5-volt drop across the plate-load resistor. The plate of the audio tube usually reads about 295 volts.) You'll find other voltages used, but the principle is the same in all circuits of this type.

The audio output stage, with fixed bias on the grid of the pentode, has a certain amount of voltage-regulator action. The fixed bias holds the grid voltage almost constant, so there is little fluctuation in the average plate current. The audio fluctuation is filtered out in the cathode circuit by large capacitors that aren't shown here.

The actual bias on the tube is  $-5$  volts;  $145 - 150 = -5$ . This bias is determined by the ratio of the voltage-divider resistors and by the B+ supply voltage fed to the divider.

Many other circuits can be fed from the 150-volt line. For example, one TV model feeds the sync separator, video i.f., agc tube, and the CRT brightness control from the 150-volt line. Troubles in any of these stages could be due to something in the audio output stage. Therefore, it's a good habit to look at the schematic to see if the set you are working on uses stacked stages. If you don't have a schematic, measure the cathode voltage of the audio output tube. If this is 150 volts or so, then you can be fairly sure that there is a stack circuit involved. If the cathode is at ground, no.

You'll find stacks in other places. The 6BQ7 in tuners is basically a stacked-stage arrangement. Also, many sets use stacked video i.f.'s; the first two tubes will be stacked, with 300 volts on the input plate and 150 volts on the second.



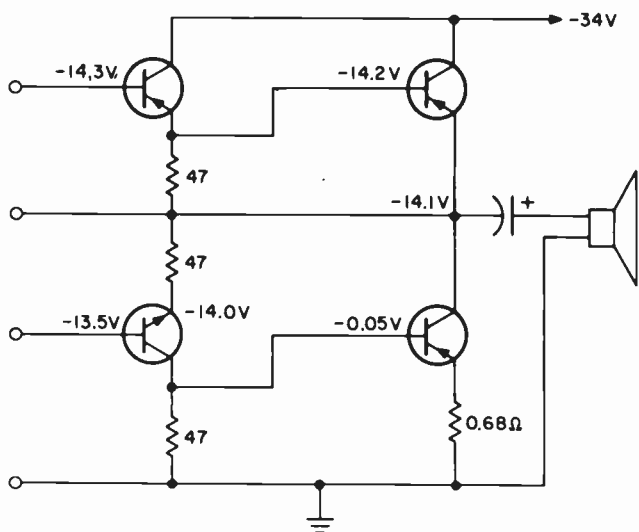
If one of the electrolytics is leaky or shorted, away we go. For example, if C1 shorts, this will put 300 volts on the 150-volt line. If C2 shorts, it will ground the 150-volt line. Either of these could cause symptoms that might mislead you—if you forget to check the voltage on the 150-volt line to be sure it's okay.

The audio-coupling capacitor can cause some odd symptoms if it becomes leaky or shorted. Note that it is actually connected between 70 and 145 volts. If it should get leaky, the result would not be the expected one—making the grid go more positive—because the grid is already more positive than the preceding plate. Heavy leakage could cause a *drop* in the positive voltage on the grid (measured to ground), which would drive the grid of the audio output tube more negative. This, of course, would drive the output tube toward cutoff; we'd get little or no signal through it. Since the plate current would be nearly or completely cut off, the voltage on the 150-volt line would drop toward zero and things would be upset in all directions. If you find several apparently unrelated troubles at the same time, take a look at the 150-volt line. Pay special attention to such components as the coupling capacitor and the electrolytic filter capacitors.

Interelectrode leakage in one of the tubes fed from the 150-volt line can cause trouble, too, by increasing the current drain. In this case, the voltage will go down, upsetting all the other stages fed from this point. The best and quickest cure is tube substitution, plus a resistance check to ground to catch any signs of leakage in filter or bypass capacitors.

### 3-14. TRANSISTORS IN STACKED CIRCUITS

In transistor amplifiers, we find the equivalent of stacked-tube stages, in various output-transformerless and direct-coupled stages; an example is shown in the figure. As in the case of tube circuits, the term stacking refers to the dc voltage distribution between the two (or more) transistors. The circuit shown is used in a commercial stereo amplifier and is a section of only one channel. It is a direct-coupled driver and OTL (output-transformerless) output stage. The circuit works in class B, with one transistor handling the positive half-cycles and the other handling the negative; the speaker is connected to their midpoint and ground.



Notice that the maximum power-supply voltage is connected to the collectors of the upper transistors, and that the emitter of the upper output transistor does *not* go to ground, but to the collector of the lower transistor. The emitter of the lower transistor is connected to ground, which is the positive point of the power supply. (Remember, in any transistor circuit, the polarity of the power supply is determined by the type of transistor used—nnp or pnp.) You can have a supply voltage of -34 volts for one type or 34 volts for the other and it'll work out the same. What we're mainly interested in now is the proportion of the supply voltage taken by each transistor, because this will tell us if the circuit is working properly.

Notice that the voltage does not split in the middle, as it usually does when similar vacuum-tube stages are stacked; maximum supply voltage is -34 volts, but the midpoint of the circuit has only -14.1 volts. The mid-



point value must be checked on the schematic, so that you will know what is correct.

Incidentally, in transistor circuits we do not have the rather wide voltage tolerance that we have in most tube circuits. If the schematic specifies 14.1 volts, it doesn't mean 14.3 or 13.8—it means 14.1 volts! In most circuits, a change of only 0.2 volt can cut a transistor completely off or drive it to full conduction and overheat the junction. So, we must learn to measure these very small voltages with extreme care. More on the how and why later, but measuring the collector current is a very good way to check the bias voltage. You have a much greater meter deflection, and it is easier to read on shop-type equipment.

Troubles in circuits like these are the same as in other stacked circuits; resistors that have changed in value, transistors with leakage between elements, interelement shorts, etc. The emitter-base voltage, which is the bias, is a very good place to start measuring if you suspect trouble. Use a sensitive and accurate vom, and read the voltage directly from emitter to base. If this voltage is in tolerance, the transistor is probably okay. If it's off by more than 0.2 volt, then there is very likely something wrong in that stage.

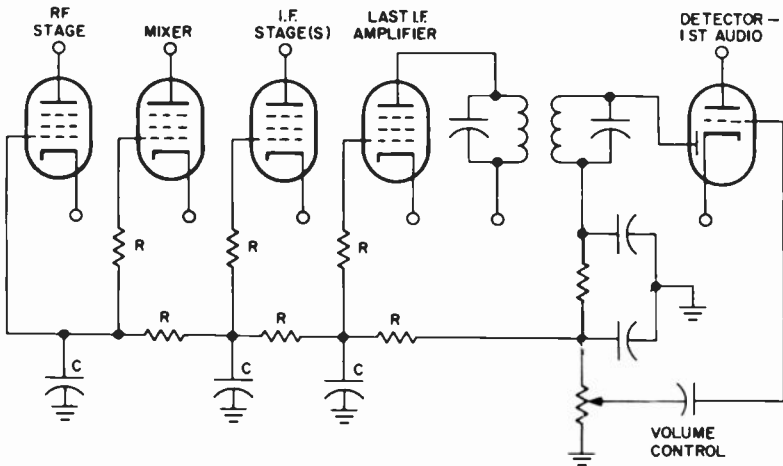
Note the direct coupling used in the driver transistors (the left-hand pair in the diagram). This is a very common circuit, and you'll find the same type of voltage distribution as in the push-pull circuit. The available supply voltage will divide between the two, in a ratio determined by the type of transistor and by the bias on each one. Consult the schematic diagram to verify the right voltage.

## Section 4

### Signal Tracing and Alignment Tests

#### 4-1. AVC VOLTAGE AS AN ALIGNMENT INDICATOR FOR TUBE RADIOS

The first output meter used for aligning tube radios was an ac voltmeter across the speaker-voice coil. A 400-Hz am signal was used. This was nice, but noisy. Of course, you can always unhook the speaker and substitute an equivalent resistor. An easier way is to use a vtvm on the avc line. The avc voltage developed across the diode detector is always directly proportionate to the amount of signal. This is a negative-going voltage, and you'll find values from 1 volt to 15-20 volts.



The figure shows a typical avc circuit as used in tube radios. This one is rather elaborate; you'll find fewer filter resistors and bypass capacitors in the smaller sets, but they all work in the same way. The avc voltage appears at the top of the volume control, which is the diode load resistor. In most cases, you can pick up the avc at the mixer-grid section of the variable capacitor, so that you won't have to take the set out of the case. It can be picked up at any point along the avc circuit. Since the avc circuit has a very high impedance, you'll have to use a vtvm to get a readable deflection.

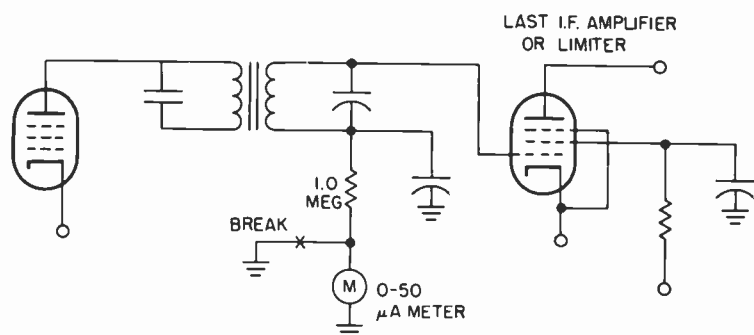
For best results, keep the input signal down to the point where it causes the smallest readable voltage on the avc; 1 volt is a good average value. By doing this, you avoid the danger of overloading rf stages and flattening the response peaks.

## **4-2. ALIGNING FM I.F. STAGES WITH A DC MICROAMMETER IN A GRID RETURN**

In aligning AM i.f. stages, we can use avc voltage as an indicator by tuning for maximum negative voltage. In FM i.f. stages we run into problems since many of them do not use conventional avc, or need it. In fact, signal overload is no problem in FM; the more signal, the better it works. A high-level input signal causes clipping, but this is fine; it clips off noise peaks and makes the system quieter. Limiter stages run saturated for best results.

There is one quantity, however, that we can use for alignment indications; this is the grid current drawn by the limiter and even the i.f. stages. The harder these stages are driven, the more grid current flows, especially in limiters. The value of this grid current is directly proportional to the amplitude of the input signal, which gives us the kind of alignment indicator we want.

We must not disturb the tuned circuits, so we need to get at this current at some point where our test instruments will have no detuning effects. We can open the bottom end of the grid resistor, and insert a very sensitive ammeter. In this case, a 0-50- $\mu$ A meter is about right, as shown. Incidentally, the meter is a common type, used in 20,000-ohms-per-volt vom's.



With the meter in the grid-return circuit of the last limiter, we feed an i.f. signal in at the mixer grid. This is an AM signal, remember, and can be either modulated or unmodulated; it makes no difference. Now we increase the rf output until we get a readable meter deflection, usually 10–20  $\mu\text{A}$ . Now tune all i.f. transformers for maximum meter readings.

If you're thinking about the bandpass of the i.f. transformers, this is usually built in: Almost all FM i.f. transformers have a response curve that is just slightly peaked in the center; it is this peak we're tuning for. The design of the transformers then gives the proper bandpass. If special i.f. transformers are used—for example, triple-tuned types with tertiary windings, etc.—check the alignment instructions and they'll tell you what procedure should be followed. You can make a rough check of bandpass by moving the signal generator dial back and forth either way from the center frequency; this will show you about where the 3-dB-down points are. If you can get a bandpass of at least 40 kHz either side of center, it's okay for cheap sets. Hi-fi FM tuners should have at least 75 to 100 kHz either side.

There's another application for the test just described: measuring the amplitude of the voltage developed by an oscillator. Again, we place a sensitive microammeter in the grid return. This does not detune the oscillator circuit since the meter is in the ground end of the grid circuit.

The current reading allows us to estimate the amplitude of the signal voltage present at the oscillator grid. For example, if we read 32  $\mu\text{A}$  and the value of the grid resistor is 470K, we have  $(32 \times 10^{-6}) (470 \times 10^3)$ , which figures out to approximately 15 volts. This is the peak value of the grid alternations during each half-cycle.

This test can be used to check oscillators for sufficient injection voltage, output, crystal activity, etc.

### 4.3 CHECKING THE CALIBRATION OF AN RF SIGNAL GENERATOR

Do you want to set your rf signal generator exactly on 455 kHz to re-align the i.f. stages of a radio? Do you have doubts as to the accuracy of the generator's calibration? Then use the most convenient source of highly accurate test signals—broadcast stations. All AM radio stations are required by the FCC to keep their carrier frequencies within  $\pm 20$  Hz of their assigned frequency. Most of them hold to within  $\pm 5$  Hz.

To set your generator precisely on 455 kHz, get any radio that will pick up several stations. Its dial calibration doesn't matter, we're only going to use the receiver as an indicator. Listen to a station long enough to determine the call letters and then look up the carrier frequency of the station. Choose a station as close to 910 kHz as you can find. Tune the signal generator to 455 kHz and then zero-beat this with the station carrier, using an unmodulated rf output. Your generator's second harmonic is beating with the station's fundamental.

If you can't find a station exactly on 910 kHz, locate one on each side as close as possible. Check each one, and note the error in the signal-generator dial. You can use this error to get the dial set on-frequency. For instance, if each station shows that the signal generator is one dial-marking low, then include this same amount of error when you set the generator for 455 kHz.

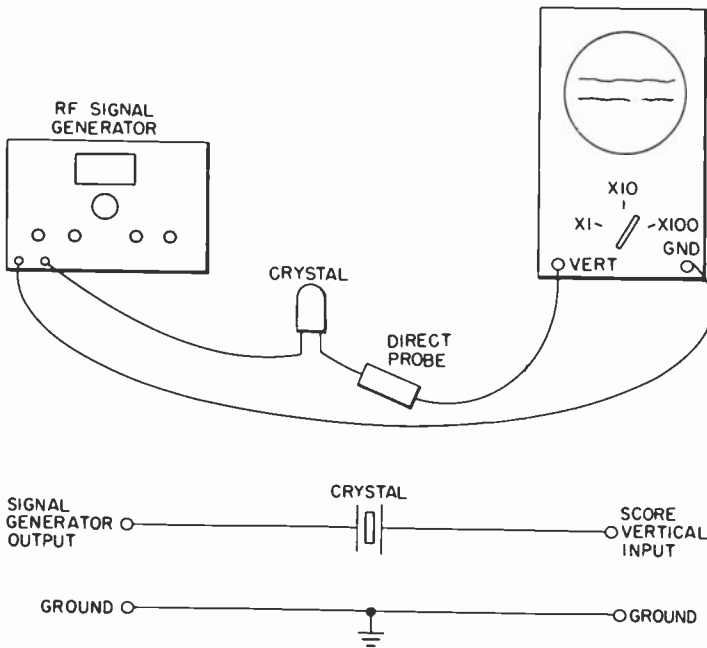
If you can't find stations close enough to the right frequency try the third harmonic. At a 455-kHz fundamental, this will be 1,365 kHz so use a broadcast station at 1360 kHz (all radio stations are on even number 10 kHz apart).

For high-frequency checking, use standard-frequency stations WWV or (in Hawaii) WWVH. You'll need a communications receiver that will cover to 30 MHz, but the actual dial calibration of the radio is not important. These stations broadcast accurate test signals at 2.5, 5, 10, 15, 20, and 25 MHz. You can identify them easily by the 440-Hz beep tone, broken up by ticks at one-second intervals. Incidentally, these two stations also give standard time signals that are used the world over, in case you want to check your watch.

#### 4-4. SETTING AN RF SIGNAL GENERATOR ON A CRYSTAL FREQUENCY

Every now and then we need to set a signal generator to an exact frequency, either for alignment or calibration purposes, or to check the calibration of the signal generator. If we have a crystal that operates at or near the frequency we need, setting the generator is easy. Some signal generators have provisions for plugging in crystals, but a crystal can be used even with a generator that does not have these provisions.

Connect the crystal between the rf output of the signal generator and the vertical input of a scope, using a direct probe (see the figure). Set the rf output to maximum and turn the scope's vertical gain full up. Connect the ground leads of both instruments together as shown. Now, tune the signal generator *very slowly* back and forth over the frequency of the crystal. When you hit the exact frequency, you'll see the scope pattern increase in height.



The crystal here is acting as a very sharp resonant filter. When we hit the right frequency, the rf voltage developed across it rises sharply; in typical tests, it may go from .05 to 0.5 volt p-p. The scope need not be a

wideband type; all we're looking for here is an increase in pattern *height*. You'll have to tune the signal generator *very* slowly, because the point of resonance is very sharp, and you may pass it unless you're going very slowly.

You can use an ac vtvm instead of the scope, or the DC-VOLTS range of a vtvm with a diode in series with the probe. The polarity of the voltage you will read depends on how the diode is connected, but this isn't important; all we want is the peak.

You can also hook the crystal up in shunt: Connect the rf output lead and the scope input lead together, connect the ground leads together, and hook the crystal across them. Now you'll see a pattern on the scope (or a voltage on the meter) at all times. When you hit the crystal frequency, you'll see a very sharp dip in the pattern height or in the voltage reading.

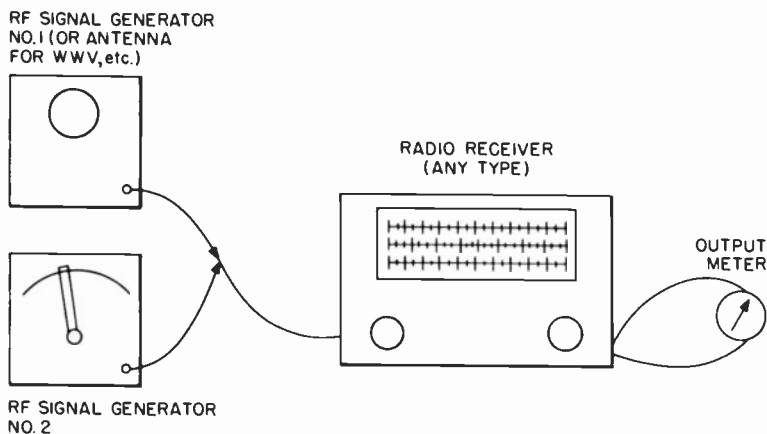
When adjusted to the peak (crystal in series) or the dip (crystal in shunt), the signal generator is tuned to the frequency of the crystal and can be used as a standard for aligning rf or i.f. stages, receivers, or whatever is necessary. This test will work pretty well with crystals up to 4.5–5 MHz, but above this frequency we usually run into low output from signal generators (the average shop signal generator uses harmonics in the vhf range, thus reducing the output by half or more). Therefore, we don't have enough rf power to get a usable reading on an indicator. The test would still work, of course, but we'd have to use some kind of an amplifier or booster to get the output up to a readable level.

Although it isn't too reliable, this test can serve as an indicator of crystal output or activity; a broken or bad crystal won't respond at all. Also, and this is rough, it will identify the frequency range of unknown crystals. If you test a crystal and get more than one reading, you can still identify the fundamental frequency of the crystal; it will make a deeper dip or give a higher output (in the series test) than any harmonic.

## 4-5. FINDING THE EXACT POINT OF A ZERO BEAT

When we're checking radio frequencies, we often want to find the exact frequency of a signal, or set our bench signal generator exactly on a given frequency. We do this by checking against a standard frequency of known accuracy. The easiest way is by zero-beating the unknown signal with the standard. All we need is a radio receiver that will pick up the standard frequency. The standard itself can come from an accurate rf signal generator, from radio station WWV, etc. The receiver doesn't have to be accurately calibrated; it serves only as an indicator—a device for making the two frequencies beat against each other.

By ear alone, it's often hard to tell where the exact zero point of zero beat is. So, we hook an output meter (an ac voltmeter) to the radio output.



Now the signal generator to be checked is coupled to the antenna of the radio, along with the standard. Sometimes just clipping its output lead to the insulation of the antenna lead is enough. Tune this signal to the test frequency, listening for a zero beat in the receiver output as you tune. As the unknown signal approaches the frequency of the standard, you will hear a high-pitched tone that gradually goes lower as you get closer, until you can't hear it at all. It starts to go higher again as you tune past the standard.

Since the beat frequency goes down to zero, below the audible range, the exact zero point is hard to detect by ear. If you want to be very precise, tune for the lowest audible beat frequency and then start watching the meter. When you reach a very low frequency, you'll see the meter needle start to wiggle as it tries to follow the beat note. At the same time, it will swing slower and slower. Tune for where the needle moves slowest.



#### **4-6. TEST RECORDS: GOOD SUBSTITUTES FOR THE AUDIO-SIGNAL GENERATOR**

The average shop needs a high-quality audio-frequency signal generator, but seldom has one. It has to make-do with the 400-Hz audio output of an rf signal generator, although this will do the job for signal tracing and such work.

However, we can get any kind of audio test signal we need at a very low cost, compared to the \$300 or more for a high-quality af generator. The source is a test record, and a great many different types are available—stereo, mono, or a combination of the two. With a suitable test record and an inexpensive record player, you're ready for any kind of audio work.

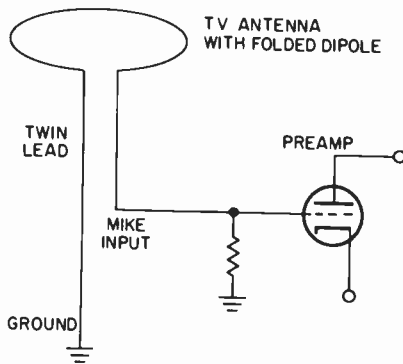
A typical test record will have single-frequency bands for checking distortion or stylus wear, and a frequency-run series from 30 Hz up to 20 kHz. For stereo, it will have left signal, right signal, and both for speaker phasing. Most test records also have many others. The single-channel stereo signals are very handy for checking separation, etc., and even for identifying channels.

In most cases, you won't even need an audio amplifier; the modern crystal cartridge has an output of up to 3–4 volts, and this can be fed directly into many audio circuits. If you want to, you can pick up a small, used amplifier, repair it if necessary, and it will give you output signals up to 30–40 volts for checking speakers, signal tracing in high-power af stages, etc. This amplifier needn't be hi-fi; you can use it to get the amplifier being tested into working condition, and then feed a signal directly from the cartridge into the input for distortion checks of the complete system with a scope.

## 4-7. USING RADIO SIGNALS FOR TESTING HI-FI OR PA SYSTEMS

When checking out hi-fi, stereo, or PA-system amplifiers, we often need a signal source so that we can let the amplifier cook for a while after the repairs are finished. We could use a record changer, but we'd have to stop and reload the changer every so often. An audio signal generator could be used, but the constant tone would drive you nuts. So, use the local radio station.

The input stage of the average high-gain audio amplifier will act as a detector for rf signals. Hook your TV antenna right across the input, as shown. Of course, we must have a closed circuit here. The lead-in and dipole make up a sort of long-loop antenna. Anything like a conical antenna, for example, which has no continuity across the lead-in, won't work; you'd get a tremendous buzz or hum.



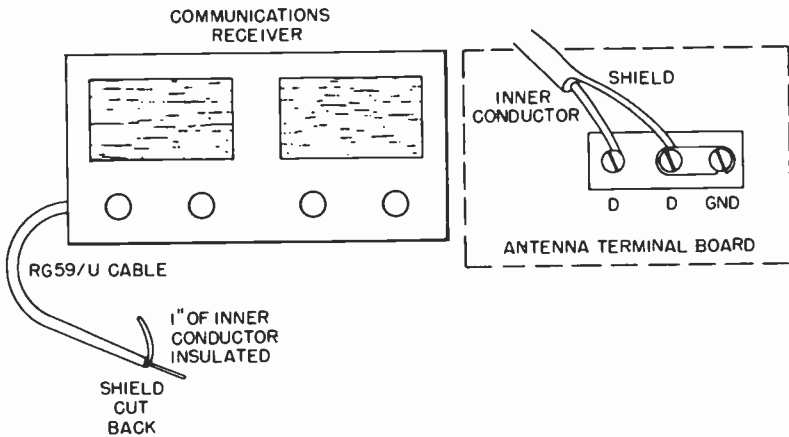
This technique works best if there's a local radio station near enough to put a good big signal into your shop area. However, if the signal is too weak, you can pick up music from a surprising distance by adding a detector diode in series with one side of the lead-in, or in shunt across the input.

If you have several strong locals, this system doesn't give a single clear sound. An alternative is to pick up the audio from the volume control of a small radio, either tube or transistor. You can set the gain wherever you want it and listen to the music as you cook the amplifier.

## 4-8. USING A COMMUNICATIONS RECEIVER AS AN RF SIGNAL LOCATOR OR TRACER

Every now and then we need an instrument that will help us find or trace an rf signal through a circuit, identify an unknown rf frequency, or signal-trace through a circuit to find where the trouble is located. There are special signal-tracing test instruments, but a standard communications receiver (of the kind we used to call a short-wave set) will do the job nicely.

Such receivers have antenna inputs that can be used on dipole antennas or converted to match 75-ohm coaxial cable; a shorting link on the antenna terminal board is used to make the conversion, as shown in the figure. Get a piece of RG59/U coaxial cable 3–4 feet long and prepare one end to hook up to the terminal board. Cut off about 1 inch of the shield braid on the other end, exposing the insulated inner conductor. Don't take the insulation off; in fact, pull it out over the tip of the inner conductor so that the wire can't make contact with anything. This is our probe.



Now, we can find and identify any rf signal within the tuning range of the receiver. For example, if we're checking a high-frequency oscillator circuit and want to know whether it's working on the right frequency—or working at all, for that matter—we simply put the probe end of the cable close to the circuit and tune for the oscillator signal on the receiver dial. The end of the probe cable can be bent into a little hook that can be hooked over wires, etc., near the circuit we're testing.

An unmodulated rf signal will be heard as a little thump in the speaker as we tune across it. Tuned directly on it, we'll hear a rushing sound or

blow. A better way to identify it is to turn on the receiver's beat-frequency oscillator (bfo). Now, if we cross an rf signal we'll hear the characteristic beat note, or squeal. This is a good way to find the signal.

If we want an indication of the strength of the signal, we can hook a dc vtvm to the test receiver's avc circuit. For convenience, we can run a lead from the avc to a jack on the receiver panel or back apron, etc., and connect our vtvm there. If the receiver doesn't have avc, we can use the dc voltage developed across the audio detector; this is usually where the avc voltage comes from anyway. The voltage will go more negative as the input signal strength increases.

A receiver with a probe and an avc meter attached makes a handy little alignment indicator. For example, if we are tuning up an rf amplifier stage, we feed in a signal at the desired frequency, tune the rf stage to it, and then pick up the rf signal output at the mixer grid with the probe. Now, we can adjust the input signal to a very low level and really sharpen up the tuning of the rf stages.

You can also follow an rf signal through these stages to determine if it is getting through, if there is a loss or gain in each stage, and to make many tests that are impossible with other test equipment. The probe will not seriously detune any stage, since it should never make actual contact. Because of the sensitivity of the test receiver, the probe will pick up plenty of signal when it is placed near any circuit.

You can use this for netting CB transceivers—that is, tuning all transmitters and receivers in a system exactly to each others' frequency. Tune the test receiver to the CB transmitter by keying the transmitter and tuning for maximum avc voltage. Next, tune your rf signal generator to the same frequency in the same way. Now feed the signal from the rf generator into the CB receiver, and tune it up for maximum output. The test receiver can be used as an output indicator by picking up the i.f. signal at the CB audio detector. A scope or output meter could also be used. The CB transmitter itself can be used for this of course, but the rf signal generator will do a better job because its output can be controlled. We should always make this kind of alignment adjustment on the smallest possible rf signal, to avoid flattening the response curves or overloading the high-gain rf circuits.

In some vhf receivers, such as in two-way FM systems, you'll find frequency multiplication used to produce a vhf frequency from a low-frequency crystal oscillator. These receivers can be very confusing if you're not sure the multiplier coils are tuned to the correct harmonic! Set the dial of the test receiver to the correct harmonic frequency, hook the probe over the output lead of the multiplier coil, and tune for maximum.

## 4-9. THE AC VOLTMETER FOR GAIN CHECKS AND SIGNAL TRACING

The ac voltmeter can be a handy instrument. The standard rectifier-type voltmeter has a good frequency range, making it especially useful for gain checks and signal tracing in audio amplifiers.

Feed an audio signal—about 400 Hz—into the input of an audio amplifier. Put a blocking capacitor of any size from .01 to 0.1  $\mu\text{F}$  in series with the meter. (Rectifier-type meters are affected by dc; the capacitor blocks any dc and lets you read only ac or signal voltages.) Now you can start at either end of the amplifier and trace the signal through each stage to find out whether there is gain or loss.

This test is handy in amplifiers that are weak but not dead. It's a rapid way to find the defective stage in a dead amplifier, too. Simply run through the circuit until you find the stage that has signal on the input but none on the output, and there you are.

This technique works with tubes or transistors and is especially useful in transistorized PC-board circuits. By using signal tracing first, you save the trouble of making voltage measurements and unsoldering parts before you have actually found the defective stage. The basic thing to check for here is small signal on the input (base or grid) and larger signal on the output (plate or collector), which would indicate that the stage does have gain. When you find a stage with no gain, or with a loss, that's the faulty one.

There is one exception to this rule in tube circuits and, to some extent, in transistors—the split-load phase inverter. As a rule, this stage is not designed to have any gain, but merely to divide and invert the signal. In the tube circuit, the load resistance is divided equally between the plate and cathode circuits. Thus, equal signal voltages appear on the two elements, but one signal is  $180^\circ$  out of phase with the other. There are several transistor circuits that do the same thing. To check for proper operation of such a circuit, measure the signal voltages on the input elements (grids or bases) of the following push-pull stage. The two signals should always be equal in amplitude. You can't check the phase without a scope, but chances are, if the signals are of equal amplitude, everything else is okay.

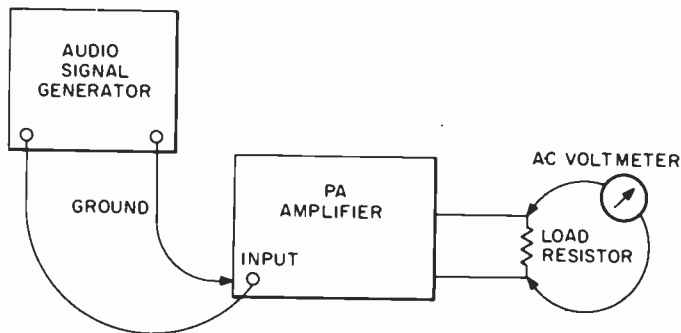
The ac voltmeter is also handy for finding troubles in stereo amplifiers. Feed the same audio signal into both inputs at the same time. Now measure the signal levels in corresponding stages of the two channels. At a given point, if you find one channel with a much lower signal than the other, that's the source of the trouble. Use the good channel as a

guinea-pig to find out where the trouble is in the other channel.

The gain setting must be the same in both channels to prevent confusion. A good procedure is to turn both gain controls full on and then reduce the input signal level until the output level is about right. Don't overdrive; most stereo amplifiers have high gain and need only a small input signal. For the average phono input, 1 or 2 volts is plenty; for a microphone input, much less will do—.005 volt or less. Very high input signals can cause severe distortion and may even damage transistors.

#### 4-10. POWER OUTPUT TESTS FOR PA AND HI-FI AMPLIFIERS

We should check the power output of PA amplifiers *and* hi-fi's to see if that 30-watt amplifier is actually able to deliver 30 watts output. There is a simple test. After repairs have been completed, and the amplifier is theoretically in first-class shape, hook up a properly matched load resistor across the output, feed in an audio signal, and read the power output by measuring the audio voltage across the load resistor. Ohm's law does the rest.



The figure shows how the equipment is set up. We need a resistor that matches the output impedance of the amplifier and has a rating high enough to handle the power, with a safety factor. For a 30-watt amplifier, a 50-watt resistor is fine. You can often get such resistors from surplus stores at reasonable prices. Otherwise, you can make them up from stock values. For instance, PA and hi-fi tube amplifiers usually have output transformers tapped at 4, 8, 16, and 500 ohms. Five 75-ohm 10-watt resistors in parallel give 15 ohms at 50 watts (for equal resistors,

power ratings are totaled), and this is close enough for the 16-ohm tap. Five 2,500-ohm resistors in parallel give 500 ohms, etc.

With the load resistor hooked up, feed a low-level audio signal into the input; 1,000 Hz is a good frequency since most audio measurements are made at this frequency. Actually, the frequency doesn't make too much difference, as long as you're somewhere between 500 Hz and 5,000 or 6,000 Hz. (On most transistor amplifiers, especially the older ones, *don't* feed in a high-frequency signal—say, 15,000 Hz—at high power. The output transistors will overheat.) Remember this precaution: *Never* turn on an amplifier without the load resistor or the speaker hooked up. Even in tube amplifiers, you can burn out the output transformer in a very short time. And transistors can go in a fraction of a second if they are run without the proper load. Never short transistor outputs!

The service data will give the correct input level for many amplifiers. However, what we're interested in here is the power output stage; can it deliver the rated power? To find out, we hook an ac voltmeter across the load resistor and fire up the amplifier. If we're using a 15-ohm resistor, and the amplifier is rated at 30 watts, for example, we should read at least 21 volts. Using  $W = E^2/R$  and transposing to calculate E, we get  $E^2 = 30 \times 15$ , which gives us about 21 volts for E.

This is also a good voltage-amplification or sensitivity check. For example, on a phono input you should get full power with the normal input level. With a high-output phono cartridge, this would be about a 2-volt input signal. On a low-output microphone, it would be about 5 mV, etc. If you can get full output only by overdriving the input to two or three times normal, then one of the voltage amplifier stages isn't giving enough gain.

## Section 5

### Oscilloscope Tests

#### 5-1. TESTING WITH THE OSCILLOSCOPE: INTRODUCTION

A typical service-type oscilloscope will not read dc voltage, dc current, ac current, or even ac voltage—directly. (Please note I said *directly*. We can read ac voltage on a scope, but only by *comparing* the vertical deflection to the vertical deflection of a known ac voltage from a calibrator.) Despite this, the scope is the handiest instrument in the whole shop. It can do something no other instrument can—read *signals*. In one of the most simple tests—using a test probe to touch one point and then another in a circuit—the scope tells us immediately and definitely if a given stage has any gain. Since we spend a lot of time trying to locate certain stages with no gain or insufficient gain, the scope can be a real timesaver. In many cases, it is the *only* instrument that can give us the necessary information.

An ac voltmeter can tell us if there is any ac voltage in a circuit, but the scope is the only instrument that determines whether the voltage is hum, vertical sync, video, audio, or some other type of waveform. By comparison with a voltage standard (calibrator), it informs us if this signal is of the right amplitude.

We can make gain checks with the greatest of ease: Feed in a test signal of the frequency normally used in the circuit, and check the signal levels at the input and output of any amplifier stage. If we read a vertical deflection of 1 unit on the input and 8 units on the output, the stage has a voltage gain of 8.

The scope is the closest we have to a really universal test instrument. It works with tubes, transistors, printed circuits, integrated circuits, or any other kind of circuitry with equal ease. Why? Because it reads signals, the one thing all circuits have in common. No matter how a circuit is built



or what voltages it uses, it handles signals—amplifies them, clips them, shapes them, or does something to them—and we can check these actions with the scope.

We should use the scope in radio and TV work as often as we do the vom or vtvm; it really speeds up the work.

Let's examine a few typical scope patterns—learn to recognize and interpret them. Like most tests, the important question isn't "What have we got here?" but "What does what we've got *mean*?" Look at Fig. 1. (This photo brings to mind the airman taking a flash-card aircraft-identification test. He identified a B17 bomber as "a four-motored blur, sir." Fig. 1 is "a rectangular blur, sir." But it *does* have meaning!)

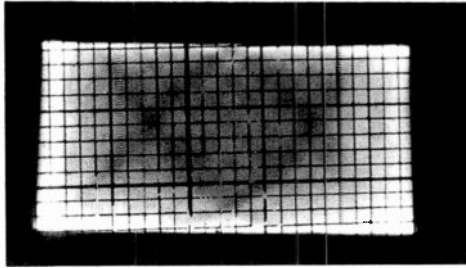


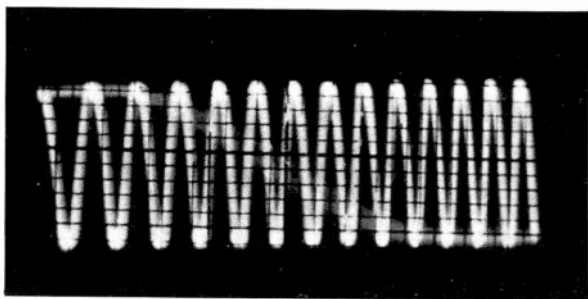
Figure 1

Notice that the pattern height covers 12 small squares on the calibrated screen. The vertical deflection represents an ac signal, but the scope sweep is set off frequency, so we can't see the individual cycles of the signal. It could be a sine wave, square wave, or anything.

However, this scope image can be used. Suppose we're feeding an audio signal into the input of an amplifier and we grab the scope and touch the probe to the circuit. If we see this pattern on the input of a stage (tube grid or transistor base) and then move the probe to the output (tube plate or transistor collector) and see the same pattern, height and all, it means that the stage has a gain of 1.

What this signifies depends on what we're testing. The scope reads *voltage*. If we're testing the preamplifier stage of a tube amplifier, we're in trouble; this stage should have a very high voltage gain, up to 50. However, if we're testing a transistor preamp stage, then a 1:1 voltage ratio may be perfectly normal; such transistor stages often have a 1:1 voltage ratio but a large *current* gain which gives the required gain in signal *power*. If we find a voltage ratio of 1:0.25, then we have found trouble.

If we're looking for distortion, we do need to see the individual cycles. We feed in the signal and touch the probe to any point in the circuit where the signal can be seen (preferably at the input), so that we will know what the test signal looks like before we start. Then adjust the scope's horizontal sweep so we can see the individual cycles, as in Fig. 2. Adjust the sync-lock control of the scope to stop the pattern. This is a fairly good sine-wave pattern, but we really should spread it out a little to get a better look at the waveshape. To do that, use a faster sweep or turn up the horizontal-gain control.

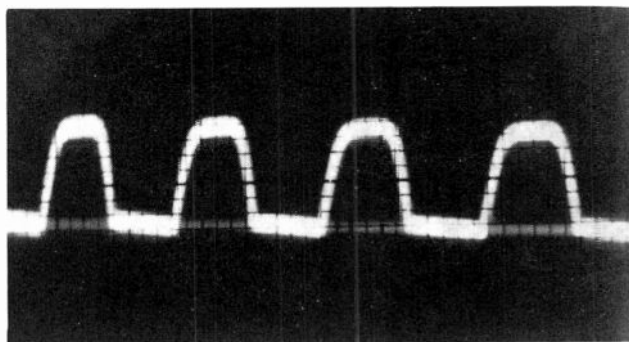


*Figure 2*

If the waveform shows distortion and we suspect that there is clipping of the signal somewhere in the amplifier, trace the signal through the amplifier from the input until a pattern similar to Fig. 3 appears. Fig. 3 shows a decided clipping on one-half of the sine-wave signal. By checking the circuit, we can tell what part is most likely to cause this distortion. In certain circuits, this could be the correct waveform. In a transistor class-B output stage, each transistor carries one-half of the sine-wave signal. However, if the output at the speaker looks like Fig. 3, only one-half of the circuit is working so we should look for trouble there.

We can identify positive and negative halves of a sine wave. We only need to know which way our scope deflects on a positive-going signal. Most scopes have a reversing switch that will invert the pattern, and this switch must be in the *NORMAL* position before the test. Hook a 1.5-volt battery to the vertical input and see which way the beam jumps. Most service scopes are set up so a positive voltage makes the beam go up with the reversing switch in the normal position. In an ac-coupled scope, the beam will jump up or down, then come back to the original position. In dc-coupled scopes, the beam will be permanently deflected by a specific amount.

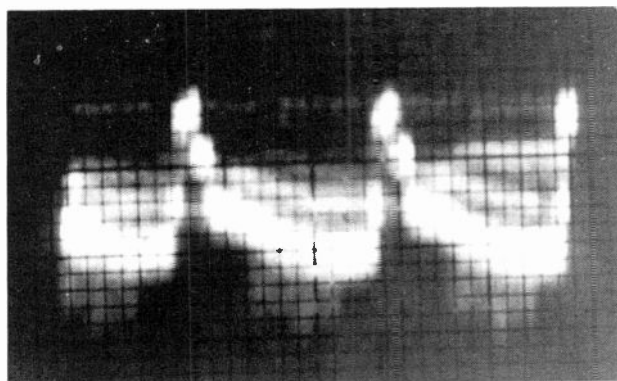
By setting the switch so the positive voltage makes the beam deflect up,



*Figure 3*

we can identify the positive and negative halves of the signal waveform. This is useful in the class-B transistor-output stages just mentioned. We can also tell where the zero line is. The zero line is the position where the beam rests when there is no signal input. By adjusting this to the center line on the calibrated screen, we can tell how much of a waveform is positive and how much is negative.

It is not imperative for a scope pattern to be clear and sharply focused to be useful. In the horizontal-oscillator tests given later, we can use a pattern like the one shown in Fig. 4. What we're looking for in this case are horizontal sync pulses in a TV signal. The figure shows three of them; the third is at the extreme right of the pattern. (Our scope sweep therefore, is running at 15,750 Hz divided by 3, or 5,250 Hz. We can use this setting to make comparison tests anywhere in the horizontal sweep circuits.) Don't waste time trying to make picture-book patterns, when all you need to know is the number of cycles of signal that can be seen on the scope.



*Figure 4*

## Calibration for Direct Measurements

The height of the pattern on the scope screen depends on the setting of the vertical gain control. A 2-inch pattern means nothing, *unless* we have previously set the vertical gain so that we see a 2-inch deflection when a known voltage (1 volt p-p, or 10 volts p-p) is applied to the input. One way to set the gain is with an external voltage calibrator, which is just a tapped transformer with an accurate ac voltmeter connected across the output terminals. The scale on these meters is usually calibrated in rms, peak, and peak-to-peak voltage. A given deflection can be read as any one of the three, depending on what we want it to mean in a particular test. *Unless a special probe is used, a scope always displays peak-to-peak voltage.*

Many scopes have built-in voltage calibrators. Some have variable calibrating volages with a volt-reading knob. Others have a regulated 1-volt p-p output. By using the calibrated step attenuator, we can set the scope up for 1 volt on the lowest (most sensitive) range, and then turn the attenuator to  $\times 10$  and read 10 volts for the same deflection; to  $\times 100$  and read 100 volts for the same deflection; etc. Check the instruction book for your scope to see how this attenuator is marked. Some are marked in gain and others in attenuation. They do the same thing, the markings are just different.

If you don't have a scope calibrator, you can use any kind of variable ac voltage, measuring the value with an ac voltmeter (remember that the standard ac meter reads *rms* voltage). The filament voltage of your tube tester is a very useful calibrator, since it runs from 1.1 volts to 117 volts. This, too, is in rms values, and you'll have to use the conversion formula: 10 volts rms = 14.14 volts peak, and 28.28 volts peak to peak. If you want a very rough peak-to-peak measurement, just figure that the peak-to-peak is three times the rms voltage.

As we go through the various scope tests that you can use to speed up radio-TV-electronics servicing, you'll see that we're using the scope mainly to answer these questions: "Is it there, or isn't it; if it is there, how big is it?" This information is very helpful in getting the first clue about a problem.

## 5-2. OSCILLOSCOPE PROBES

The purpose of any test is to discover what's going on in a circuit. During a test, we don't want to disturb the circuit any more than is absolutely necessary. That is why we prefer the high-resistance vtm to the vom. A vom could have as little as 40,000-ohms input resistance (on a 2-volt scale, 20,000 ohms-per-volt). The most sensitive instrument in the shop is the oscilloscope; its normal input has a very high resistance—up to several megohms—and a very small shunt capacitance—only a few picofarads. The direct input of a scope can be used for many tests as is. It can also be used in any audio-frequency circuit, most video-frequency circuits, for ripple testing, etc.

There are specialized probes we can use to get information concerning special circuits—tuned circuits, very high resistance circuits, etc.—where we must have a minimum of capacitance and a maximum of resistance to keep from upsetting circuit conditions when we attach our test equipment. These special probes have cylindrical housings with test tips of various kinds and are attached to the vertical input of the scope through well shielded cables to keep them from picking up stray signals that we don't want—for example: radiation from the horizontal-sweep circuit, hum, etc. The probe bodies are usually shielded as close to the tip as possible for the same reason, and the ground lead is usually kept very short and attached directly to the probe body itself.

### The Low-capacitance Probe

Perhaps the low-capacitance probe is the most popular of the specialized probes. Fig. 1 shows the schematic of a typical unit. Notice that there are actually two capacitors in series in the input. The  $.05\text{-}\mu\text{F}$  serves mostly as a dc blocking capacitor; low-capacitance probes are used at high frequencies, and the series reactance of a  $.05\text{-}\mu\text{F}$  capacitor is so low at such frequencies that we can usually neglect it. The capacitor that counts is the little 9-pF unit shunted across the 1.8-meg resistor.

This capacitor, in series, actually forms an ac voltage divider with the input capacitance of the scope. The size of the capacitor and the value of the cable capacitance are so proportioned that the probe has a 10:1 step-down ratio; it is called a divider probe. Therefore, if you see a 1-volt peak-to-peak deflection on the scope, it means that the actual signal voltage is 10 volts p-p. The little trimmer capacitor shown above the resistor is used to make fine-tuning adjustments of the total probe series capacitance in order to match it exactly to the input capacitance of the scope itself, and to the cable capacitance. Proper matching is needed to obtain

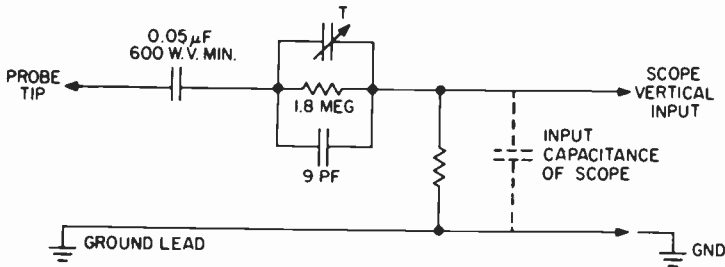


Figure 1

the right division ratio and to sharpen the high-frequency response. The resistors used here are all big ones and their exact values are not usually critical.

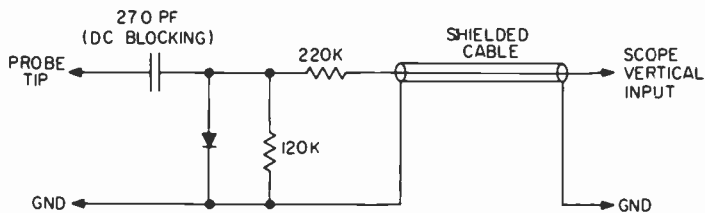
### The Detector Probe

The detector probe seems to be next in popularity. A scope won't show the modulation of a radio-frequency signal in the form we need until after we have gone through the set's detector circuit—the video detector in TV sets, the second detector in radio receivers, etc. If we need to read the signal level, modulation, etc., of a TV or radio signal in the i.f. stages, tuner, and other circuits ahead of the detector, we must provide our own detector. Fig. 2 shows schematics of two detector probes. Of these, the shunt type seems to be used most often, but either one will work. All they do is demodulate the signal so that we can see what's happening to it in the stage we're testing.

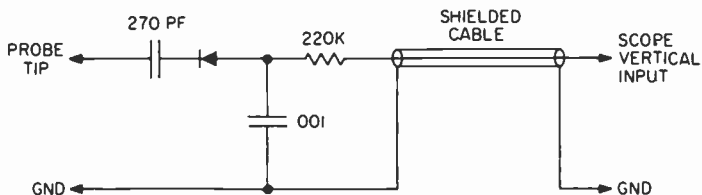
Each probe consists of a crystal-detector diode, with a couple of resistors and capacitors. For safety's sake, a dc blocking capacitor is usually placed between the diode and the probe tip in case you should accidentally touch a high-voltage point in the circuit; 200–300 volts dc wouldn't do a 1N64 diode much good.

A detector probe can be used for signal tracing through the video i.f. of a TV set if we feed in an AM signal. We'll show the special tests you can make with this type of probe as we go along.

There are also voltage-doubling probes with two diodes, but most detector probes are simple half-wave rectifiers. The type of circuit used is usually marked on the probe body.



A - SHUNT PROBE



B - SERIES PROBE

Figure 2

### The Resistive-Isolation Probe

There's one more specialized probe. It's called a resistive-isolation type, and that's just what it is—a resistor, somewhere around 50,000 ohms, mounted in a probe body. This probe is used in some tuner tests, video-amplifier tests, etc., so we get a little more resistance and can isolate the scope's input capacitance from the circuit as much as possible.

### The Direct Probe

The direct probe is just what it says: The wire from the vertical input of the scope comes straight through the probe body to the tip. The body of the probe is, or certainly should be, well shielded as close to the tip as possible, to hold pickup of stray signals to a minimum.

### 5-3. TESTING FOR FILTER RIPPLE WITH THE SCOPE

One of the best and fastest ways to check the condition of the filter capacitors in all ac power supplies (tube or transistor) is to touch the scope probe to the rectified output—to the B+ point that supplies the operating dc voltages to the circuits. The voltage at this point should be a pure dc, which would make a straight line on the scope, but normally we have a small amount of the ac left. This ac is called ripple; it looks like Fig. 1.

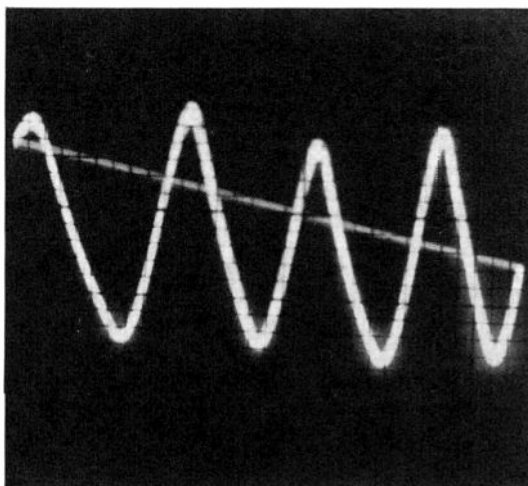


Figure 1

Note the generally triangular shape of the waves, and also note that you see a high peak, then a lower one, then another high one, etc. This unevenness is due to the fact that this is a 120-Hz waveform in a full-wave rectifier circuit; in TV sets, the vertical output circuit takes a heavy pulse of current at a 60-Hz frequency, and this causes the drop in voltage on every second peak of the ripple.

You may have encountered TV's where a dark (or light) bar floats up and down through the picture. This trouble is caused by insufficient filtering in the B+ circuits (and not infrequently by faulty silicon rectifiers.—*Editor*). If you check the power-supply ripple, you'll see a big difference between the high and low peaks, and one will usually change phase with respect to the other. The ripple waveform will writhe slowly if you lock the scope sweep to the local line frequency (Fig. 2). The cure for this is more filter capacitance since ripple is caused by a



lack of capacitance in the filter. Either the circuit didn't have enough to start with, or one of the original capacitors has gone down in value. If the original capacitors seem to be okay, add more capacitance until the ripple is reduced and the bar vanishes.

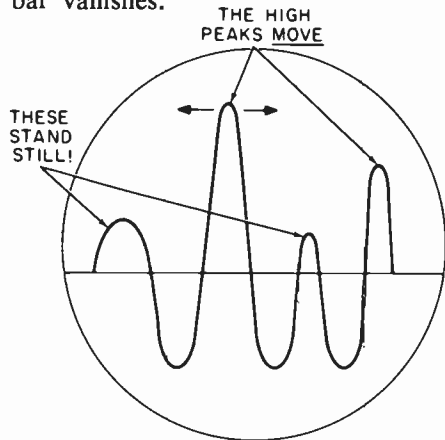


Figure 2

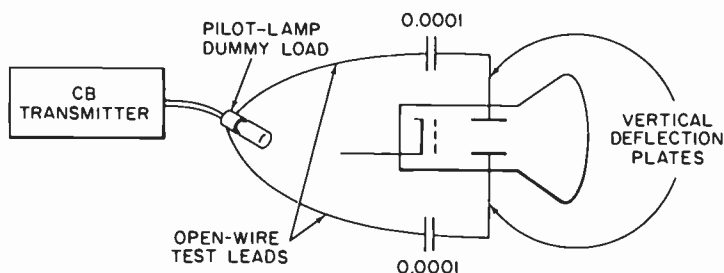
The normal peak-to-peak value of the ripple will be given on the schematics of recent sets. As an average, it shouldn't be more than about 2 volts p-p at the filter output. On the rectifier output (filter *input*) it will be higher—usually somewhere around 10–12 volts p-p, or even more. However, the ripple at the filter *output* is the one that causes trouble, so check it first.

#### 5-4. CHECKING CB TRANSMITTER MODULATION WITH THE SCOPE

The oscilloscope will do a good job of measuring the audio modulation of a CB transmitter if we use it correctly. We need to measure the rf output with and without modulation. However, even the wideband color scopes with bandpass up to 5 MHz won't do too much on a 27-MHz rf signal. You'll get only a line on the scope screen. When you modulate the transmitter, the modulation will appear on the screen. This is what happens: The vertical amplifier in the scope simply won't pass the high-frequency rf carrier, but it will detect the audio modulation and show a good-sized deflection.

To get a true picture of the rf output, feed it directly into the vertical plates of the scope CRT. This gives you an almost unlimited bandpass, but no gain since you're going around the vertical amplifiers of the scope.

You'll probably see a line about  $\frac{1}{2}$  inch in height, at most, for the unmodulated carrier. If you feed an audio signal into the microphone, or whistle into it, you'll see the modulation.



By estimating the increase in pattern height, you can tell if the transmitter is modulating properly. If it should be overmodulating, the carrier will break up into the characteristic string-of-beads pattern. Check the modulator or rf stages; too much audio or too little rf output have the same pattern and effects.

Another good cross-check for modulation is to use a pilot lamp as a dummy antenna. With the transmitter unmodulated, it should glow a bright yellow; whistling into the microphone should make it glow more brightly.

Some older scopes have provision for connecting directly to the vertical deflection plates by turning a switch on the front marked AMP OUT. Others have terminal boards on the back of the scope case, with links that can be opened to give access to the vertical plates.

In either case, use plain, unshielded test leads for this test. Don't use shielded wires: the shunt capacitance of even the lowest-capacitance coax will reduce the signal strength greatly, and there isn't any to spare. Put a small blocking capacitor in series with each lead—a  $.0001\mu\text{F}$  (100 pF). Connect the test leads directly across the dummy-load lamp.

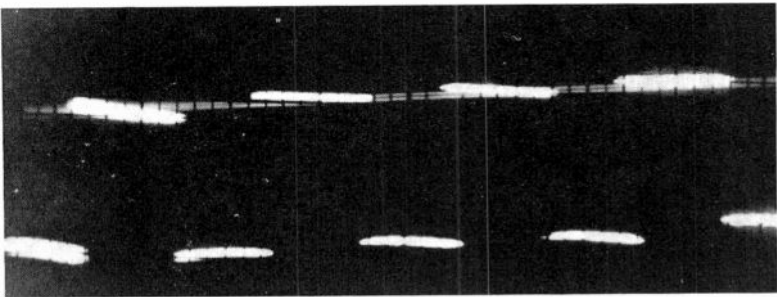
If your scope uses only one vertical-deflection plate with the other tied internally to one of the horizontal-deflection plates, use the free plate as the hot lead and connect the common plate to the CB-set chassis. Keep the test leads well apart, and make sure they aren't moved during the test; movement could change the shunt capacitance and the readings.

## 5-5. SQUARE-WAVE TESTING

A square-wave signal is more than a sine wave with the tops and bottoms clipped, although this is the way many commercial signal generators make them. If you want to get mathematical about it, a true square wave is a signal of periodic recurrence made up of an infinite number of odd harmonics of the fundamental frequency. You can make complicated scientific tests with square waves if you want, but there's one test that we can use in the service shop with no math.

If we feed a good square wave, such as the one in Fig. 1, into an amplifier and get a signal that looks anything like the original, it is a good amplifier. The first thing we must do is check the frequency response of our scope by feeding the square-wave signal directly into the vertical amplifier. If your scope does show signs of tilt on the tops and bottoms of the square waves, or any other troubles, you can often get around this by switching the vertical amplifier off and feeding the signal directly to the vertical-deflection plates. Most scopes have provisions for doing this. You will always have a good-sized signal at the output of an amplifier under test, so you'll get plenty of vertical deflection without using the amplification of the scope. Incidentally, a square-wave signal is also useful for finding horizontal nonlinearity and other troubles in the scope amplifiers.

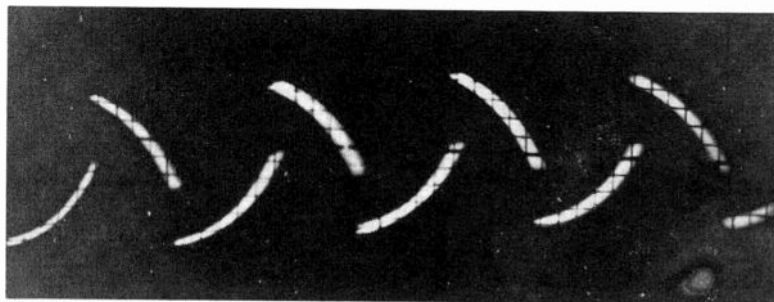
In the waveform of Fig. 1 all you see are the tops and bottoms of the signal. The vertical lines aren't visible because they rise and fall too fast to register. This is the sign of a good square wave (and also a fairly good scope amplifier, even if it is just a service-type scope). However, even if the vertical lines are visible on your scope, it doesn't matter. What does matter is the distortion that may be added to the square-wave signal on its way through the amplifier being tested; all we need to do is com-



*Figure 1*

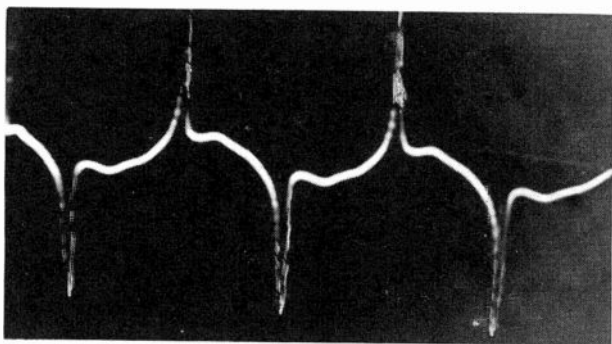
pare the input and output signals, and we'll learn what we want to know about the amplifier's performance.

For instance, if the square wave at the output of the amplifier looks like Fig. 2, then the amplifier has poor low-frequency response. Poor high-frequency response shows just the opposite reaction; the tops of the waves slant up toward the right.



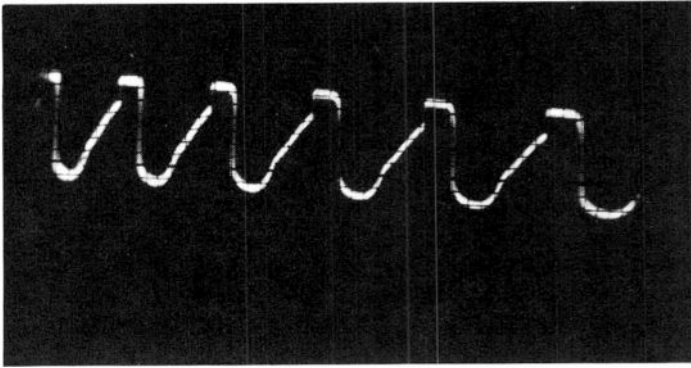
*Figure 2*

If you feed in a good square wave and get something out like Fig. 3, the amplifier is differentiating the square pulses—making spikes out of them. This is usually due to a load resistor that has gone down in value,



*Figure 3*

to an open capacitor, etc. The type of distortion seen in Fig. 4 could be caused by a leaky coupling capacitor, a load resistor that has fallen off in value, incorrect bias, etc. This basic pattern can also be found in push-pull circuits where the two halves aren't balanced; note that the top halves of the wave differ from the bottom. This always means an imbalance somewhere.



*Figure 4*

Don't be too critical. If your output waveform is a reasonable duplicate of the input, take it and be happy. An amplifier that could reproduce a perfect square wave in the output from a square-wave input of 1,000 Hz would need a bandwidth of more than 20,000 Hz. Even the best hi-fi amplifiers have a maximum bandwidth of about 50,000 Hz, and these are the very high-quality, expensive types. Cheaper amplifiers have a maximum bandwidth of about 18,000 Hz, so you'll never find perfect reproduction. In fact, if the output signal is as good as Fig. 4, but without the imbalance, take it; it's not so bad.

Square waves can also be used to check out video amplifiers. These amplifiers will show better-looking output signals than audio amplifiers do since they have bandwidths up to 3 or 4 MHz. To get the best results, pull the socket off the CRT and pick up your signal at the video-input element—grid or cathode. By doing this, you substitute the input capacitance of the scope for that of the CRT and get better high-frequency response.

Slanting tops and bottoms of waveforms indicate a poor low- or high-frequency response, as we have mentioned. Round corners indicate poor high-frequency response, while a sharp-cornered wave, perhaps with some overshoot spikes at the leading and trailing edge, means that the amplifier is overpeaked and has too much high-frequency response. Overshoots usually mean the amplifier circuits have a tendency to ring at high frequencies.

## Section 6

### Component Tests

#### 6-1. DETECTING THERMAL DRIFT IN RESISTORS

Thermal drift in resistors is one of the most common and annoying troubles in all kinds of electronic equipment. It causes such symptoms as "it plays for an hour and then acts up," etc. If a carbon resistor changes in value as it heats up, it changes the circuit characteristics.

The time constant will tell you a lot. If the trouble shows up inside of 15 minutes, it is probably due to self-generated heat in a resistor. This is heat generated in the resistor because of the current it is carrying; heat occurs in plate-load circuits, voltage-dropping resistors, etc. If the trouble takes an hour or so to appear, then the resistor is being affected by heat traveling through the metal chassis or from a hot component close by.

The best test for a suspected resistor is to heat it up artificially and watch for the trouble to appear. For example, if we had a long-time-constant sync trouble, we could turn the set on, adjust it for correct operation, and then apply heat to each of the resistors in the sync circuit. Place the tip of a soldering iron on the body of each resistor, hold it there for 45–60 seconds, and watch for the sync trouble on the screen. Normal operating temperature in a TV set is 120–130°F. The tip of a soldering iron runs about 600°F, so don't hold it on the resistor too long—just long enough to get the resistor warmer than normal or too hot to hold a fingertip on it. If the resistor has a tendency toward thermal drift, this test will reveal it.

The high-value (6-, 8-, 10-, and 20-meg) resistors found in agc circuits are frequent offenders. You can find the guilty resistor by turning the set on, heating each one up in turn and watching the screen for any sign of the original trouble. There may be more than one defective resistor in a given circuit, so check them all while you're there.

## 6-2. CAPACITANCE TESTING: HOW AND WHAT FOR

There are only two things we need to know about almost any paper, ceramic, or mica capacitor: Is it open, or is it leaky or shorted? But how about measuring the capacitance value? It's seldom necessary, since this information is normally stamped or color coded on the capacitor itself. Capacitors of these types are not likely to shift in value, so the real question boils down to is it good or bad?

A capacitor tester, such as the one shown, is handy for determining whether a capacitor is open. We can hook it up and turn the dial rapidly from one end to the other, past the nominal value of the capacitor. If the tuning eye on the tester opens at all, the capacitor is not open.



We can make the same check with an ohmmeter for values larger than  $.01 \mu\text{F}$  by touching the ohmmeter across the capacitor and watching for the charging kick. (Smaller values give a charging kick too, but it is too small to show on the meter.)

Next, and most important, check the capacitor for leakage. A dead short or high leakage can be caught with the ohmmeter. If the ohmmeter shows any deflection at all on the highest ohms range available, the capacitor is bad. For very critical applications, such as audio coupling capacitors in vacuum-tube amplifiers, we need a test instrument that will read very small leakage—such as the one shown. This instrument has an insulation-resistance test (the meter in the upper right corner)

that can read leakage up to several hundred megs. Even a leakage of 100 megs is enough to cause trouble in a coupling capacitor.

The fastest test for a possibly open capacitor is to bridge another one across it. If you suspect oscillation is caused by an open bypass capacitor, for example, bridge it. If the oscillation stops, you have found the trouble. If a coupling capacitor is suspected, you can test it in two ways: (1) Check for the presence of signal on both the input and output sides of the capacitor. (2) Bridge another capacitor across it; if the signal now goes through, the original is open. If a capacitor opens, it has the same effect as taking the capacitor completely out of the circuit. So, replace it by bridging, and see if the trouble stops.

### **Electrolytic Capacitors**

Electrolytic capacitors, unlike paper capacitors, can change value by drying up. A dry electrolytic is not dry, any more than a dry-cell battery is. If the electrolyte evaporates in either one, it stops working. The battery dies, and the capacitor becomes completely open.

With electrolytics, the best test is again, "How well do they work?" If the service notes specify that a power supply should have 275 volts at the rectifier output, and you find only 90–100 volts, the input capacitor is very likely open. Bridge it with a good one; if the voltage jumps up to normal, that was the trouble. If the ripple or hum level is given as 0.2 volts p-p at the filter output, and your scope shows 10–15 volts p-p there, bridge the output capacitor. If the ripple drops to within the proper limits, that capacitor was open.

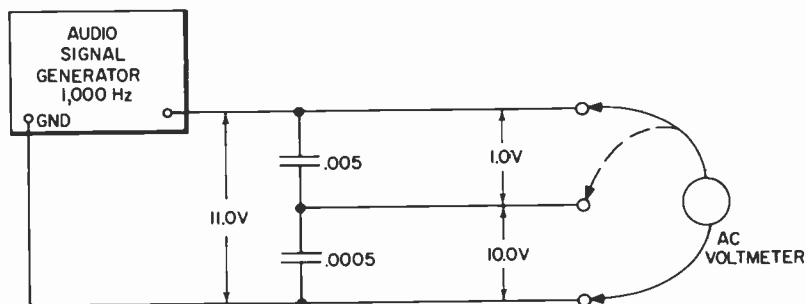
For bridging purposes, the test capacitor need not be an exact duplicate of the original. It can be much larger or smaller in value, but it must have a working voltage able to stand whatever voltage is present in the circuit. It is not a good idea to bridge electrolytics in transistor circuits with the amplifier on. The charging-current surge of the test capacitor can cause a sharp transient spike in the circuits, and this can puncture transistors. So, to bridge test in transistor sets, turn the set off, clip the test capacitor in place and then turn the set on again. With the instant starting of transistor circuitry, this won't waste any time.

If one unit in a multiple-type electrolytic is found to be bad, replace the whole can. Whatever condition existed inside that can to make one unit go out will eventually cause failure of the rest, since they're all parts of the same assembly. To avoid an almost sure callback, change the whole thing at once.



### 6-3. FINDING THE VALUE OF AN UNKNOWN CAPACITOR

There's a quick way to find the value of an unknown capacitor. It isn't accurate unless you have a precise ac voltmeter or calibrated scope and an accurate test capacitor, but it'll do. The method is handy for finding the values of those odd mica capacitors that everyone has floating around and can't read the color code on.



Put the capacitor in series with a known capacitor as shown, and apply an ac signal voltage across the two. Measure the voltage across the known capacitor, then measure the voltage across the unknown capacitor. The voltage ratio will give you the ratio of the capacitances, after some figuring.

What we're doing is putting two reactances in series across an ac-voltage source. The result is a voltage divider that works the same way as two resistors in series across a dc source. Suppose, for instance, that you put 11 volts at 1,000 Hz across a series combination consisting of a  $.005\text{-}\mu\text{F}$  capacitor and an unknown capacitor. Suppose then you measured 10 volts across the unknown, and 1 volt across the known.

Now the figuring. The voltage ratio for the unknown and known capacitors is 10:1, and so is the ratio of reactances. The ratio of *capacitances* is just the opposite, or 1:10. This is because the reactance of a capacitor is inversely related to the capacitance: As capacitance increases, reactance decreases, and vice versa.

In the example given, the unknown capacitor has a value one-tenth as great as the known capacitor, or  $.0005\ \mu\text{F}$ . Remember: A voltage ratio of 10:1 means a capacitance ratio of 1:10.

If you prefer, you can work with reactance values, reading them from a table and then using the table to find the corresponding capacitance values. You can find such a table in the *Radiotron Designer's Handbook*, Fourth Edition, page 1378.

## 6-4. MEASURING INDUCTANCE

The question is often asked, "How can you measure inductance?" The best answer is, "You can't." Inductance measurements, with common shop equipment, are a practical impossibility. Oh, you can read it by spending lots of time and doing a lot of mathematics, but the best advice we can offer is, "Don't."

In practical service work, we seldom need to read the inductance of a coil or transformer in henrys or millihenrys. We are usually interested in just one thing—continuity. This is a simple ohmmeter test. All service data give the dc resistances of coils, and as long as your resistance reading on an inductor is within 5% of the specified value, the inductor is probably all right.

There are only two things that can happen to an inductor: It can open completely (which is fairly easy to find!) or it can develop shorted turns. In power transformers, etc., shorted turns will give a very definite indication—smoke. In other circuits, such as output transformers, shorted turns cause a drastic loss of output, and we can locate this by elimination tests and power measurements.

Flybacks are a special case; they act more like tuned circuits than ordinary transformers do. They are tested by a special instrument that connects the coil into a circuit and makes it oscillate. The Q of the coil is then read on a meter. However, flybacks can be checked for shorts by reading the cathode current of the horizontal-output tube and then disconnecting all loads, such as the yoke and damper circuits, and reading again. If the cathode current is far above normal, the flyback is internally shorted. When the loads are disconnected, the current should drop to about one-fourth its normal full-load value.

To get an inductance of any particular value, there's one easy way—buy it. You can wind coils all day, trying to get an 8.3- $\mu$ H choke, but if you'll call your distributor, he can have a choke coil with exactly 8.3  $\mu$ H in your shop in a few minutes. Coil and transformer makers have a tremendous selection of coils in all conceivable sizes, listed by their inductance, mounting style, etc. By far the easiest way to work with inductors is to go buy an exact duplicate when you need it.

## 6-5. TESTING INTEGRATED CIRCUITS, MODULES, AND PC UNITS

Printed-circuit units are appearing in radios and TV sets in large numbers. These devices range from a simple R-C integrator used in vertical sync circuits to the equivalent of a whole amplifier circuit, each in one sealed package. Admittedly, these units are impossible to check in detail since we can't get into them to test individual parts. However, there is at least one reliable check and that is an output check.

In the integrator circuit, we check to see that the proper composite sync signal is present at the input. If the correct sync waveform is not found at the output, the unit is bad. This method can be used on any module. There are three things that must be carefully checked before any printed-circuit unit is condemned: (1) the supply voltages and currents; (2) the input signal; and (3) the output signal.

For instance, if the modular circuit is an audio amplifier, it will need a certain amount of dc voltage supply, and draw a certain amount of current. With 0.5 volt of audio signal on the input, it will have a normal output of 5 volts. If the unit meets these specifications, we look elsewhere for the trouble. Don't replace units at random. Make definite tests and be positive you're right before you replace any units.

The scope and signal generator tell you definitely if a stage is bad by checking input vs output. If it is bad, don't overlook the supply voltage; many of us do now and then.

## 6-6. A QUICK CHECK FOR MICROPHONES

There's a good, quick check for almost all microphones, especially the common dynamic and crystal types: Make them talk rather than listen. Any of these microphones will reproduce sound as well as pick it up. For instance, if you have a tape recorder that won't record, the first question you should answer is whether the trouble is in the mike or the amplifier. Feed an audio signal into the mike itself, and listen.

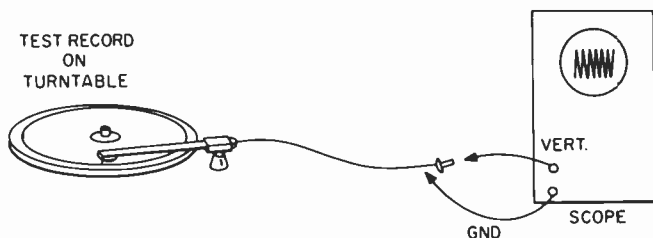
You can use an audio-signal generator or any audio signal from a radio or TV set. It takes only a very small signal to make a mike talk. A dynamic microphone is nothing but a specially built dynamic speaker. Crystal mikes won't talk as loudly as dynamics, but even the variable-reluctance types used in communications work will talk. Incidentally, this is a good quality check for microphones if the complaint is distortion in the sound output of a PA system or transmitter. By feeding a music or voice signal into the mike and listening to it, you can detect dragging voice coils, buzzes, etc.—defects that would distort the sound pickup. Also, if you happen to have a replacement cartridge for the type of mike you are testing, you can easily make A-B comparison tests of the sound quality of each.

This test can be reversed, too. If you have a complaint of possible mike trouble, hook up a small dynamic speaker to the mike input and talk into it. If the mike input is high impedance, use an output transformer to bring the low voice-coil impedance up enough to work. Actual high-impedance mike transformers will be up around 50,000 ohms, but you can use almost any output transformer. One of the old 25,000-ohm transformers is good, but the test will work with even a 10,000-ohm type. If you're checking for possible mike distortion, hold the mike at least 10–12 inches away as you talk. You'll be surprised at the quality of the sound. Transistor radio speakers make good test mikes because of their tiny size.

## 6-7. CHECKING PHONO CARTRIDGES WITH THE SCOPE

When we find low gain in record-playing systems, one of the first things to determine is whether the trouble is in the cartridge or amplifier. The scope is a quick check for the cartridge. With its high-gain vertical amplifier, we use it as a sensitive ac voltmeter.

Put a single-tone test record on the turntable, disconnect the cartridge leads at the amplifier (although this isn't really necessary if they're soldered in) and hook the vertical input of the scope to the hot wire, as shown. Set the vertical-gain control of the scope to give about 1 inch deflection for a 1-volt p-p input. Put the stylus on a band of continuous tone—say 400 Hz. For the average crystal cartridge, the output will be from 1–3 volts.



If you want to make a frequency run on the cartridge, you can do it even with a narrow-band scope. Most of these scopes will go up to at least 50 kHz without trouble. You'll need a test record with a band of all frequencies on it, starting at 30 Hz and going to 20–30 kHz, at the same output level. Several test records of this type are available. This test can also be used on the whole amplifier.

One valuable application of a scope test is checking stereo cartridges for equality of output in the two channels. Use a test record with a monaural band at about 400 Hz, or a stereo band with equal outputs in the two channels. Several test records have this band for checking speaker phasing, channel balance, etc. Just read the output from each side of the cartridge; the two should be the same.

Cartridge tests can also be made with an ac vtvm. The readings will be the same as with the scope: 1–3 volts p-p. Even an AC-VOLTS scale on the vom will do, although the meter must have a sensitivity of at least 10,000 ohms per volt on ac. The low input impedance of the vom will reduce the readings. They will average from 0.3 to 0.4 volt, where the scope reads 1–3 volts. Crystal and ceramic phono cartridges should work into a load impedance of 3–4 megs.

## 6-8. VIBRATOR TESTING WITH THE SCOPE

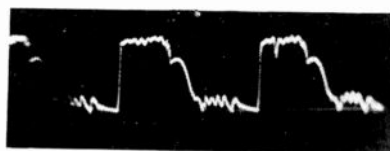
There is little equipment around any more that uses vibrators; these devices went out as the transistorized auto-radio came in. However, you will come across one now and then.

The condition of the contact points in the vibrator is a big concern in any vibrator-equipped power supply. With the scope, you can get the answer in a short time. (In fact, the scope is about the only instrument that can give you this information.)

Connect the direct probe across the primary of the transformer. This is usually connected to the small pins of a 4-pin vibrator. If the vibrator is good, you'll see a nice clean—though odd-looking—square-wave pattern, as in Fig. 1. The top and bottom of the wave represent the contacts, one contact for each. If either contact is not making a good contact, or is bouncing, the pattern will be very ragged, similar to Fig. 2. If half of the wave is gone, one contact isn't functioning at all. In all cases, if you see anything in addition to the clean square-wave pattern, put in a new vibrator; the old one isn't going to last long.



*Figure 1*



*Figure 2*

## Section 7

### TV Tests

#### 7-1. DC CURRENT MEASUREMENTS IN TV HIGH-VOLTAGE AND SWEEP CIRCUITS

In all tube-type TV sets, both color and black-and-white, all of the power used by the horizontal-sweep and high-voltage circuits is supplied *through* the horizontal output tube. We can tell a lot about the condition of this circuit by reading this current and comparing it to the normal value given on the schematic. Each likely trouble condition is indicated by its effect on the current. A leakage, short, or low-drive condition will make the current go up; an open circuit will make it go down. We can disconnect parts and check the effect on the current to get the necessary "split" in the circuit to find a starting point for diagnosis (see Fig. 1).

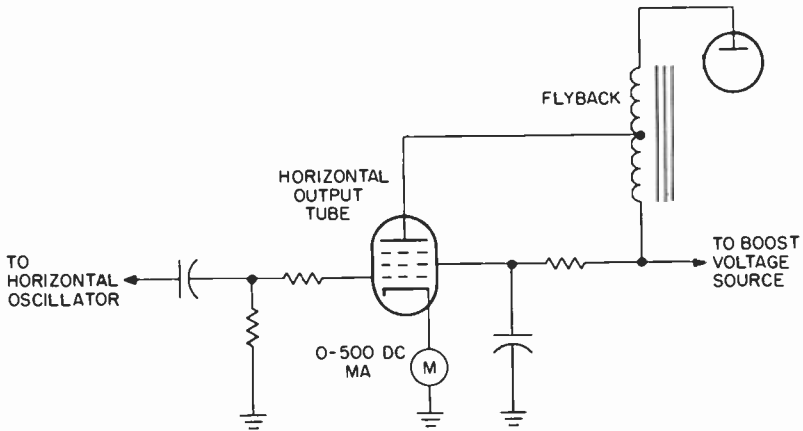


Figure 1

There is an easy way to measure the current of the horizontal output tube. We put the tube on a special test adapter that breaks the cathode circuit. Then, we can connect a dc milliammeter in series with the cathode and read the total tube current. If we want to, we can deduct the 12 to 15 mA of screen-grid current to get the exact plate current. However, this isn't usually necessary; we use the total current.

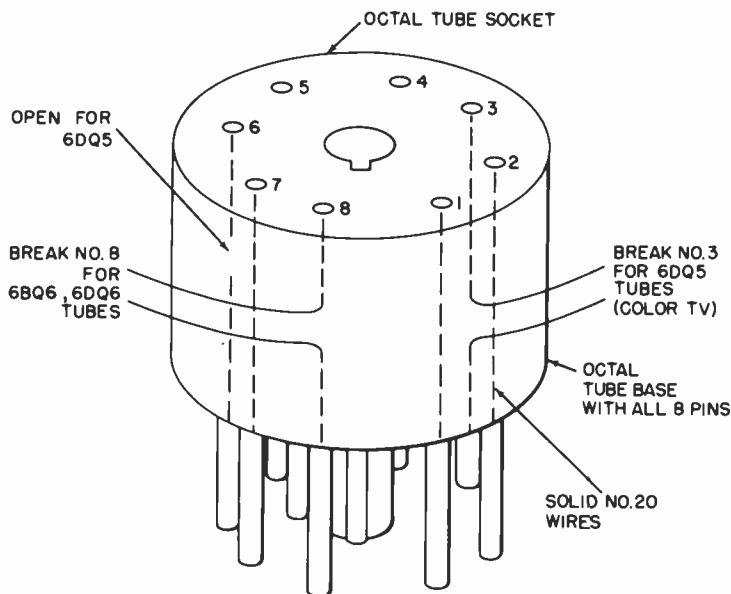


Figure 2

Fig. 2 shows how to build the test adapter. The base from a dead octal tube having all 8 pins is cleaned out. An octal socket is mounted on top. All pins except the cathode are run straight through—1 to 1, 2 to 2, and so on. If you use solid No. 20 wire, it will hold the socket firmly on the base. If it becomes loose, the socket can be cemented in place. Leads for measuring the cathode current are brought out the side as shown—one lead from the socket terminal, the other from the base pin. Test-lead wire, which is very flexible and well insulated, should be used for these. Put pin tips on the ends to match the jacks on your vom.

Check the tube manual to make sure which pin is the cathode of the tube used in the set you are testing. For the older tubes in b-w TV, such as 6BQ6, 6CU6, and 6DQ6, pin 8 is used. In the 6DQ5 tubes used in a great many color TV sets, pins 3 and 6 are the cathode, etc. In the 9- and 12-pin types, such as 6JE6, etc., used in color sets built after about 1965, pin 3 is the cathode. (You'll probably have to buy special test adapters



for these because you can't use the tube base; it's made of glass. However, test adapters are available, and these can be converted.)

In many sets, pins 3 and 6 are tied together at the socket; in most cases, pin 3 seems to be the favorite for making the ground connection. The service manuals specify opening this ground lead to hook up the milliammeter, but this means that the chassis must be taken out of the cabinet. With a suitable adapter, you can take the same reading from the top and save lots of time.

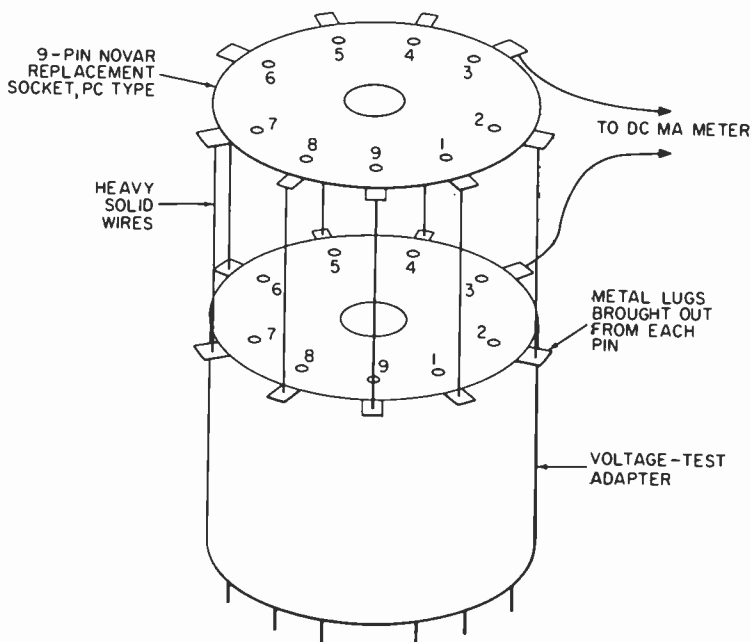
Normal current will be specified. After a little practice, you'll learn the average current drain for the popular tube types. For example, 6BQ6 tubes should draw about 95 mA maximum; 6DQ6 tubes can carry up to 120–130 mA safely; and 6DQ5's in color sets draw up to 185–200 mA. If you find a new tube type, check the tube manual to see what its safe cathode current is, and to learn its pin connections.

## **7-2. CURRENT TEST ADAPTER FOR 6JE6 AND OTHER NOVAR TUBES**

Current-test adapters for Novar tubes may be on the market by the time this book is printed; but if not, you can make one up yourself. Get a 9-pin Novar voltage test adapter, which consists of a base and socket, with a small metal lug brought out from each pin at the top. These lugs are designed for voltage measurements on top of the chassis; the adapter is plugged into the socket, and the tube into the adapter.

To modify such an adapter for breaking the cathode circuit, get a replacement-type Novar socket, preferably of the PC-board type. Set this on top of the adapter socket, as shown in the figure, and solder the socket pins to the corresponding lugs of the adapter, leaving the cathode pin connections open. (The cathode is pin 3 in the 6JE6 tube, among others.) Connect your meter leads to these two points, and there you are.

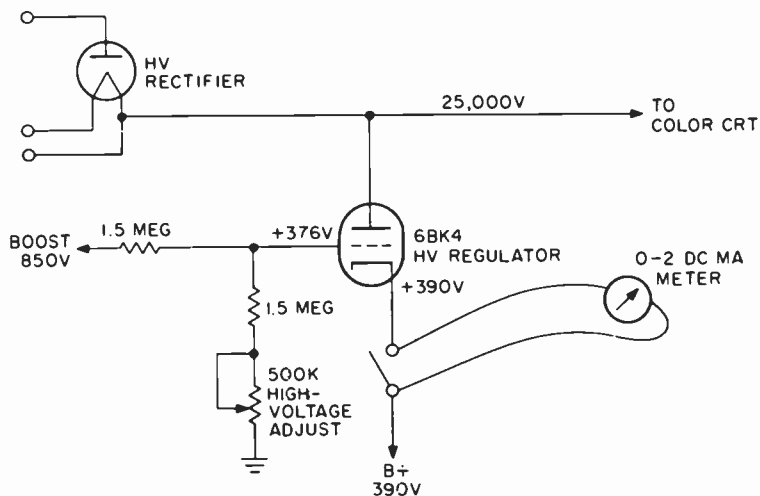
The socket terminals can be connected to the lugs with short pieces of heavy wire, if they won't meet well enough to make a good solid joint. The spacing of the adapter in the drawing is exaggerated to show how it's hooked up; the socket should fit down over the adapter much closer than this. Similar adapters may be made for 12-pin tube types and any others.



### 7-3. HIGH-VOLTAGE REGULATOR CURRENT TESTS IN COLOR TV

The majority of color TV sets use a shunt regulator circuit to hold the high-voltage output at a constant level. A specially designed triode tube, the 6BK4-A, is used. Its plate is connected to the high-voltage line, and its cathode is returned to B+. The control grid goes back to boost, through a voltage divider, as you can see in the figure.

If the picture tube is showing a dark scene, it takes relatively little beam current. This reduces loading on the flyback, so the voltages will go up (more positive). Since the boost voltage comes from the same source, it goes up, too. This makes the control grid of the regulator tube more positive, and the tube draws more plate current. This puts an additional load on the flyback, and the high voltage is pulled back down to normal.



To adjust this circuit for normal action, we put a 0-2 dc milliammeter in the cathode circuit; a special link is provided for this. The high-voltage voltmeter is hooked to the high-voltage connector on the picture tube, with an average scene being shown. The exact value will vary between sets: some call for 24,000 volts, some for 25,000, and so on; check the service data.

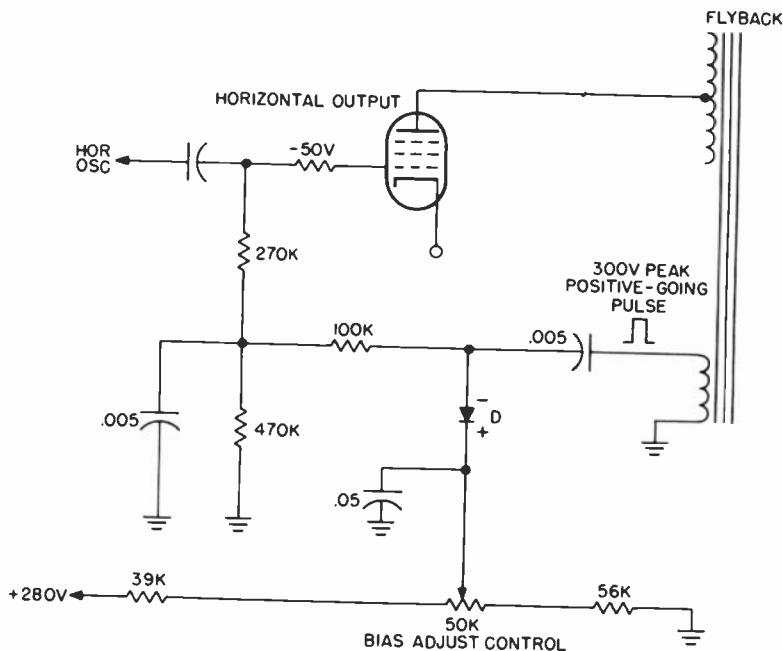
Now, check the action of the regulator by turning the brightness control up and down. It should work like this: At maximum brightness, a heavy beam current is going to the CRT, with very little current flowing through the regulator, so regulator current should fall to almost zero. At minimum brightness (dark screen), all of the current will flow through the regulator, since the picture tube is cut off. This current should be between 0.8 and 1.2 mA (800 to 1,200  $\mu$ A). This value, also, will vary between sets.

If the circuit doesn't work as it should, and the regulator tube draws too much or too little current, check the bias voltage. If any of the resistors in this circuit change value, they will upset the bias and cause the regulator tube to draw too much or too little plate current.

Despite its size, the big regulator tube has a limited plate-current carrying ability; maximum is about 2 mA! So, if the tube is trying to carry too much, it may break down. This can blow the high-voltage rectifier, horizontal output tube, and even damage the flyback, if the fuse doesn't let go quickly enough. Incidentally, the plate of this tube will sometimes show color (glow a dull red) in normal service, when it is carrying maximum current. If the glow is not too bright, it may be okay. To be certain, measure the maximum plate current.

## 7-4. GRID-CONTROLLED HIGH-VOLTAGE REGULATORS

Some color TV sets use a grid-control method of regulating the high-voltage output. The basic principle is the same as that of the shunt regulator, but the circuit is different. The figure shows one of these grid-controlled regulators used in several Motorola color TV chassis.



We can control the output of a tube by changing its grid bias. All we need is an indicator of the amount of output. The grid resistor is divided into two sections. On the flyback, a special winding provides a positive-going pulse of 300 volts p-p. This pulse is fed through a blocking capacitor to the anode of a diode rectifier.

To make this rectifier conduct at the right point, a positive bias is placed on its cathode, through a voltage divider from the 280-volt source. The diode will conduct during each pulse, because the 300-volt pulse on the anode is well above the 150 volts on the cathode. When the diode conducts, electrons flow up through the 470K resistor in the grid circuit. This makes the top end of the resistor, the tap in the grid circuit, negative.

If the horizontal output goes up, the pulse goes more positive; that is, higher in amplitude. This puts a higher voltage on the anode of the diode,

and it conducts more heavily. This in turn makes more electrons flow up through the 470K resistor, thus applying a more negative voltage to the control grid of the horizontal output tube. The negative voltage reduces the output, and things go back to normal.

If the output drops, the same reaction takes place in the opposite direction. The 300-volt pulse becomes smaller, the diode conducts less, and the smaller current in the 470K resistor allows the grid to go more positive. A positive-going voltage on a control grid makes a tube conduct more; so, the output tube develops more output and the voltages rise until conditions return to normal.

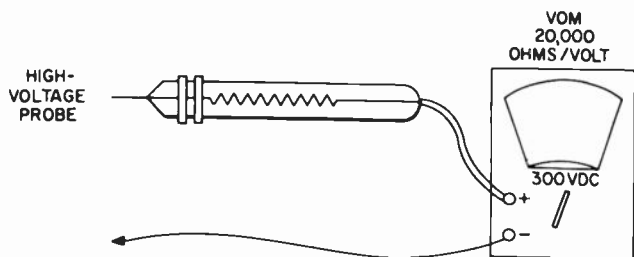
Adjustment of this circuit is simple. A high-voltage voltmeter is hooked to the CRT high-voltage connector, and the bias-adjust control is set to give 26.5 kV. (Check this value on the schematic for the set you are working on, because it may be different; this is the value used in the Motorola TS-912 chassis.)

Servicing should be simple. The diode must be perfect as far as leakage is concerned, and the resistors in the B+ voltage divider must not change in value. Capacitor leakage, especially in the .005- $\mu$ F coupling capacitor for the high-voltage pulse, would cause a great deal of trouble.

## 7-5. MEASURING VERY HIGH VOLTAGES

In black-and-white TV, we don't often check the high voltage. Perhaps we should, but most of us use the CRT screen as an indicator. If it's bright enough, we assume that the high voltage is okay, and it usually is. In color TV, however, the high voltage must be held within a fairly tight tolerance if we are to avoid purity troubles, etc. So, we must measure it. This requires a dc voltmeter with a scale of at least 30,000 volts. The easiest way to get such a range is to use an external multiplier probe with our regular dc voltmeter.

Multiplier probes are made with high-voltage insulating housings, to keep the user's hands as far from that hot stuff as possible (see figure). The flanges are placed on the base to make the insulation path long. Inside the probe a special high-voltage resistor—made by depositing a carbon film on a glass cylinder and then coating the whole thing with a high-voltage insulating plastic—is held between spring mountings, which keep the contacts tight. The probe housing is sealed to keep any moisture out; moisture might cause flashovers along the multiplier resistor when the probe is in use.



If we have a 20,000-ohms-per-volt vom, we can set it to the 0–300-volt dc scale (to make the math simpler). What we need is a meter with a *total* resistance of 30,000 times 20,000 or  $(3 \times 10^4) (2 \times 10^4) = 6 \times 10^8$  ohms. If we write out all the zeros, this is 600,000,000 ohms or 600 megs. Our 20,000-ohms-per-volt meter already has  $300 \times 20,000$  or 6 megs, on its 0–300-volt scale, so we have to subtract this from the total. This leaves us with a probe resistance of 600 megs — 6 megs, or 594 megs. With a 594-meg probe connected, the 0–300-volt scale of the meter is multiplied by 100; it reads 30,000 volts full-scale.

A multiplier probe can be used with any meter, provided the correct multiplier resistance is used. What we do is find the resistance of the vom on the scale we want to multiply (full-scale voltage reading multiplied by

the ohms-per-volt rating), then figure the total resistance we'll need to make the meter-probe combination read as high as we want. The meter resistance is subtracted from this total, and the remainder is the resistance we need in the multiplier probe. Probes are available in a variety of resistance values at radio distributor's stores.

For a vtvm or tvvm, we have to use a slightly different method to determine the multiplier resistance. When we change ranges on a vom, we change the meter resistance (0-3-volt scale, 60,000 ohms; 0-300-volt scale, 6 megs; etc.). On vtvm's and tvvm's, the total input resistance stays the same for all scales. This resistance may be 11 meg or 16 megs, or whatever the instrument designer decided to use.

To figure the probe resistance we use the same *principle* as before, but we get a different result. Say that we have a 0-500-volt scale and want to make it read 0-50,000 volts. This calls for multiplication—multiply by 100. First we find the input resistance of the vtvm. Say that this is 11 megs, a common value. Of this resistance, 1 meg is in the regular DC-VOLTS probe; so, the resistance of the internal voltage divider is 10 megs. In most vtvm's, the regular volts probe is disconnected and the high-voltage multiplier probe plugged in its place. So, we have a meter resistance of 10 megs. To multiply readings by 100, we need to multiply the input resistance by that figure, obtaining 1,000 megs as the required meter-plus-probe resistance. Subtracting the 10 megs we already have, the multiplier resistor in the probe will be 990 megs.

Now, here's the difference between the vom and the vtvm: Since the input resistance on a vtvm never changes, we will multiply all of the dc voltage ranges by the same figure when we hook up the high-voltage probe. Even the 0-3-volt range becomes 0-300 volts, etc.

If the regular probe resistor stays in the circuit when the high-voltage probe is attached, consider that when figuring out the high-voltage resistor value. In the case just figured, if our meter resistance was 11 megs, the multiplier would be 1,100 megs — 11 megs, or 1,089 megs. One popular meter uses a 22-meg input resistance with a 7-meg resistor in the DC-VOLTS probe. By removing this probe we have 15 megs left; so, a 100:1 multiplier would require 1,500 megs — 15 megs, or 1,485 megs. You'll find the exact input resistance of your own meter in the instruction book.

## 7-6. MEASURING FOCUS VOLTAGES IN COLOR TV

In color TV we often need to check the focus voltage. The best way is to take this reading right at the base of the color TV CRT, to make sure that this important voltage is getting to where it is used. Also, we need to check the action of the focus control to see if it gives the proper amount of variation. This variation is usually 4,000–5,500 volts dc. This voltage comes from the flyback, through a special rectifier—sometimes a small tube, sometimes a special high-voltage silicon rectifier.

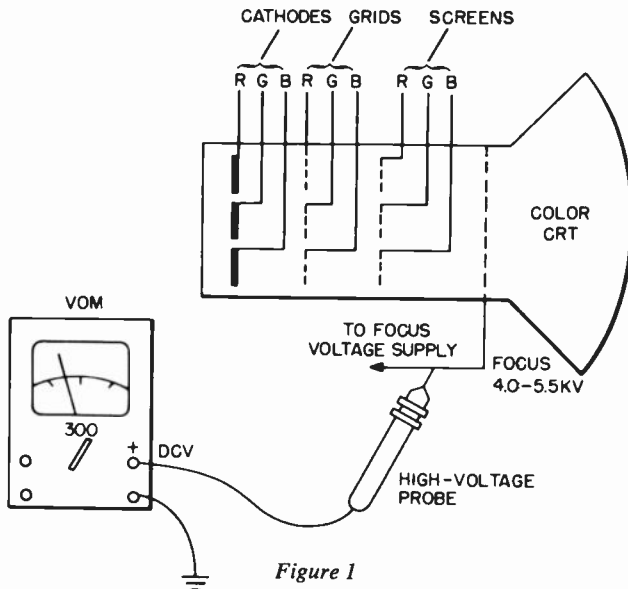


Figure 1

In the original 21-inch color tubes, and in many later ones, the focus electrode is pin 9 (check the schematic to make sure). You'll usually be able to tell just by looking at the set—many CRT sockets leave a blank space on either side of pin 9 to provide more insulation for the high focus voltage.

There's an easy way to make a focus-voltage measurement. You need to make contact on the base pin of the CRT itself. This is hard to do if the CRT socket is pushed tightly on, as it should be. In some sets, you can pull the socket back just a little and get at pin 9 with a thin test prod. However, some of the other pins may not make good contact if this is done. The answer is to make up a gadget that will let you get at this pin without disturbing any of the others.

One such device is a small clip made out of spring wire, as at point A in Fig. 2. This is slipped over pin 9, and the socket is pushed back



tightly. The meter prod is then touched to the exposed end. (Just make sure that the meter prod is the *only* thing that touches; 5,000 volts can bite!)

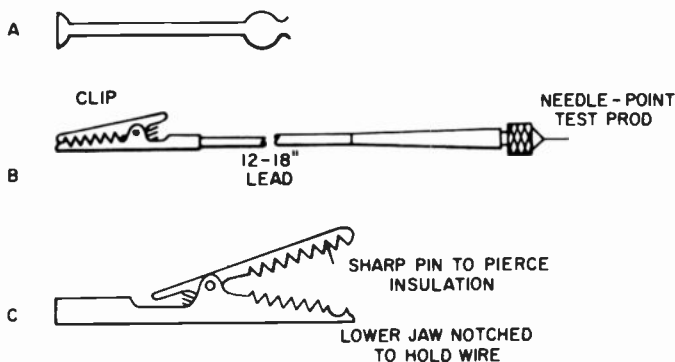


Figure 2

Or, you can use a needle-point test prod. Fit this to a short piece of test-lead wire with an alligator clip on the other end. Now the regulator high-voltage probe can be laid on top of the cabinet or on the bench, with the clip hooked to the end. This can be done with the insulation-piercing clip, too. The use of test clips like these leaves your hands free to adjust controls, etc., and keeps them as far as possible from that "hot stuff." Just be sure that the exposed ends of probes, etc., are far enough away from grounded parts so that there won't be a flashover when you turn the set on.

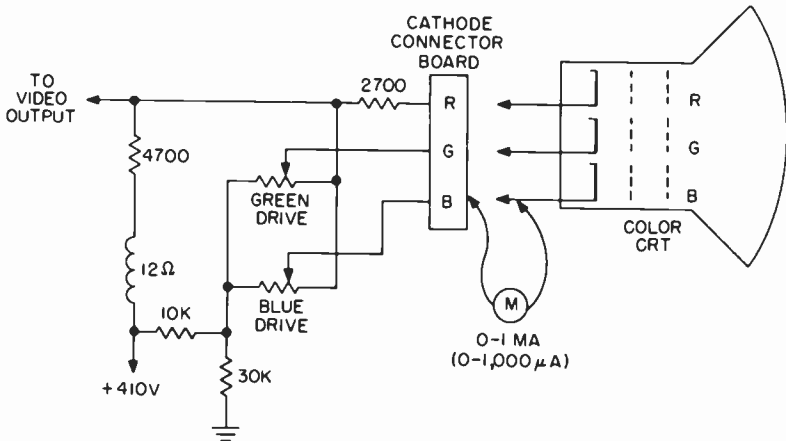
To check focus, turn the set on with the meter attached; move the focus control and see if it gives enough range of adjustment—4,000–5,500 volts for the average color set. Check the raster for normal, sharp focus of the scanning lines. In most sets, this occurs between 4,600 and 5,000 volts; but in a few cases, you'll find voltages higher or lower than this. As long as you can get a good, sharply focused raster, it's okay.

If the focus voltage should be lower than about 10%, go to a higher scale and read the high voltage. The trouble may be caused by something in the horizontal output tube, flyback, damper, yoke, etc. If it is, then *both* focus and high voltage will be low by the same percentage. If focus voltage is down 40%, and high voltage only 10%, look for trouble in the focus-rectifier circuits, etc. If the percentages are reversed—focus voltage only 10% low and high voltage 40% low—check the high-voltage rectifier, voltage regulator, and the circuits that affect only the high-voltage output.

## 7-7. CHECKING COLOR PICTURE TUBES WITH A VOM

Your vom can be a pretty good picture-tube tester, especially with color CRT's. One of the best ways to measure the quality of any picture tube is to read its beam current, which is the cathode current. It will run 300–400  $\mu\text{A}$  maximum in most b-w tubes, and about the same for all three guns (total) in color picture tubes.

Many color TV sets have provisions for unplugging each cathode lead of the picture tube, as shown. This is done so that the technician can adjust the beam currents of the three guns, if there happens to be a phosphor imbalance (this isn't as common as it once was). The three cathode leads are usually provided with push-on connectors, which fit onto a terminal board on the back of the chassis. In some sets, you'll find the leads soldered to a terminal board.



As you can see, the red cathode lead goes through a small resistor, and the other two go to adjustable resistors. These are the drive controls, and are intended to help the technician get a true black-and-white screen when he's setting up the color temperature. They're used for making the screen color "track" when the brightness is turned up and down, so that it stays black and white. (In color sets, the video or brightness signal is applied to all three cathodes of the color picture tube.)

To check beam current, unhook the cathode of the gun you suspect. Connect a 0–1-mA dc meter in series with it. Turn the set on and adjust the screen for average brightness; you should read about 100 microamperes (0.1 mA) on each gun, within about 10%. If one of the guns has

an exhausted cathode, its beam current will be very low, and nothing you can do—such as turning up that screen voltage, etc.—will bring it up to where the other guns are running. Use the currents of the other two guns as a standard; all three should match.

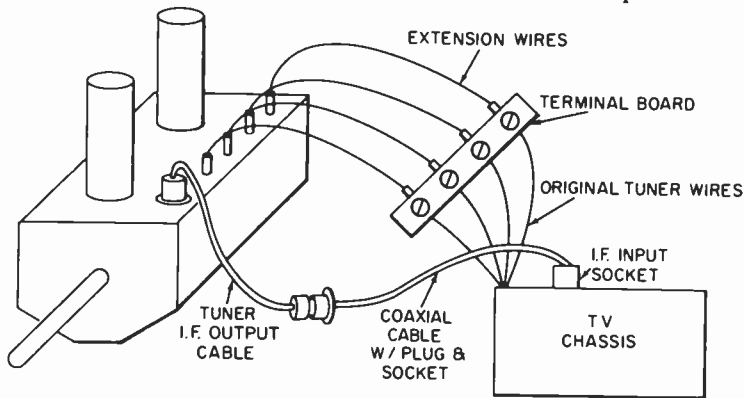
If one gun has a heater-cathode short or something like it, you'll probably see all green or all red, or whichever one is faulty. Checking the cathode current of the defective gun will probably show you that it is running up to 1 or 1.5 mA instead of the normal 100  $\mu$ A. The brightness controls will have no effect. Measuring the cathode-grid voltage will probably show you that this gun has zero bias. (Note: If you read 175 volts on the cathode and 175 volts on the grid, that gun has zero bias. The difference voltage between grid and cathode is what you must read. Cathode, 150 volts; grid, 125 volts. That would mean the grid has a - 25-volt bias on it.)

If this test shows that a gun is bad, verify it by checking the color CRT on a good CRT tester; if this gives you the same answer, then the gun is probably bad. Considering how expensive color picture tubes are, never take the word of only one test before deciding that a color tube is bad. The trouble may be in the operating voltages; check all dropping resistors, supply voltages, etc., before making up your mind that it's the tube. As we said before, the voltages and operation of the other two guns are handy as a standard since all are fed from the same supply in most sets.

## 7-8. EXTENSION CABLES FOR TESTING TV TUNERS

You don't like to work on TV tuners? Why not? They're simple—only a few circuits. However, they can be hard to get to without the right tools. If you can bring a tuner out where you can get to things, servicing isn't bad at all. Try this.

Many tuners today are separate—connected to the chassis by wires, with a coaxial cable to the i.f. input. You can remove the tuner and leave the chassis in the cabinet. In many cases, however, these wires aren't long enough to leave a console on the floor and have the tuner up on the bench.



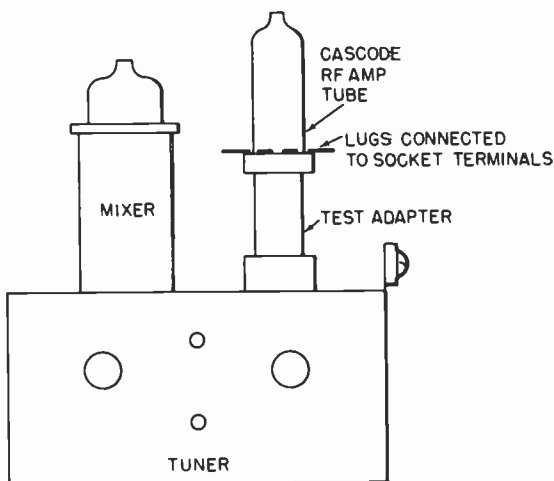
The solution is to make up a set of extension wires with a terminal board on one end, as shown. Use different-colored wires so that you can keep them straight. If the tuner wires are soldered, disconnect them one at a time and tack the extension wires in their place, fastening the ends of the original wires under the terminal screws. If the tuner has a plug-in cable, you can make up a plug-and-socket extension cable for about 50 cents.

The i.f. output cable from the tuner is often a plug-in type, with plugs like those used on phonographs. Make up an extension for this, too, with a lug and socket. Any kind of small coax will do, since you'll add only a very few picofarads of shunt capacitance. The picture and sound will come through in surprisingly good shape.

You can make a rack to hold the tuner while it's on the bench, or just block it up with a couple of empty cardboard boxes. Now you can test alignment, make voltage measurements, and make gain checks, etc., a lot more easily than before. Except for the i.f. output, all of the alignment adjustments of the tuner can be set up while the tuner is on the extension cables. The i.f. output can be adjusted easily after the tuner is back on the original cable.

## 7-9. READING DC VOLTAGES IN CASCODE RF STAGES

The popular cascode amplifier stage uses such tubes as 6BZ7, 6BQ7, 4BS8, and so on. It is basically a stacked-stage circuit. The plate of the input triode is connected to the cathode of the output section, and has about half of the applied voltage on it. If you take the tube out of the socket, this voltage can't be measured because it won't even be present unless the tube is in place.



Test adapters are available at all radio supply stores. The typical adapter consists of a plug with a tube socket on top, with each pin of the plug wired to the corresponding socket terminal. Around the top of the adapter are small, numbered lugs, each connected to one socket terminal. The adapter is plugged into the tube socket of the tuner, and the tube is plugged into the adapter socket. Now you can touch a vtvm probe to any lug and read the actual voltage with the tube in operation.

A test adapter can be used in any stage, of course, but it is essential in cascodes. Check the maximum plate voltage, which will be on the output-section plate. Then measure the voltages on the input-section plate and the output-section cathode. This should be almost exactly half the supply voltage on the output plate. Also, while you're there, measure the dc voltage on the grid of the output-section triode. This should be only slightly negative, relative to the plate-cathode combination; in one actual tuner, this grid reads 120 volts to ground and the plate-cathode reads 125, giving a -5-volt bias. If you find an imbalance, replace the tube first, then check coils and resistors.



the screen. These will react exactly like the pattern you get with an off-frequency horizontal oscillator; when they're far out of sync, you'll see many fine bars of color, slanting almost straight across the screen. As you get close to the right point, you'll have fewer bars, and they'll be closer to straight up. When you hit exactly the right place, you'll see only three colors—red, blue, and green. These will suddenly snap into place and the picture will have color again. (If you keep on turning the coil core, the color will fall out of sync and slant the other way.)

When you reach the exact adjustment, you'll have a zero beat between the color and the set's 3.58-MHz oscillator, and the colors will be correct. Leave the adjustment right here and remove the short from the reactance-tube grid. Now the color should snap in and lock firmly.

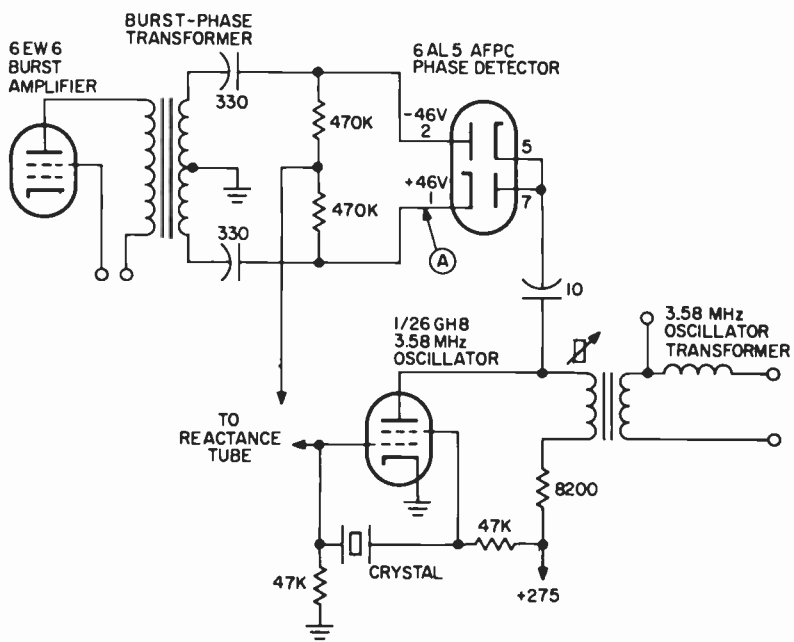
If the color suddenly goes out when you put the reactance tube back in the circuit, the oscillator is okay and the reactance-tube circuit has trouble! Check it out and find what's wrong.

### **7-13. CHECKING FOR OPERATION OF THE 3.58-MHZ COLOR OSCILLATOR**

If we find a loss of color or color sync, one of the first things to find out is if the 3.58-MHz oscillator is running. In the circuit used for many years in RCA sets, this is not difficult. The burst and 3.58-MHz signals are fed into a phase detector, as shown in the figure. This stage is exactly like the common horizontal-afc phase detector or an FM ratio-detector circuit.

To check the oscillator activity, we measure the dc voltage developed across one of the phase-detector diodes. As you can see, in normal operation the two develop equal voltages of opposite polarity, so you can read either one. For example, if you put the meter probe (use a vtvm since this is a high-resistance circuit) on pin 1 of the 6AL5 afpc detector, you'll get about 46 volts. On pin 2, a plate, you'll read -46 volts. There is little tolerance as far as the exact voltage is concerned, but the two voltages must be of equal and opposite polarities.

To eliminate the influence of an incoming signal, we can short the grid of the burst-amplifier tube to ground. If the voltage isn't high enough, we can adjust the bottom core of the 3.58-MHz oscillator transformer for peak reading on the vtvm. Then, the short on the burst-amplifier grid is re-



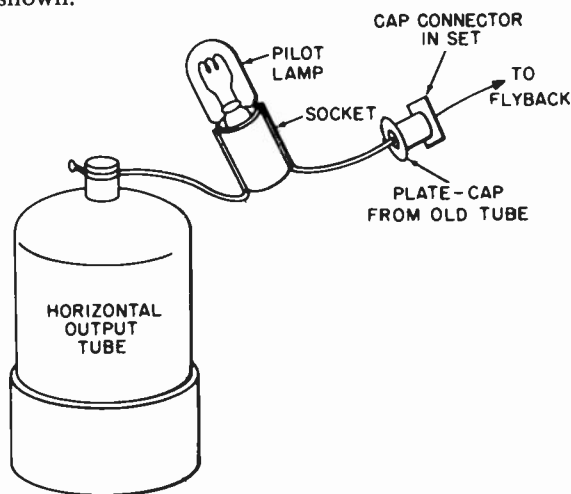
moved, and the burst-phase transformer is adjusted for maximum voltage reading. If there is trouble in any of this circuitry, these voltage readings will promptly tell you.



## 7-14. USING A PILOT LAMP TO ADJUST A HORIZONTAL EFFICIENCY CONTROL

The horizontal-linearity control, or horizontal-efficiency control in color sets, should be adjusted for the point of minimum current in the output tube, just as in tuning a radio-transmitter plate tank for a dip. Since both circuits are resonant, they are actually the same type of adjustment. We can connect a milliammeter into the circuit for the most precise adjustment, but there is another way to adjust the circuit, if necessary.

Make up a gadget with a pilot-light socket, the plate cap from a dead tube, and a plate-cap clip, as shown. For color sets, use a 250-mA pilot lamp; for b-w sets where currents run about 100 mA or less, use a No. 47 lamp. Pull the plate cap of the horizontal output tube and hook in the adapter as shown.



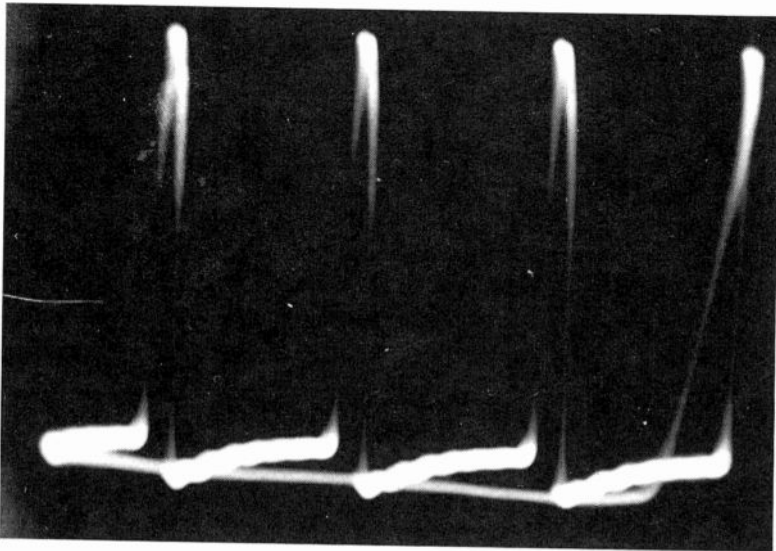
Turn the set on and note the amount of glow in the pilot lamp. Set the controls (brightness, etc.) as specified in the service data, and tune the horizontal-efficiency or horizontal-linearity control for a dip. When you hit the right point, you'll see a decided drop in the brightness of the pilot lamp. That's it.

The lamp can also be used to check for intermittent shorts or overloads in this circuit. For example, the normal current here in a color TV set is about 200 mA. If a 250-mA pilot lamp burns a bright blue-white, look out! That means too much current.

## 7-15. SCOPE TESTS FOR PRESENCE OF HIGH VOLTAGE, HORIZONTAL SWEEP, ETC.

The TV screen is dark; is there any high voltage? Is the horizontal output tube working? Is the horizontal oscillator working? We can answer these questions very quickly with a scope, and get a handle on the problem in a very short time.

Hold the scope probe near the plate lead of the horizontal output tube. Don't touch the plate cap; the pulse voltages there will break down the input capacitors of the scope, and may cause other damage. You don't need to touch it, anyway. You'll get plenty of pattern height from the tremendous pulse voltages, as you can see in Fig. 1.

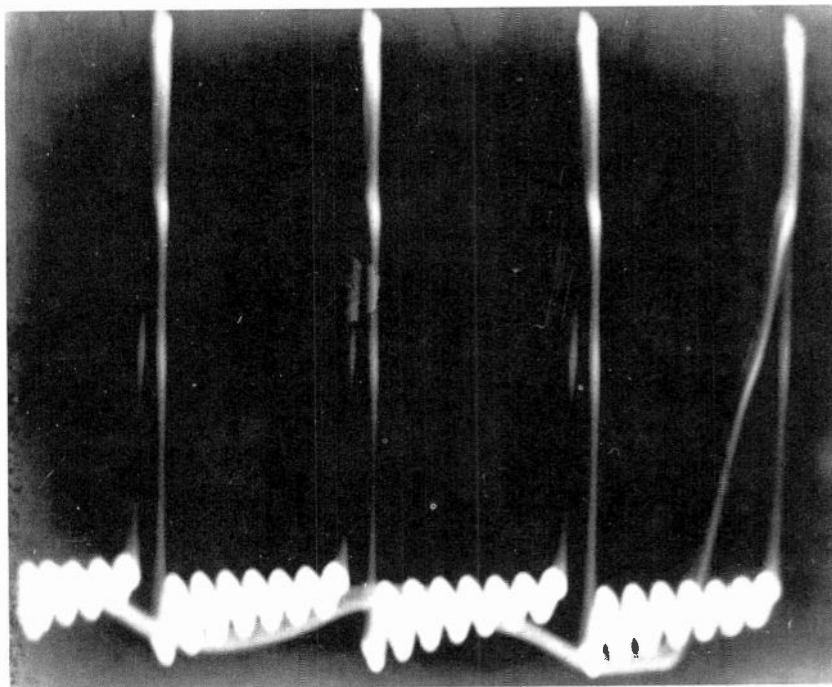


*Figure 1*

You can check the horizontal oscillator frequency at this point by using the frequency-set method outlined in an earlier test. If you see too many or too few cycles, the horizontal oscillator may be so far off frequency that the output stage will not work.

To check the high-voltage rectifier tube, hold the probe near its plate lead (or even near the bulb). You'll see the same pattern, but with much higher spikes since the pulse voltage is very high at this point if the output tube and flyback are okay. Holding the probe near the high-voltage rectifier output lead to the picture tube will also show you the same spikes if the filtering is okay. However, if you find a pattern with

small waves on the horizontal parts, as in Fig. 2, this indicates a severe ringing in the flyback or yoke. In a few cases, an open high-voltage filter capacitor may cause this same symptom. Also, trouble in the horizontal-linearity coil or capacitors, or a bad balancing capacitor in the horizontal yoke, can make this kind of pattern.



*Figure 2*

If you see high spikes when you hold the probe near the high-voltage rectifier plate, but none on the dc output lead to the picture tube, the high-voltage rectifier is very apt to be dead. There will usually be good sized spikes on this lead, even though its voltage is supposed to be filtered.

## **7-16. CHECKING FOR HIGH VOLTAGE WITH A NEON TESTER**

A neon lamp will glow in a strong electric field. Such a field exists around the flyback and the plate leads of both the horizontal output tube and the high-voltage rectifier in all TV sets. Special high-voltage testers are made in the form of a rod of insulating material with a neon lamp in a clear plastic housing on one end. If you hold one of these lamps near the plate lead of the high-voltage rectifier and it glows brightly, you know that the horizontal output tube and flyback are working. There is definitely a good deal of energy around there. If there is no dc high voltage, the high-voltage rectifier tube is probably bad.

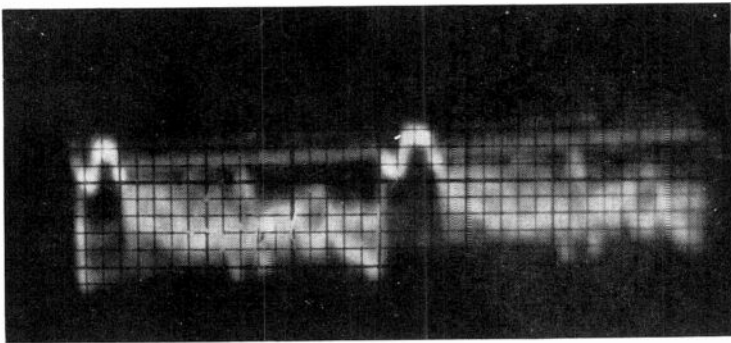
A neon lamp will also serve as an indicator of the presence of energy around the plate lead of the horizontal output tube, although the lamp won't glow as brightly as it will when near the high-voltage rectifier plate; the rf field here isn't quite as strong, but there will be a definite glow.

## 7-17. SETTING A HORIZONTAL OSCILLATOR ON FREQUENCY BY COMPARING WITH VIDEO

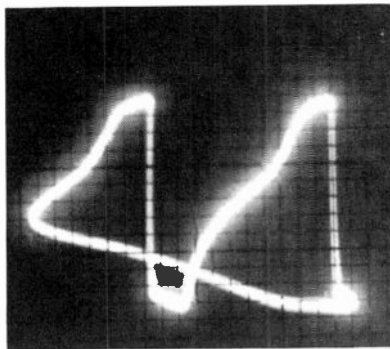
You'll find many TV sets in which the horizontal oscillator is obviously off frequency. In some, the oscillator can be thrown so far off by mis-adjusted controls that you lose the raster, boost voltage, etc. (Kids and unqualified technicians are sometimes to blame.) We need a quick way to check the frequency of the oscillator.

Once again, we use a comparison method. The standard is the horizontal-sync pulses of the video signal. Hook up the scope with a low-capacitance probe and pick up a signal at the video-amplifier plate. Adjust the scope sweep to about 7,875 Hz, until you see two horizontal sync pulses on the screen (Fig. 1). Set the frequency control and sync lock of the scope to hold them as steady as possible.

Now, without touching the sweep controls of the scope, move the



*Figure 1*



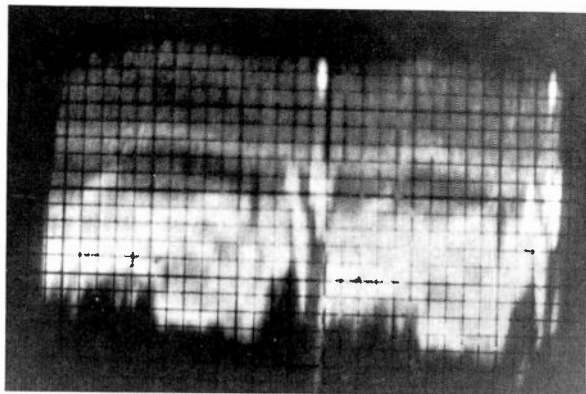
*Figure 2*

probe over to the horizontal-oscillator circuit. The grid of the horizontal output tube is a good place to pick up a signal. You can adjust the vertical-gain controls to keep the pattern on the screen, if necessary. Without touching the scope sweep controls, adjust the horizontal-hold control, coils, etc., until you get two cycles of the horizontal frequency on the scope screen (Fig. 2).

If misadjustment was the only trouble, your raster will come back and you can use the TV screen to make the final adjustment.

## 7-18. TESTING FREQUENCY IN VERTICAL-OSCILLATOR CIRCUITS

If you need to test the frequency of the vertical oscillator and see no picture for some reason (no high voltage, no picture tube, or whatever) you can make the test with a scope. Compare the oscillator signal with the video signal used to test horizontal-oscillator frequency. Set the scope frequency to show two or three cycles of video signal, near 30 Hz. You can now see the vertical sync pulses, as in Fig. 1. Here again the pattern is badly blurred, but all you need are the two vertical sync

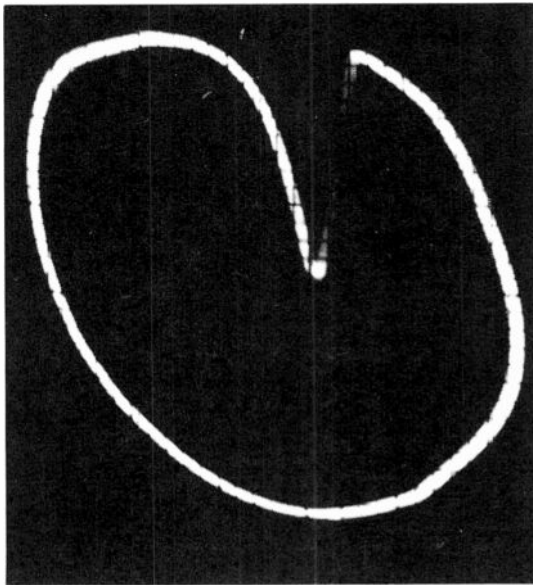


*Figure 1*

pulses—the bright pips at the top of the waveform at the right and center. (You can spread this pattern and make it easier to see, but we have deliberately used this blurred pattern to illustrate how easy it is

to identify the sync pulses.) Move the scope probe to the vertical-oscillator circuit, and adjust the vertical-hold control to show two cycles.

There is another way. Set the scope for line sweep, which is a 60-Hz sinusoidal sweep instead of the sawtooth. Now feed in a pulse from the vertical-oscillator circuit. By juggling the vertical- and horizontal-gain controls, you can make the trace an oval or even a circle (Fig. 2). The notch is the spike from the vertical oscillator. If you see only one notch, and it's standing fairly still on the circle, the vertical oscillator is running at 60 Hz. If the frequency is off 1 Hz, the notch will go around the circle once each second.



*Figure 2*

This procedure is often needed in transistor TV sets that have several ailments at the same time. For example, in one make, if the vertical circuits are out of adjustment, the vertical-output stage will draw such a heavy current that it will kick the circuit breaker, causing you to waste time looking for nonexistent shorts. Setting the vertical oscillator on frequency will eliminate this, even if you have no high voltage and can't see a raster.

## 7-19. FINDING THE CAUSE OF SYNC CLIPPING WITH THE SCOPE

If you find a TV with a case of sync clipping, or sync trouble of any kind, there are several possible causes. The only quick way to find the trouble is to separate the various possibilities with a scope.

To begin with, check the video signal at the sync takeoff point. You can use the direct probe on the scope since this is a high-level signal. You should see a normal video signal, as shown in Fig. 1, the sync tips form 25% of the total height of the pattern, and the video forms the other 75%. If you find a pattern like this, then the video detector and video output are okay; the trouble is actually in the sync-separator circuits.

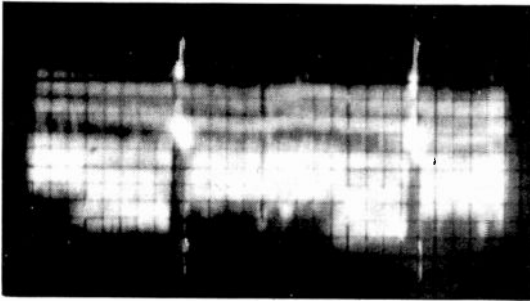


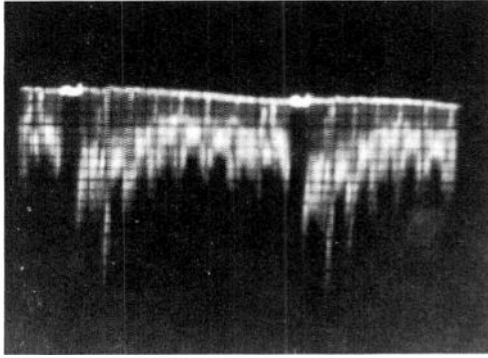
Figure 1

However, if you find something that resembles Fig. 2, don't go to the sync separators yet. There's trouble before that point. Notice that here the sync tips are so compressed that they are not actually visible. The video is about normal, but there is little sync. This kind of trouble is usually due to a bad tube in the tuner or i.f. stages, incorrect voltages on the i.f.'s, incorrect agc voltages, or even a bad video-detector diode.

The symptom in Fig. 3 is the exact opposite; it is referred to as white compression. This signal is also a clipped waveform, but notice that the sync tips are normal in height. It's the *video* that is being clipped. The result is a nice, clean raster (no snow) with the picture signals visible only as vague outlines on a very bright background. In bad cases, you will usually have to turn the brightness far above normal to see anything.

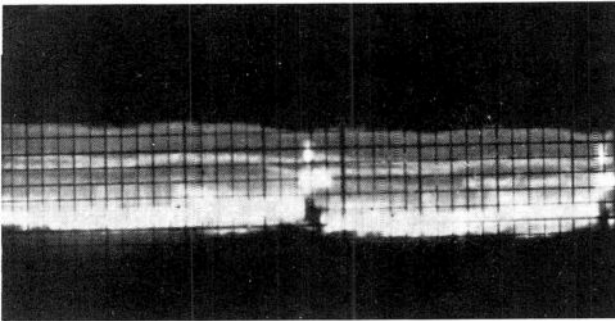
The most common cause of this symptom is a video output tube that is very weak, gassy, or has heavy grid emission. In some cases, a bad





*Figure 2*

video-detector diode will do it; you'll have to go by the scope patterns on the input and output of the video amplifier. If the signal is clipped on the video-amplifier grid, the trouble is being fed into the tube and does not originate there. If you do suspect the video amplifier, replace the tube first, then check for correct operating voltages, especially grid bias.



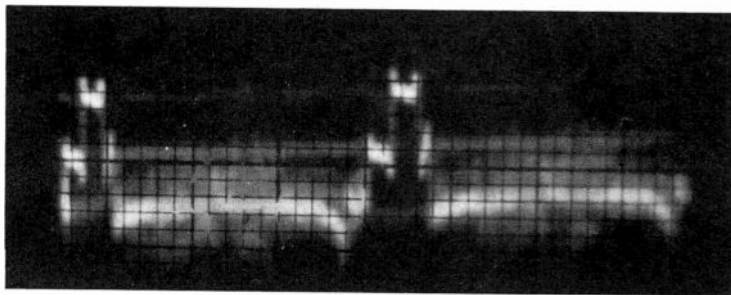
*Figure 3*

White compression is sometimes confused with a weak picture tube because of the loss of contrast. However, there is one basic difference; if white compression is the trouble, the picture tube will still be able to make a very bright, well-focused raster. If the CRT is weak, you'll have very low brightness, and probably loss of focus, especially in highlights. With white compression, highlights smear out, but are very bright. If you can get about 50 volts p-p of good clean video at the grid or cathode of the CRT, but still have a poor picture, then the picture tube should be suspected.

## 7-20. FINDING SYNC TROUBLES WITH THE SCOPE

When we encounter sync troubles, there's only one instrument that will get in there and tell us anything useful—the scope. All sync trouble can be found in the least time by following the sync signal from the point of origin through the various sync-separator and amplifier stages until we find the point where it disappears. Voltage and resistance checks will then pinpoint the cause of the trouble.

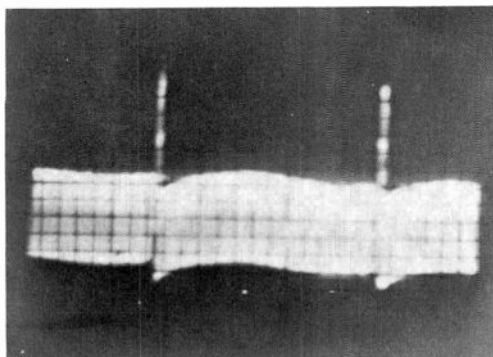
Because most of these are high-impedance circuits, we use the low-capacitance probe to keep from disturbing them too much. Start at the sync takeoff point which is usually in the plate circuit of the video-output stage. Make sure the composite video signal is there—with plenty of sync—before you go any further. The signal will look like Fig. 1. You may see signs of video compression; in fact, the photo shows a sync-to-video ratio that is closer to 50:50 than to the 25:75 ratio we look for in the full video signal. However, this waveform was taken off at a point lower in the video-output circuit than the full video signal applied to the picture tube. What we must have is plenty of sync, and obviously we do.



*Figure 1*

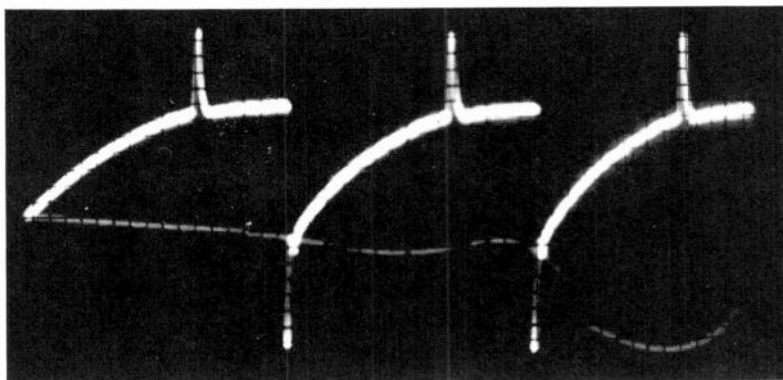
The correct scope patterns for various points in the sync circuit are usually shown in the service data or on the schematic diagram. For instance, the stripped sync may be similar to Fig. 2 after the video has been clipped. This is the type of pattern you'll see at the input to the vertical integrator in many sets. The sharp spikes are vertical sync; the rest are horizontal sync pulses.

Vertical-oscillator circuits depend mainly on the amplitude of the sync for proper operation. Horizontal sync works mostly on phase, and will lock in on a weak signal far longer than will the vertical. So, any weak-sync condition will show up as vertical-roll troubles first.



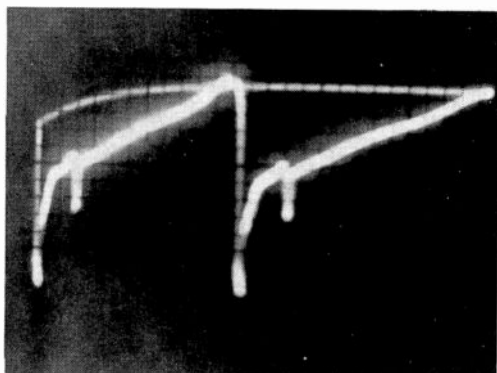
*Figure 2*

To check for sync amplitude, hook the scope to the vertical oscillator circuit. Fig. 3 shows a typical pattern on an oscillator grid, and Fig. 4 shows one as seen on a plate. By turning the vertical-hold control so that the blanking bar rolls slowly down, you'll see the vertical-sync pulses appear as pips on the waveforms. Although some vertical oscillators will lock satisfactorily on less sync than this, it's always nice to have a sync pulse of this amplitude, for a good, tight locking action.



*Figure 3*

Ordinarily, we just look at this waveform and get a good idea of the sync amplitude (in proportion to the amplitude of the full waveform). If we want to, we can read the sync-pulse amplitude by itself. Kill the vertical oscillator, and take a reading of the sync at either the grid or the plate of the vertical oscillator—depending on where the sync-injection point is in this circuit. In all cases, it will be found at the output of the vertical integrator, coming from the last sync-separator or sync-amplifier stage. The amplitude of sync for the set being tested is usually



*Figure 4*

given on the schematic. Sync fed to a grid is positive-going, and negative-going to a plate, in most circuits.

You can tell if there is any sync in the vertical circuits by rolling the picture down with the vertical hold control. If the blanking bar crosses the bottom of the screen with no hesitation, and if you can also roll the picture up smoothly without any stopping or jumping as the blanking bar leaves the screen, there is no vertical sync. Normally, as you roll the picture down, you'll see the blanking bar snap out of sight when it gets 2 or 3 inches from the bottom of the screen. This indicates good sync-lock. If you turn the hold control the other way, the picture should hold to a given point, then break loose and travel upward very rapidly. To distinguish between the two, most technicians call downward movement rolling and upward movement flipping. In all cases, if you can roll a picture slowly and smoothly upward, there is sync trouble.

### **Horizontal Sync and AFC Checking**

Horizontal sync circuits are just as easy to check as vertical circuits. In many sync circuits, you'll find composite sync at the output of the sync separator: Vertical and horizontal sync pulses are separated by resistor-capacitor networks. The low-frequency vertical sync goes through large capacitors, with good-sized bypass capacitors that shunt the higher-frequency horizontal sync to ground; the horizontal sync goes through very small capacitors, which have a high reactance to the low-frequency vertical pulses.

The typical horizontal afc circuit is a phase comparer. The horizontal sync from the TV signal is compared in phase to a pulse from the horizontal oscillator. This pulse is sometimes taken from the oscillator itself, sometimes from a special winding on the flyback. Both signals are

usually shaped into a sawtooth waveform by resistor-capacitor networks. Fig. 5 shows a typical sawtooth found on an afc diode plate.

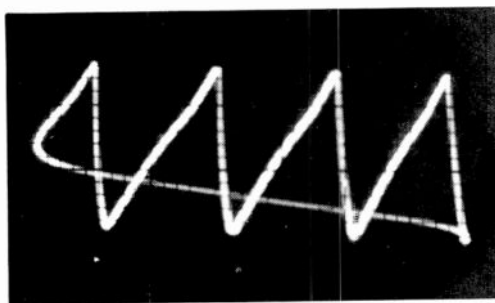


Figure 5

Check for the presence of both sawtooth waveforms and compare their amplitudes to the values given on the schematic. As we said, horizontal sync works on phase, so the amplitude isn't too critical. However, it must have a certain minimum value before the afc circuit will work properly.

The easiest way to check an afc circuit is by the process of elimination. Take it out of the circuit by shunting the horizontal oscillator grid, etc. Then see if the oscillator will work alone. If so, it will make a single, floating picture on the screen. Now put the afc back; the picture should lock in and stay in sync. If replacing the afc makes the picture go *out* of sync, or if the picture continues to float (no sync), then the afc circuit must be bad.

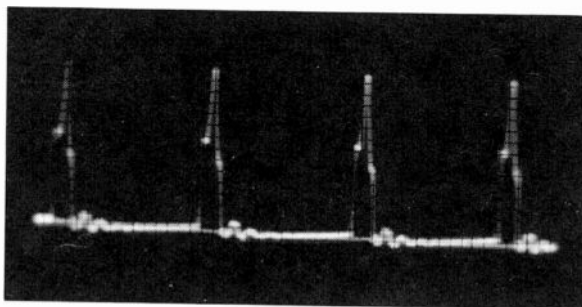
If the afc uses a pair of diodes, check them—preferably by substitution, but they can be checked for front-to-back resistance ratio, or shorts, or opens, etc. If the diodes are okay, then check the little sync-coupling capacitors, the 82–100-pF micas. These capacitors have been known to leak; if they did, they could upset the dc balance of the afc circuit. Also, check all resistors and capacitors. There are only six or eight of them in an afc circuit and they must all be good if the set is to work properly.

## 7-21. CHECKING KEYED OR GATED STAGES

Only one thing distinguishes a keyed or gated stage from others. That is the keying pulse applied to it from the flyback—usually to the plate, but it could be on the screen grid or control grid, etc. and still do its job. This pulse is the plate voltage in most gated stages, such as 6BU8 agc-sync stages, etc. The pulse is usually positive going and runs from 400 to 700 volts peak.

To check out a keyed stage, first measure all of the dc voltages; make certain they are within 5% of the values given on the schematic. Next, check for the presence of the keying pulse on the plate and note its amplitude. Although a given stage may go into conduction at 500 volts, a pulse that should be 700 volts peak, and isn't, usually indicates trouble elsewhere in the set.

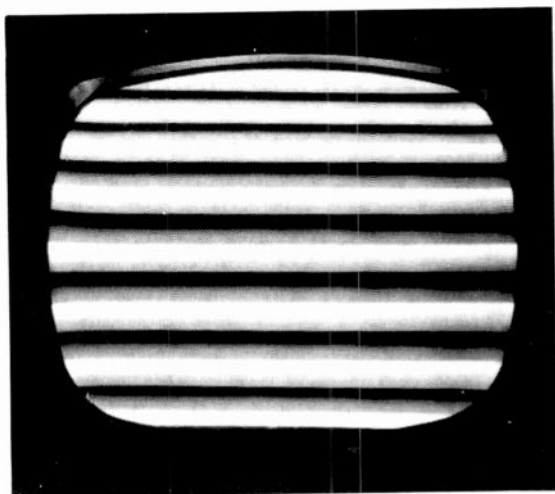
The pulse is shaped into a steep-sided form by a resistor-capacitor network. If the capacitor becomes leaky or the resistor changes value, the pulse shape or amplitude will change and you'll have troubles. The figure shows a typical keying pulse. Note the narrow width. Keying



pulses can be of several shapes around the peak (this one is sharply pointed, some are flat topped), but variations aren't too important as long as the general tall, narrow shape is present. The keying-pulse waveform is usually shown on the schematic, and the pulse you observe on the scope should be pretty close to that.

## 7-22. TV SIGNAL TRACING AND GAIN CHECKS WITH AN RF OR AF SIGNAL GENERATOR

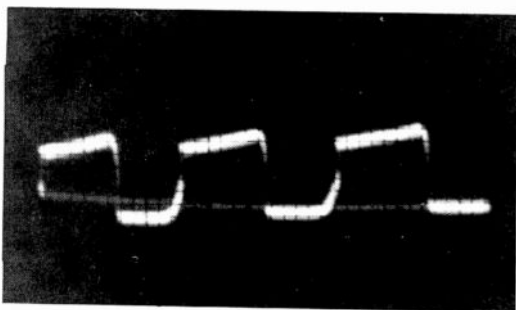
You can check out a video-amplifier stage, video-detector stage, or video i.f. stage with an rf or af signal generator. The audio output from the rf signal generator can also be used if you don't have a separate af generator. Fig. 1 shows the pattern when a square-wave audio signal (about 600 Hz) is fed into the input of the video amplifier of a b-w TV set. Notice the sharp horizontal bars on the screen. (This test can also be used to adjust the vertical linearity—note the compression near the top of the screen.)



*Figure 1*

The contrast of the bars is used to check out the gain of the video amplifier. The input signal level should be 2–3 volts p-p in single-stage video amplifiers like this one. In color TV video-amplifier stages, check the schematic for the average level of video output. If a low-level signal is needed and the attenuator of the signal generator won't go down that far, you can make up a simple resistive voltage divider as described earlier. Don't overload the input, especially in the video stages of transistor TV's.

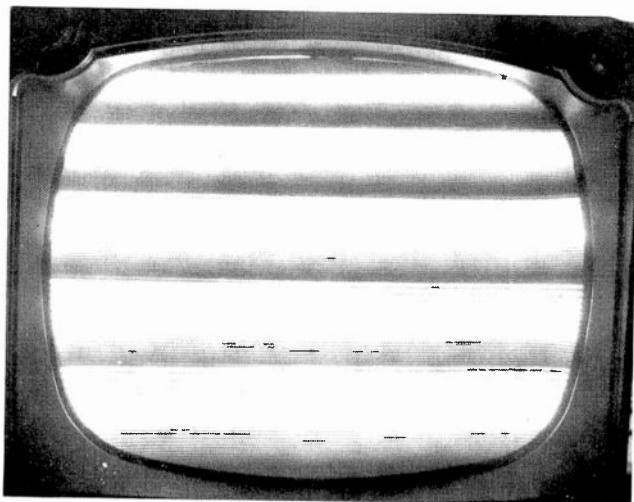
A scope pattern of the signal in Fig. 1 is seen in Fig. 2. Notice that there is some distortion of the square wave. If a video amplifier has a very wideband output, and if test conditions are just right, you'll see an almost perfect square wave—up to about 10 kHz, with sharp, clean bars on the CRT. However, the set used for this test produced a very



*Figure 2*

acceptable picture, so don't be overly critical. You can often improve the scope pattern at the output by taking off the picture-tube socket and picking up the signal at the grid or cathode pin of the socket. This substitutes the input capacitance of the scope for that of the picture tube and sharpens the pattern. The pattern of Fig. 2 was made with the CRT still hooked up.

A sine-wave signal can also be used. In fact, you can feed an amplitude-modulated rf signal into the input of the set's video i.f. stages and see the resultant on the screen, as in Fig. 3. (The contrast of the bars

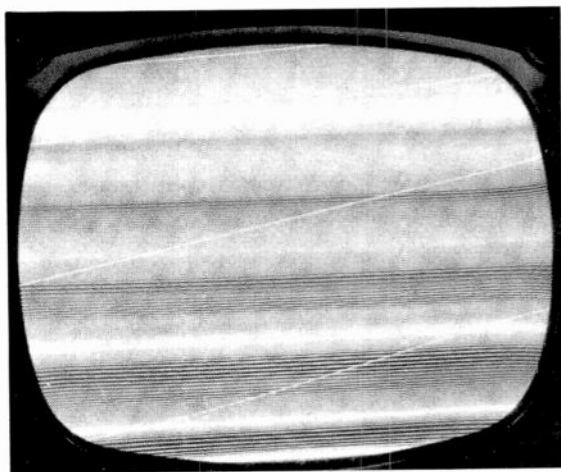


*Figure 3*



also gives you a good idea of the condition of the picture tube.) This is a valuable shortcut test when the big question is whether the trouble is in the video i.f. or in the tuner. If an rf signal at the picture i.f. frequency, modulated by a 400-Hz sine wave, will pass through the i.f. stages, video detector, and video amplifier, and make a pattern on the screen, then you can be fairly sure the trouble is in the tuner, especially if the original complaint was "no picture" or "white screen."

Fig. 4 shows what a weaker signal looks like on the screen. The bars are pale, and the retrace lines show up. By checking several working TV sets with your own rf generator and noting the setting of the output attenuators when you get a good black pattern on the screen, you can make rough gain checks on the i.f., etc. If you have to use twice the normal amount of signal to get a good black-bar pattern, something is weak. By starting at the video detector and working back toward the tuner, you can locate a weak or dead i.f. stage.



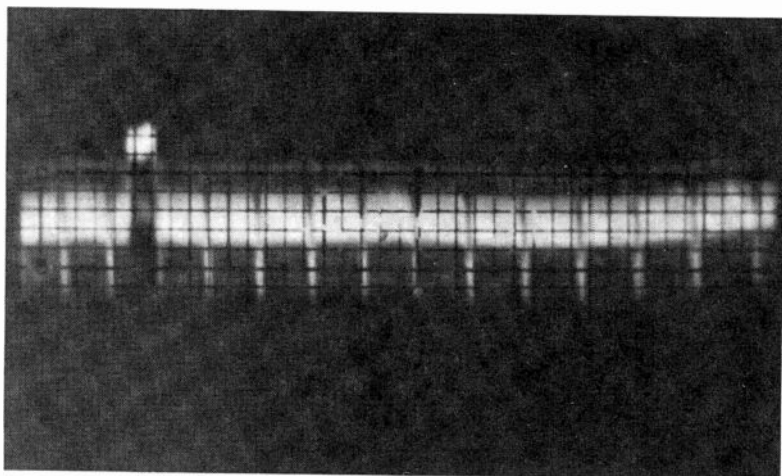
*Figure 4*

In fact, you can check video-detector diodes with this test. If an i.f. signal fed into the input produces very pale bars, but an audio signal fed into the video-amplifier grid produces good, sharp bars with plenty of contrast, then the video-detector diode could be leaky or open. When making this test, check the setting of the agc control. If the agc is too negative, it will cut the i.f. gain and make the picture weak and washed out.

## 7-23. SIGNAL TRACING WITH THE SCOPE AND COLOR-BAR PATTERNS

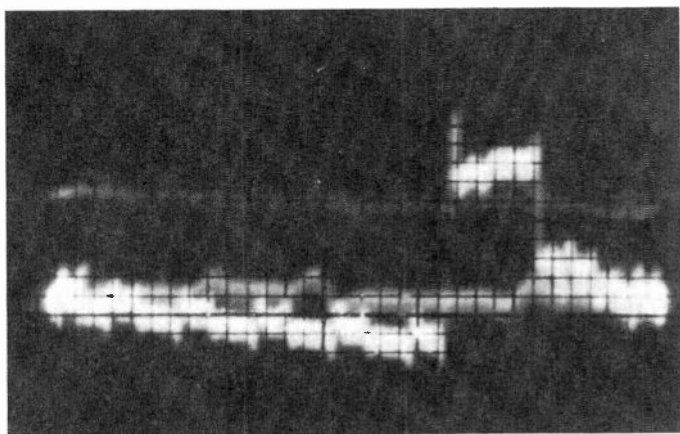
If we run into trouble in the video i.f. or video-output stages, we can signal trace through these circuits with the scope to find where the signal stops or loses gain. If we have an easily identified pattern, the job will be easier. Such a pattern can be supplied by the signal from a bar-dot generator set for the color-bar signal or the crosshatch. In circuits where the signal is still rf, such as the video i.f., we will need a crystal-detector probe on the scope; after detection, we can use the direct probe, although a low-capacitance probe is handy in many cases.

The main benefit in using this signal is that it can be readily identified. Fig. 1 shows a crosshatch signal, taken at the plate of a video amplifier through a low-capacitance probe. Fig. 2 shows a color-bar signal at the same point, taken with a direct probe. The square pulse near the right is



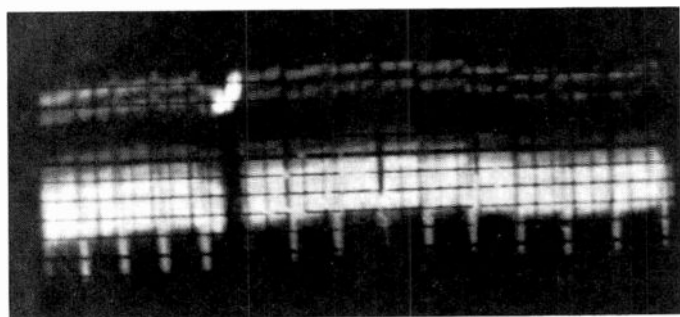
*Figure 1*

the horizontal sync bar of the signal. The set used for these photos was a black-and-white TV, so the color-bar signals are not so plain as they are in color sets. Nevertheless, the characteristic shape of the signals can be seen. Most bar, dot, and crosshatch signals, displayed on the scope at a vertical rate of 30 Hz, will resemble a comb. Check them out on a set that is working, so you'll know what they should look like. So far, we're mainly concerned with amplitude rather than waveform. Don't be too critical of any distortion, at least not yet.



*Figure 2*

However, a test pattern can be useful for detecting sync clipping—check Fig. 3.



*Figure 3*

## 7-24. USING THE SCOPE TO SET THE DUTY CYCLE OF A HORIZONTAL-OUTPUT TRANSISTOR

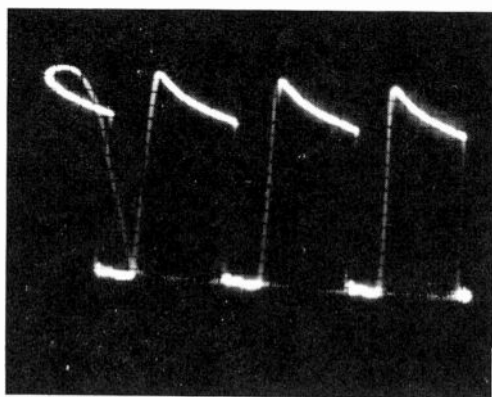
Correct adjustment of the oscillator-drive waveform in a transistor TV is not as simple as in tube types. The wrong adjustment can cause trouble in a hurry—even faster than in tube sets.

The horizontal-output transistor actually works as a switch; it is driven by a rectangular pulse waveform. In such sets as the RCA KCS-153, you must use the scope to set the ratio of off time to on time (duty cycle) in this waveform.

If the on time is too long, average current will go up. This can cause overheating of the junction and even blow the transistor or kick out the circuit breaker. By using the scope to display the waveform, we can measure the ratio between on time and off time directly.

Here's the complete procedure. It is similar to the procedure used in the old, faithful synchroguide circuit. Two stabilizing coils are used. One controls the oscillator off time, and the other (which is actually resonated at about 40 kHz) controls the on time. To make the preliminary setup, ground the collector of the sync-separator transistor and hook a jumper across the sine-wave coil. Now, turn the set on and adjust the hold control for the most stationary picture. The picture floats since there's no sync or stabilization, but we can get a single picture by juggling the hold control.

The bottom core of the coil (the 40-kHz section) is adjusted for a pulse-width ratio of 1:2 (1 on—2 off). The waveform is shown in the figure; the wide pulses should be at least twice the width of the narrow ones. If you want the exact recommended figures, the narrow pulses (downward-going) are 18  $\mu\text{sec}$ , and the wider off pulses are 60.5  $\mu\text{sec}$ .



As long as the ratio is greater than 1:2, it's fine. You can measure this by setting the pattern width on the scope so that you can measure the two pulses on the calibrated screen.

Next, turn the set off and remove the jumper across the sine-wave coil. (We do not connect or disconnect anything in a transistor circuit with the power on. It's dangerous. Making or breaking a connection could cause transients that would puncture transistors. Turn the set off!) Turn it back on and adjust the top core—the sine-wave coil—for a locked-in picture. Remove the scope and the job is done. Disconnect the jumper that grounds out the sync, too, before you forget it.

## 7-25. HOW NOT TO READ VOLTAGES: THE "DO-NOT-MEASURE" POINTS IN TV

We've told you how to read dc voltages at typical points of a TV circuit. Now, let's see about those points that must *not* be measured—such points as the plate of the horizontal output tube, the high-voltage rectifier plate, the damper tube, and the vertical output plate. You'll find these marked "Do Not Measure" on the schematic.

These points say "Do Not Measure" because there is a very high *pulse* or *spike* voltage present at all times, besides the dc plate voltage. During normal operation, these spikes may reach 15,000 or 20,000 volts peak. Such spikes of voltage can damage the multiplier resistors in your vom by causing a flashover, or internal arcing, in the precision resistors. These resistors are seldom rated at more than 1 watt, and usually less. So, vom's should never be subjected to this kind of mistreatment. Once a multiplier has flashed over, the meter will be inaccurate until it is recalibrated.

You *can* read the dc voltages on these TV circuit points, if you use the right methods. In each case, the voltage is fed through a coil—the horizontal or vertical output transformer, etc. So, turn the set off and read the resistance of the coil primary. Check this against the value given on the schematic. Now, turn the set on, and read the dc voltage at the *bottom* of the coil—the opposite end from the plate of the tube. This is where the supply voltage is fed in; if it's okay there, and if the coil winding shows continuity, there *is* plate voltage on the tube in question.

## Section 8

### Special Tests

#### 8-1. MEASURING PEAK VOLTAGES WITHOUT A VOLTMETER

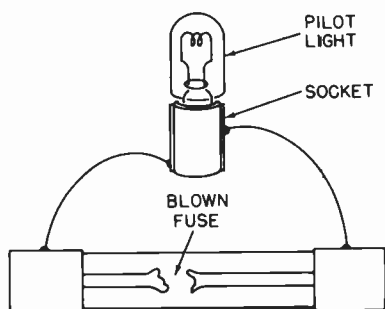
We often need to know the peak-to-peak drive signal voltage—on horizontal output tubes, vertical output tubes, oscillators, etc. Normally, we read this voltage on a calibrated scope or with a peak-to-peak-reading ac voltmeter. However, if these instruments aren't available, we can always use the low milliamperere range or the microampere range of the vom.

Open the bottom end of the grid resistor and hook the microammeter in series with it. Connect the positive terminal of the meter to ground, and the negative terminal to the resistor. With the circuit in operation, multiply the current you read by the value of the grid resistor. The result, according to Ohm's law ( $E = IR$ ), is the peak value of the grid voltage. Note that we said peak, not peak-to-peak; the grid conducts current only on the positive-going halves of the drive signal. So, to get the peak-to-peak value most often specified in service data, we double the value we have calculated.

In one actual test, a 6DQ6 tube with a 470K grid resistor read a bit over 100  $\mu\text{A}$ . This gives us 47 volts *peak*; the *signal*, measured with a calibrated scope, was about 90 volts peak-to-peak. Resistors in such circuits aren't precise; tolerances are 10% to 20%. Voltages obtained by this method won't be exact; but they will be accurate enough to give us the information we need pertaining to the drive signal voltage. Remember to double the reading for a peak-to-peak value.

## 8-2. USING A PILOT LAMP FOR CURRENT TESTING

When you encounter one of those jobs that runs along fine, then suddenly blows the fuse, it can be expensive as well as annoying. Fuses cost money, especially if you blow four or five of them without finding the short. Make up a test adapter with a pilot-light socket wired across a blown fuse, as shown. Use a pilot lamp that has a rated current a little higher than the normal drain of the circuit.



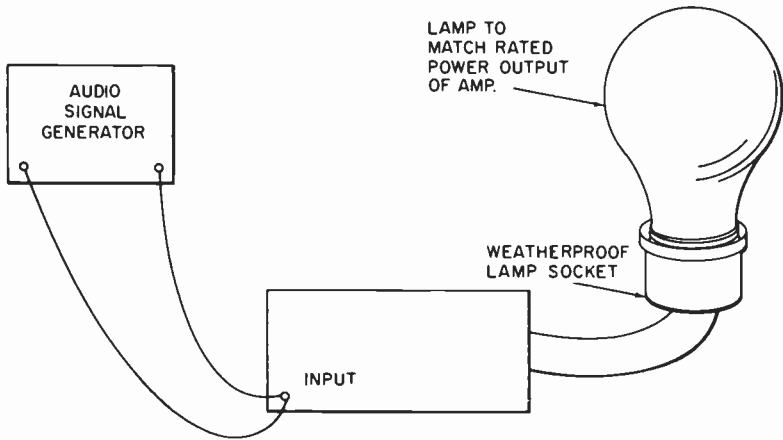
For instance, if you're checking the B+ supply of a TV set rated at 200 mA, use a 250-mA pilot lamp—No. 44. There are pilot lamps with current ratings all the way from 150 mA (No. 40, No. 47) to 0.5 amp (No. 41, etc.). There are special lamps rated as low as 60 mA (No. 49) if you happen to need them.

Now, when you turn the set on, the pilot lamp will glow a medium yellow. You can watch this while you tap, move, heat, or test parts in the circuit. If you hit something that is causing the short, you'll see the lamp flare up to a bright blue-white. A dead short will blow the lamp out, of course, but pilot bulbs are usually cheaper than slow-blow fuses!

As a matter of fact, Motorola and other two-way radio manufacturers have used pilot lights as B+ fuses in power supply for several years. If you run into one of these circuits, be sure to use the same type of lamp as a replacement. It must have the correct current rating.

### 8-3. A QUICK TEST FOR AUDIO POWER OUTPUT

There's a quick and dirty test for audio power output, if you don't want to bother with calibrated resistors. Get a weatherproof lamp socket and put a couple of heavy terminal lugs on the wires—spade lugs are best. Connect this socket across the high-impedance output taps on the output transformer of the PA system. Screw a standard incandescent lamp into the socket, of a wattage to match the power you want to check. For example, on a 50-watt amplifier, use a 50-watt lamp; for a 30-watt amplifier, use a 25-watt lamp (the nearest commercial size).



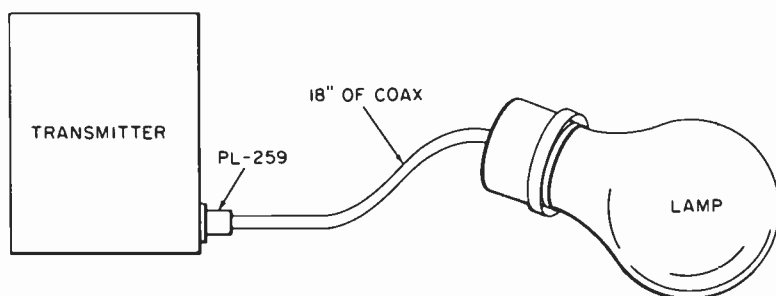
Now fire up the amplifier, and feed in an audio signal. If you have the rated power output, the lamp will light. If a 50-watt amplifier will light a 50-watt lamp to a good white, or about normal brilliance, that's it.

The impedance match is closer than you'd think on the 500-ohm output. A 25-watt lamp, for instance, draws about 0.21 amp; plugging this value into the formula  $W = I^2R$  gives us a hot resistance of about 570 ohms, which is fine for all practical purposes. If you want, you can parallel two 25-watt lamps across a 250-ohm output and get a fairly close match on a 50-watt amplifier. This method isn't good for high-power transistor amplifiers, because more critical impedance-matching is needed. This would be especially true in the output-transformerless types; for those, you'd better use the exactly matched load resistor mentioned in the earlier test.



## 8-4. A QUICK TEST FOR THE RF POWER OUTPUT OF A TRANSMITTER

An incandescent lamp of the proper wattage rating makes a good quick and dirty test for rf power output in high-power transmitters—that is, anything from about 10 watts up. Get a weatherproof lamp socket, a rubber-covered type with pigtail leads, and connect it to about 18 inches of coax with a PL-259 plug on the end. If you find a transmitter where there is doubt about the actual power output, screw this plug onto the antenna socket, put a lamp of the appropriate wattage in it, and key the transmitter.



If there is any rf power output, the lamp will light up. Since there is nothing but rf in the antenna circuit, a glowing lamp means that the transmitter has rf output and the trouble must be in the modulation, frequency, or something of that sort.

This light-bulb test is very useful for getting a quick start on those troubles where the problem could be in either the transmitter's final stage or the transmitting antenna. If the lamp lights up to a good white glow, but there's very little output from the antenna, then check the antenna and transmission line; that transmitter's okay. Although the mismatch between the transmitter and the lamp is theoretically something awful, you'll be surprised how little you have to change the tuning adjustments between the lamp and the regular antenna.

For CB transmitters? Use a No. 47 pilot light. Even lower power? Try a No. 49.

## 8-5. MEASURING BASE BIAS VOLTAGE IN HIGH-RESISTANCE CIRCUITS

In a few audio-amplifier applications, you'll find very high-value resistors used in the base voltage-divider circuits. One well-known make, for example, uses a 12-meg resistor as part of the network. Even the 11-meg resistance of a vtvm will upset this circuit if it is shunted across. Since it takes only a fraction of a volt to cause a big change in transistor currents, measuring the base bias directly is not a good procedure.

Setmakers recommend measuring collector and emitter voltages as given in the service data. If these are correct, then the base bias must be right. In other words, we avoid getting into the very high-resistance circuit to measure base voltage. Instead, we measure the voltages that this voltage affects.

If you want to check out the base-bias circuit, remove the transistor and measure the large resistors for proper value. If the collector and emitter voltages are off value, you should do this.

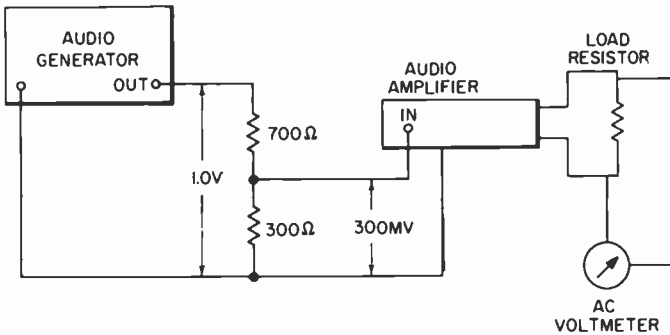
## 8-6. A VOLTAGE DIVIDER FOR OBTAINING VERY SMALL AUDIO SIGNALS

For audio-amplifier testing, we need a source of low-level signals. We must be very careful not to overload the input, in transistor amplifiers especially. Also, it is possible to make a quick check on any audio amplifier by feeding in a given number of millivolts and measuring the audio-output power. If the amplifier comes up to specifications, there's no need to go any further. This is also a fast way to isolate a weak channel on a stereo system.

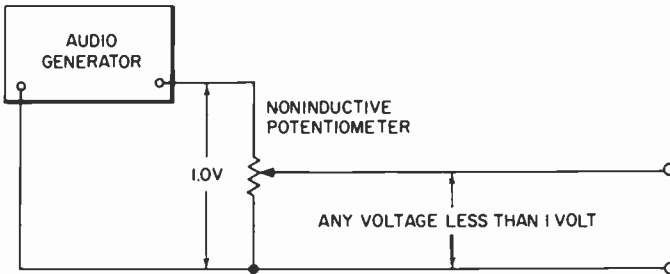
You can read the output of an amplifier in watts by substituting a load resistor of the proper value for the speaker, applying a steady signal to the amplifier input, and measuring the voltage across the load resistor. The value of power output can be figured out by the Ohm's law equation  $W = \frac{E^2}{R}$ . In many cases, you'll find the right values of voltage for both input and output given in the service data.

For instance, an amplifier may call for 2.75 volts across the output-

load resistor at an input of 300 mV. The problem is to get a true 300 mV since most shop-type audio generators don't have accurately calibrated attenuators. To get the signal we need, we can use a simple resistive voltage divider as shown at A. If the top resistor is 700 ohms and the bottom resistor is 300 ohms, and if we apply exactly 1 volt of audio signal to the whole thing, then we can take off 300 mV at the tap.



A



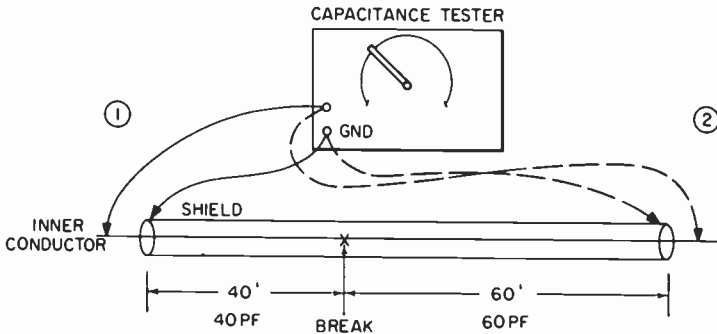
B

It may be more convenient to use a 1,000-ohm variable resistor, as at B. Hooked up as a potentiometer, the slider can be set with an ohmmeter to give any value of signal output needed. Stereo and hi-fi amplifiers designed for low-output magnetic cartridges usually call for about 5–10 mV, while “ceramic” inputs call for 700 mV up to 1 volt. With the signal-generator output set at a given level, the pot can be used to obtain any fraction of this amount. This method eliminates the need for accurate measurement of very low signals; all we need to know is the total signal across the divider and how the divider is set up.

A carbon potentiometer is best. The inductance of a wirewound pot could affect the accuracy of division at high frequencies.

## 8-7. FINDING A BREAK IN A COAXIAL CABLE WITH A CAPACITANCE TESTER

You can use almost any piece of test equipment for many applications. For instance, you can use a capacitance tester to locate a break in the inner wire of a coaxial cable, such as a microphone cable, coaxial lead-in, etc. There are two ways to do this. If you know the type of cable, you can find its capacitance per foot from a catalog or the *Radio Amateur's Handbook*. Then hang the capacitance tester onto one end. Divide the reading by the capacitance per foot, and you have the distance of the break, in feet, from the end you measured at. The second method, if you know the length of the cable but can't find its capacitance per foot, is to measure first at one end, then at the other, and note both readings down. Call one "reading 1", the other "reading 2". Divide reading 1 by



the sum of both readings, and multiply that number (which will be less than 1) by the total length of the cable. The result is the distance of the break from the end at which you took reading 1. Of course you can also use reading 2.

Most breaks in microphone cables happen near one end or the other because of the bending and flexing near the plugs. To find out which end is broken and save tearing the plugs apart needlessly, take a capacitance reading from each end. One end will show a large capacitance, the other practically none; the latter is the broken end.

A capacitance test can also be used to find a broken wire inside the insulation of a two-conductor cable. Use the good wire as the "shield" and measure the capacitance of the broken wire to this. Otherwise, the method is the same.