

## Output Stage — Transformers and Speakers

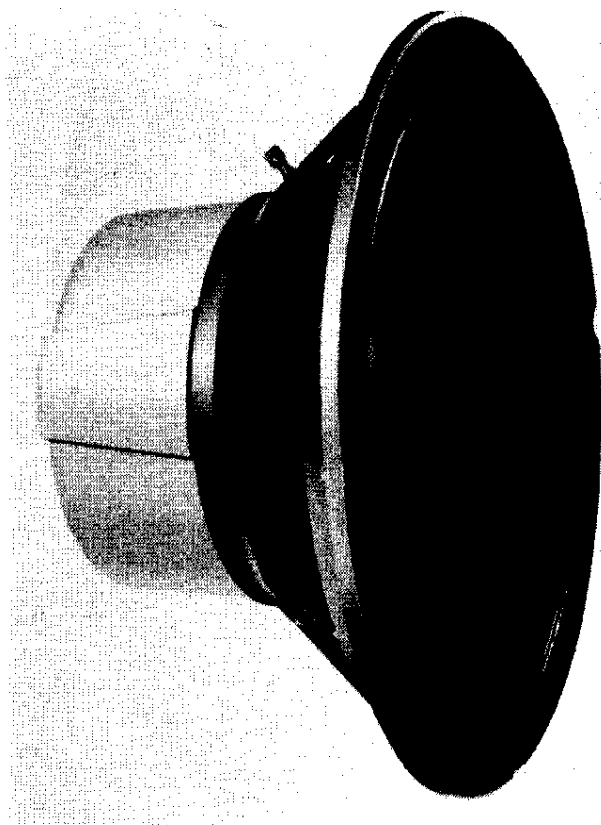
The output stage of all amplifiers is very important in more ways than one. It uses practically all of the *power* taken by the amplifier, it determines the *power output* level, and it can cause a great deal of the distortion. Parts in this stage work as hard as the parts in the power supply. So, they have a greater failure rate than others, and require more care in selecting suitable replacements. This is most especially true in transistor amplifiers and in the higher-powered tube types.

Tube and transistor output stages have slightly different characteristics, and even the output transformerless transistor output stages differ between the two basic types, the stacked and complementary-symmetry. So, you must know these characteristics for they affect the type of tests you use on them. Also, they differ in one very important respect; with tube-types, using output transformers, the speaker must NEVER be left off (open) when the amplifier is turned on. This will damage the output transformer. In transistor transformer-output types, the same applies. However, OTL transistor amplifiers can be turned on with the speaker open, with no damage; however, these circuits will not withstand even a momentary SHORT-CIRCUIT across the speaker terminals! So, while making tests, be absolutely sure that your wiring, extension leads, etc., are kept well clear so that there will be no chance of a short between the speaker leads. This can blow not only one but several large and expensive output transistors in a fraction of a second.

### SPEAKERS

Speakers, too, have changed drastically in the last few years. Not too long ago, about 15 watts rating

was the best you could get in a cone-type speaker, even in the very best "pa type" units. With the development of the super power amplifiers of today, something had to be done. So, loudspeaker makers labored mightily, and came up with super-speakers to match the amplifiers. It is possible to get single cone-type



Courtesy Electro-Voice Inc.

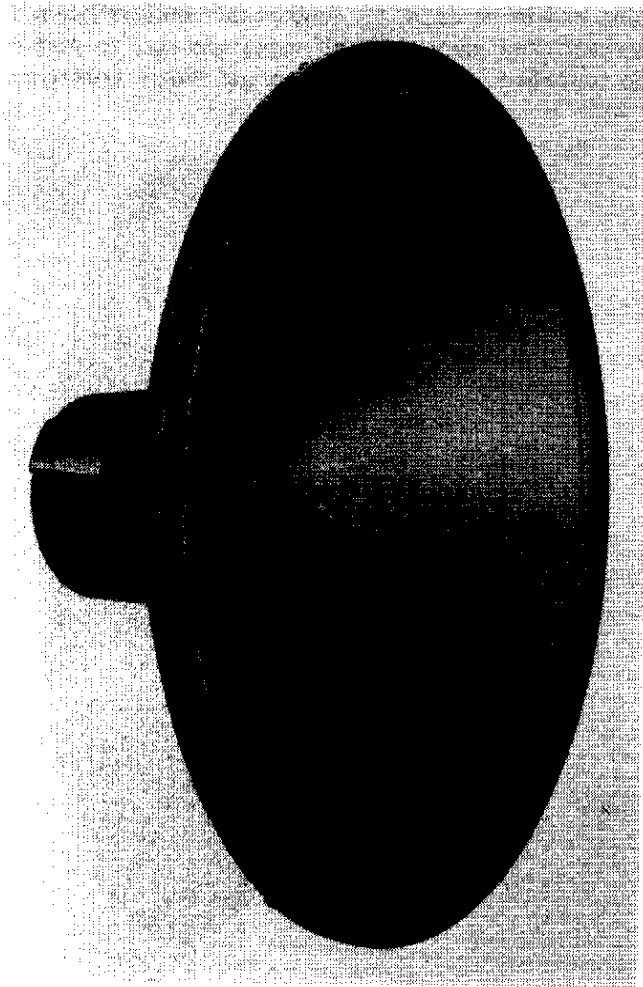
Fig. 6-1. Speaker with peak-power rating of 300 watts.

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speakers now that will actually carry 150 watts of pulsed (program) power, in a single unit. Fig. 6-1 shows one of these speakers. The *peak* power rating of this speaker is an amazing 300 watts.

The "bass-amp" speakers have the hardest work, since in all musical tones, the largest percentage of the audio power is in the lower frequencies. (It takes more power to cause the speaker cone to move over the greater excursions at slower speeds.) Here, too, the super-speakers are used. A 15-inch speaker used to be considered a big one. They are now making them up to 30 inches in diameter, as you can see in Fig. 6-2. This unit has a 100-watt rating, 200 watts peak.

When replacing speakers like this, you must be sure that the replacement speaker will handle the full power output of the amplifier. This is not too important in the smaller amplifiers, say up to 25-30 watts, but if you have one of the monsters, look out! If you replace a high-power speaker with a \$29.95 "super-



Courtesy Electro-Voice Inc.

Fig. 6-2. Speaker that is 30 inches in diameter.

bargain" import type, and turn the thing on to full output, you'll blow the cone all the way across the room. (This has actually happened; one musician blew four new speakers at the same time, so they weren't as much of a bargain as he had thought.)

## OUTPUT STAGE TESTING

If you are to service an amplifier which makes no sound at all when it's turned on, trouble in one of two places, the power supply or the output stage, is indicated. As usual, the power supply should be checked out first, since no amplifier can work unless it has the right power supply.

The first thing to check is the ac supply. This is reasonably simple; just look at the pilot light. If this lights but you hear no sound at all, you know that the amplifier is getting ac power; the line cord and plug at least are still all right. Next, check the fuses or circuit breaker. If the fuse is blown DO NOT replace it with a bigger one "for testing," especially in transistor amplifiers. You may cause more damage.

There are several ways of checking an amplifier like this with safety. One is to replace the fuse with one of the same size. Turn it on. If this pops right away, you know that there is still a short circuit. Another way is to clip a circuit breaker, of the same rating as the fuse, across the fuse terminals. If this pops out, it can be reset. (The drawback to this is that it requires quite a few different circuit-breakers on hand.)

The best way of doing this is to use the wattmeter and a variable transformer. Hook them up as shown in Fig. 6-3. The variable transformer is plugged into the wattmeter, and the amplifier line cord into the variable transformer. Replace the fuse. Now, you're ready. Turn the output of the variable transformer all the way to zero, and turn the amplifier power switch on. Note the normal input wattage on the rating-plate of the amplifier, which should be on the back apron of the amplifier chassis. Now, we're ready.

The variable transformer dial will be calibrated to show the output voltage. Turn it up slowly, watching the wattmeter. For example, this amplifier has a normal drain of 200 watts, at 120 volts ac input. As you turn the dial up, the wattmeter will begin to show

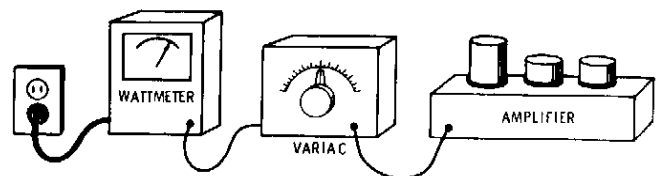


Fig. 6-3. Using a variable transformer and wattmeter to verify a short-circuit in an amplifier.

a reading. If you get up to about 35-40 volts input, and the wattmeter already shows 200 watts, stop! This tells you that there very definitely is a short-circuit inside the amplifier.

Now, we know that we have a short, and the chances are that it's in one of two places—the power supply or the output stage (the two “heavy-current” stages). So, we have to clear one or the other. The power supply is easiest. Just unhook the main supply lead to the output stage. This will be easy to identify, in most amplifiers. It'll go to the center-tap of the output transformer, in tube amps, and to the collector of the top transistor in the output pair, in solid state. This takes that stage out of the picture, leaving only the power supply.

Now, repeat the test. If the dc power supply will come up to the full ac line voltage, and shows only a comparatively small wattage drain (something like 30 to 40 watts is about right for an unloaded dc power supply), and the dc output voltages are normal or slightly high, we have cleared the power supply from suspicion. This leaves us with only the output stage. Of course, if the short turns out to be in the power supply, which it very often does, we find the shorted capacitor, rectifier, etc., or whatever it is, fix this, and then repeat the test. For a final test, reconnect the output stage power lead, and repeat the slow-voltage run-up test, to see if you can get it up to the full ac input voltage without drawing too much power. If the amplifier works, fine; the job is done.

### CHECKING TUBE OUTPUT STAGES

If the short is definitely in the output stage, turn the power on at a low level, just enough to get a small amount of wattage. For tube output stages, check the dc voltages on plates, screen grids, cathodes, and grids of the output tubes. Note the dc voltage you're getting from the power supply. This should be a percentage of the normal voltage, say 15 to 20%. This will give you enough voltage to make tests, but not enough to overload anything.

A quick check of dc voltages will probably show you some point which should have dc voltage, but has none. For example, if you get zero on the screen grids of the output tubes (a point which will normally be at full B+, several hundred volts) turn it off, and take a resistance reading to ground. If you find a short, the screen grid bypass capacitor could be shorted. Disconnect it and check.

Zero voltage at the center-tap of the output transformer primary means a short there; most likely, a shorted decoupling capacitor, which is normally a big electrolytic. Possible, but rare, is a shorted output

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transformer. Disconnecting possible suspects one at a time, and checking with an ohmmeter, will quickly show you where the short-circuit is.

If you find no “dead shorts” in a tube output stage, that is, in the dc voltage supply lines and all parts connected to them, and the amplifier draws a very heavy current, but only after the tubes warm up, look out for a *bias* problem. (This is the one that makes the plates of the big output tubes get red hot!) In high-powered tube amplifiers, you'll probably find a special negative-bias voltage circuit, to supply the high bias voltage needed to make the output tubes work in Class-B. Fig. 6-4 shows the basic circuit of this.

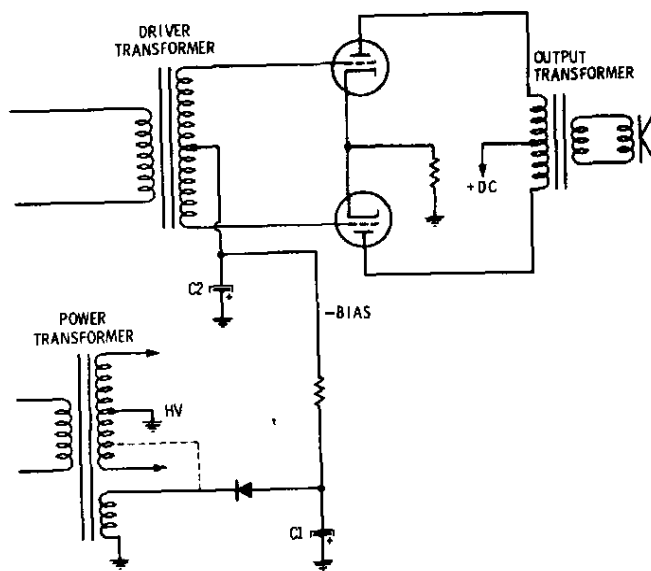


Fig. 6-4. Negative-bias voltage circuit.

This bias supply will run somewhere around 45 to 50 volts as an average. It is developed by a diode rectifier, on a special winding on the power transformer. It's filtered by a capacitor, and decoupled by an RC network. If the decoupling capacitor C2 should be shorted, the tubes will have zero bias, and draw a very heavy plate current. Quick-check for this—pull both output tubes, turn the power on, and take a dc voltage reading right on the grid terminals of each socket. This should show the negative bias voltage, slightly higher than normal reading, due to the loss of load. Actually, there is only a very minute current in *this* circuit, but the dc voltage will rise due to the loss of load current on the power transformer, from the normal heavy output-stage current. Any trouble in this is easy to fix; it will probably be a shorted capacitor, shorted or open rectifier, or open decoupling resistor, (or that classic problem “just a loose wire”). In one case of an intermittent overheating of

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output tubes, the plastic covered wire from the bias supply was found to be shorting to the sharp corner of a terminal strip.

Fig. 6-4 shows the output tubes, with a driver transformer to supply the grid-drive signal. In quite a few circuits, you will find the output tubes driven from a phase-inverter stage, with coupling capacitors to transfer the ac signal. The "other end" of these capacitors is always connected to a source of positive voltage—the plate/cathode of a split-load phase inverter, etc. So, if there is even a small dc leakage through the capacitor, this will cancel out the negative bias on the output tubes, and away we go again.

Severe leakages or shorts cause the output tubes to get red hot from loss of bias. Small leakages upset the bias, not enough to cause the output tubes to overheat, but this will cause a very severe distortion. This makes the sound very "fuzzy," due to clipping, or oversaturation of the output tubes.

Quick-check for this condition, in any amplifier, external-biased or self-biased—pull both output tubes, turn the power on, and read the dc voltage on the grid terminals of the sockets with a vtvm. In self-bias circuits, this should be absolutely zero, for there is no voltage applied. In external-bias circuits, read the dc voltage at the output of the bias supply, then at the grid terminal itself. There should be absolutely no loss or drop. For example, if you read  $-50$  volts at the supply, and  $-40$  volts at the grid, you're losing 10 volts somewhere. Disconnect the capacitor at the grid end, turn the power on, and take a dc voltage reading (vtvm *only*) on the open end of the capacitor. Needless to say, this had better be zero! If you get any "permanent" reading, aside from the initial charging kick, which should leak off in about 15 seconds, replace the capacitor.

Some of the external-bias circuits will have a "balance pot" connected in the bias circuit. This allows the adjustment of the cathode currents of each output tube, for best balance. A link will be provided in the cathode circuits, so that you can open this and hook in a dc milliammeter. You'll notice this feature in several of the larger tube amplifiers, in the schematic section of this book.

### CHECKING TRANSISTOR OUTPUT STAGES

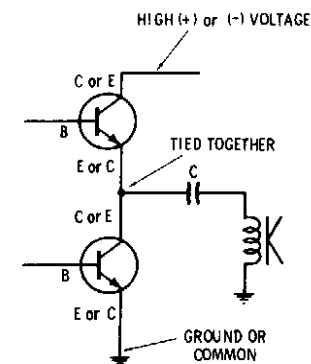
To make tests on transistor output stages, use the same power-supply test methods just given. Disconnect the output stage, and make sure that the dc power supply is in good shape. After this, use the same low-voltage setup to get some information as to what is actually going on. Due to the nature of transistor output stages, it is *very* difficult to find shorts

in the dc power supply with an ohmmeter. If you happen to connect the ohmmeter so that it forward-biases one of the rectifier diodes, you'll see what looks like a "big, fat short", but is *not!* When taking any short-checks in transistor circuits, always take the reading, then reverse the ohmmeter prods to see if the low reading you get is due to a forward biased transistor or diode junction, or not. Of course, if you get a zero reading both ways, you can be reasonably sure that something is wrong. Disconnect loads to find out.

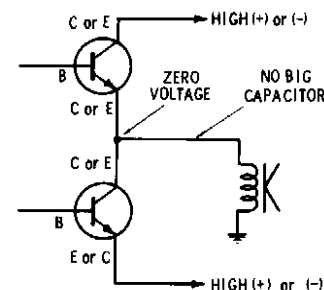
### Voltage Identification of the Circuit

Fig. 6-5 shows the two typical circuits you'll find. The single-polarity type is shown in Fig. 6-5A. You will *always* find the big electrolytic coupling capacitor used. However, depending on the type of circuit the designer chose, you may find the collector and emitter connections changed up quite a bit. The base will always be the same, the input; but you may find the other two reversed. The dc supply may be fed to the collector or emitter of the top transistor, and either the collector or emitter of the bottom one may be ground. Voltages may be either positive or negative. So, on the first check, just look for the "high voltage," and pay no attention to its polarity. What you need to know is "Is it there or not?"

The dual-polarity type of circuit (Fig. 6-5B) can be identified by several things. For one thing, there will be *no* big coupling capacitor from the midpoint



(A) Single polarity.



(B) Dual polarity.

Fig. 6-5. Voltage identification of circuit used.

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to the speaker. The speaker is connected from the midpoint to ground or common. So, this point will be at zero dc voltage. The "open ends" of the circuit, that is, the emitter/collector of the transistors, will be at the same *voltage*, but of opposite polarities.

I believe that you will find the majority of transistor amplifiers use the single-polarity circuit for the output stage, as shown in Fig. 6-6. If so, then you will have a very convenient test point—the "midpoint voltage" of the circuit. What you read here will tell you a great deal about the circuit condition.

As you can see, the two transistors are effectively connected in series across the dc power supply. The maximum dc is connected to the top transistor, and the lower one is grounded. (Note: You'll find these reversed, and of different types, in the complementary-symmetry circuit and so on, as you saw in the earlier discussion of these circuits, but the basic principle will still be the same. With a single-polarity power supply, the voltage will always divide up almost evenly.)

So, if the circuit is working properly, you'll find approximately half of the maximum dc supply voltage on the midpoint—the junction of the two transistors. If you find zero voltage at this point, check to see if the dc power supply is of the dual-polarity type. If so, you'll find a high negative voltage on one transistor, and a high positive voltage on the other (emitter or collector, depending on how they're connected). However, there is one firm clue you can use; if you see the collector (or emitter) of one of the power transistors connected directly to *ground* or common, then it's a single-polarity type of circuit.

If the midpoint voltage is zero, check the dc power supply on the top transistor. If this is the full dc supply voltage, the top transistor is open. Don't take this for granted, of course; take the transistor out of the circuit and check it. If you find the full supply voltage, or at least  $\frac{2}{3}$  of it, on the midpoint, the top transistor is shorted. (This will normally blow the fuse.) Shorted transistors can usually be checked in-circuit,

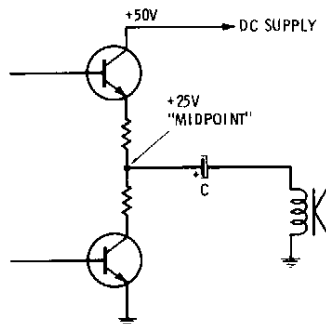


Fig. 6-6. The midpoint voltage on a transistor transformerless output circuit can provide a valuable clue.

by taking ohmmeter readings across the emitter-collector junction. If you get zero ohms with the prods both ways, the chances are it's shorted. Once more, do not take this as final; take the transistor out and repeat the ohmmeter test. If it checks shorted out-of-circuit, it is. Silicon transistors, when they short, normally go to a complete zero-ohms reading. Of course, if you check one out-of-circuit and get a completely open-circuit reaction, prods both ways, this junction is open. You should get the diode effect between any two terminals of the transistor: low resistance one way, high resistance with ohmmeter prods reversed.

With any of these troubles in the output stage, you will naturally hear no sound in the speaker. If the big coupling capacitor is open or if the speaker voice coil is open, your midpoint voltage will be away off. The actual voltage you find here will depend upon the rest of the circuitry (not shown here) but there will often be dc feedback networks which will give you enough continuity to show up some voltage at the midpoint. However, if the capacitor is open, the dc voltage on the lower transistor will certainly be abnormal, since it is from the charge-discharge action of this capacitor that it gets its power supply. The same thing will happen if the speaker is open; this is the "ground-return" for the capacitor, so it can't charge up to the normal voltage.

If the capacitor is leaky, the midpoint dc voltage will be pretty low, although some sound may go through. There will be a terrific distortion, however. This is due to the unbalance caused by the lower transistor not getting its fair share of the dc voltage. A leaky capacitor won't charge to the full voltage and hold it.

I have said and I say again: If you find one output transistor defective, in this type of stage, don't replace just one. Put in two new ones, and be sure that they are a matched pair of whatever type is needed.

### DRIVER STAGE FAULTS

In circuits using direct-coupled driver stages, be sure to check the base bias on new output transistors. The collector current of the driver is the base-current of the output transistor. Fig. 6-7 shows the basic circuit used. (Bias diodes and coupling to the lower transistor have been left out for clarity.) As you can see, the signal coming in drives the driver into conduction; its collector current flows through the base-emitter junction of the top output transistor.

So, if this driver transistor develops leakage, or if new output transistors have been installed, the output bias must be checked. Read the resting current (the current drawn by the output stage collectors, with *no*

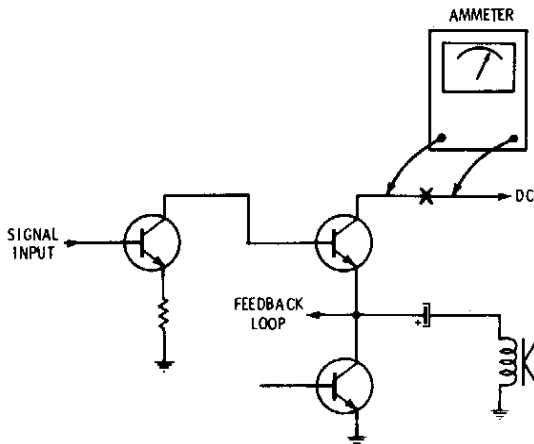


Fig. 6-7. Basic direct-coupled circuit.

input signal) of the output transistor; connect a dc ammeter into the collector supply circuit as shown. In a Class-B stage, there will be only a small fraction of the full output current flowing, with no applied signal. Some current is drawn to reduce crossover distortion.

If the rest bias is not correct, too much current will be drawn; the output transistors may get fairly warm. Normally, they'll stay quite cool, as long as there is no signal applied. If you find the transistor running warm, check the driver transistor and the dc base voltage of the top transistor. The chances are that you'll find this voltage a little too far in the "forward-bias" direction. A driver transistor, even though it checks good, can cause this if it has too high a beta. This factor is the *current gain* of the transistor; so, if it is too high, too much current will flow in the collector circuit, and over-bias the output. Try replacing it with one of about  $\frac{2}{3}$  the beta of the original. If this doesn't work, try one with a *higher* beta. Keep checking until the rest currents of the output transistors are back to normal.

You will sometimes find direct coupled preamplifier and driver stages with as many as three, four, or even five transistors all directly coupled. If so, you will have to take out at least two, in order to break the circuit to check the transistors. You cannot use an in-circuit type transistor tester in these; you have too many other things shunted across the transistor you're trying to check. The only definite test is to take it out and then check it.

### CURRENT TESTING FOR FULL OUTPUT POWER

After the driver stage, bias, etc., has been checked out following transistor replacement, connect a dummy load resistor of the correct value to the

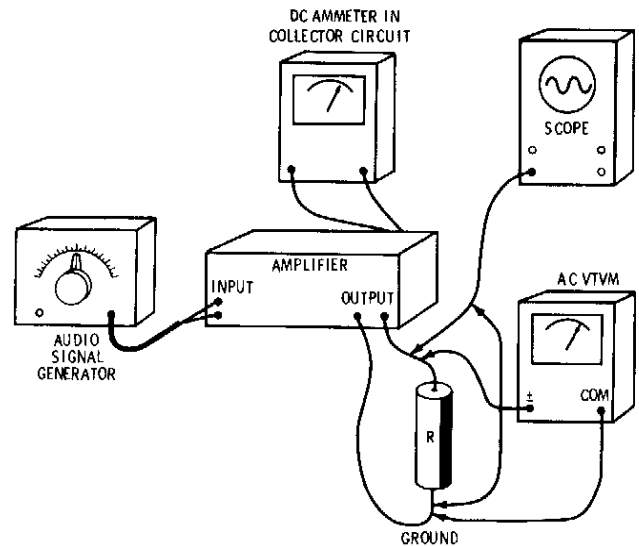


Fig. 6-8. Test setup for checking collector current, power output, and distortion.

speaker terminals. In medium-powered amplifiers, this will probably be 8 or 16 ohms. In the super-power jobs, 4 ohms. If possible, check this figure on the schematic, or look for a rating plate on the amplifier. This information *should* be plainly marked at the speaker terminals of all amplifiers, however you won't find it on a great many. In any case, NEVER use a load resistor of less than 4 ohms.

Connect a dc ammeter in series with the output stage dc supply, as in Fig. 6-7. Connect the scope across the load resistor, and also an ac vtvm or vom. Connect an audio-frequency signal generator to the input, through a voltage divider, if necessary, to prevent too much signal voltage from being applied. Now you're ready to go. Fig. 6-8 shows the complete setup.

Start by turning the main volume or loudness control of the amplifier down. Set the input signal level at about 50 mV. Now, gradually bring the volume control up, watching the collector ammeter. As the output signal rises, you'll see the ac voltmeter start to read, and the waveform rise on the scope. The square of the actual rms signal voltage shown on the ac vtvm, divided by the value of the load resistor, equals the power-output being developed at any setting. This is from Ohm's law power formula  $P = E^2/R$ . Remember, for this test, do not bother to read the scope; it is showing peak-to-peak voltage, and right now we're reading rms on the meter.

Note the collector current reading on the dc ammeter. This should always be well *below* the maximum current rating of the new transistors. Checking fuses, or noting the maximum current rating on the schematic at the dc power supply, will give you an idea of what to expect. If everything seems to be work-

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ing all right, let the amplifier run for about five minutes, at full power. Watch the collector current meter. This should *not* rise above the level you read for the full-power output. If you see this meter start to “creep up,” look out! This could indicate an excessive rise in junction temperature, and, with germanium power transistors, the chance of thermal runaway. A small increase may be all right, if it stabilizes after about one minute, but a steady creep upward should be checked out. This can be due to dry-mounting of the new power transistors, or to a very slightly leaky driver transistor, etc. Do not run this for more than five minutes at high power.

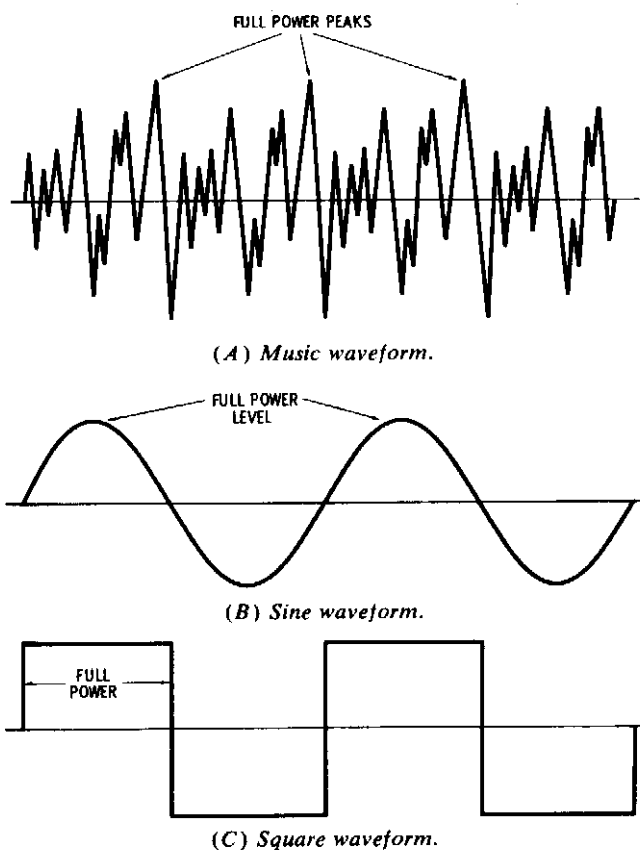


Fig. 6-9. Difference in power peaks among test signals.

Also, if your audio signal-generator has a square wave output, do not use this for this type of testing. There's a reason; the guitar amplifier is intended to develop a high output power, but musical waveforms are not “square,” they are usually sharply peaked. While it does develop high audio power, this type of waveform drives the amplifier to full output for only fractions of a second. Fig. 6-9 shows how and why.

In the music waveform of Fig. 6-9A, the full-power peaks are very sharp, lasting only for a milli-second or so. In the sine wave of Fig. 6-9B, the rounded peaks keep the amplifier driving for a little

longer time, but not too much. However, the square wave of Fig. 6-9C turns the amplifier on, full-out, and *keeps it on* for a full half-cycle, switching then to the lower transistor and repeating. So, a test of this kind can damage a perfectly normal amplifier, because of the high power dissipation due to excessive “on-time.”

### TESTING FOR UNDISTORTED POWER OUTPUT

To find out exactly how much undistorted power output an amplifier is capable of delivering, we use the same setup as before. If the collector current stays within safe limits, you can remove the dc ammeter. Feed in an input signal, at any frequency below 2000 Hz. (Most of the standard tests are made at 1000 Hz.) Set the scope sweep to display about three cycles of this signal, across the load resistor. If the scope can be calibrated in peak-to-peak voltages, use this and divide by 2.8. If not, use the rms ac voltage reading on the vtvm.

Now, we're ready. Increase the amplifier gain, adjusting the scope to keep the signal on the face of the tube. Watch for the point where the tops of the sine waves just start to flatten out. At Fig. 6-10A, the normal signal shows rounded peaks; at Fig. 6-10B, the tops of the waveforms have just begun to show flattening. This is the point where the amplifier has just begun to “clip.” This is distortion. Back the amplifier gain down until the waveforms are rounded again. Now, read the ac rms voltage and do the arithmetic. The result will be the maximum undistorted power output of this amplifier with this load. This level is sometimes found under the name “music power.”

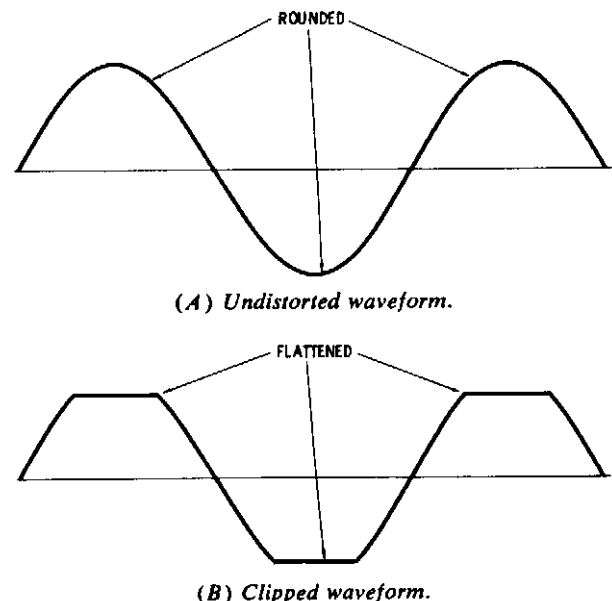
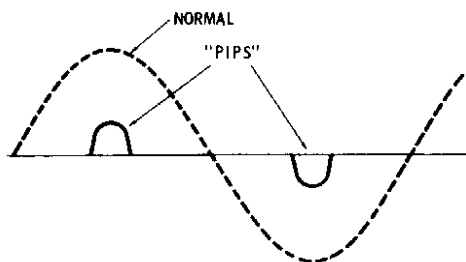


Fig. 6-10. Checking output waveform of amplifier.

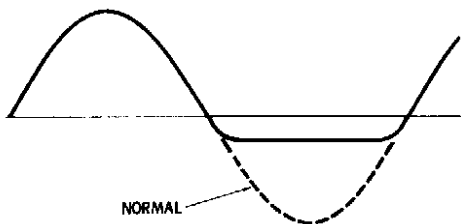
### FINDING DISTORTION OR LOW POWER WITH SCOPE

The signal you see on the scope, across the load resistor, can be very useful. It will tell you if there is any distortion in the amplifier, and, with careful checking, tell you where. For example, if you see a waveform looking something like that in Fig. 6-11A, after replacing the output transistors, even with the amplifier gain turned up, this usually indicates a lack of sufficient drive signal to the bases of the output pair, or incorrect bias on the output pair. With this type of waveform, you'll usually have a terrible distortion, and the power level will be far below normal. Instead of driving the output pair into conduction over a full cycle, the drive signal is getting high enough to cause conduction only in the very middle of the cycle. The stage should be working in Class-B, but it is actually working in something that could only be called "Class-C."

An output signal with the lower half-cycle missing or far below the amplitude of the upper half, indicates a very severe unbalance in the output pair. This is shown in Fig. 6-11B and may not look exactly like this, but, if you can see a decided unbalance, find out why. This, too, is a cause of distortion. Check the speaker coupling capacitor, any bias diodes that may be used, and the driver stages.



(A) Caused by low drive or improper bias.



(B) Caused by half of the output stage not conducting.

Fig. 6-11. Distorted output waveforms.

### A REALLY BIG MISMATCH

Fig. 6-12 shows the waveform of a really weird mismatch. This amplifier came in for service with the complaint that it "just doesn't sound right!" It didn't!

Almost, but not quite. Voltages were checked, and found to be very near normal. But, when a distortion test was made with the scope, this is what I saw. Note the crossover. One-half of the signal is apparently all right, but the lower half is "taking off" a little late. Note that it goes *along* the baseline for quite a way before it begins to conduct.

This told me right away that it was a bias problem. A careful examination of the output stage showed that *one* of the output transistors had been replaced, leaving the other original in. Both were removed, and tested. Both were good. However, cross-checking against the replacement guide brought out an astonishing fact. One was a silicon, the other was a *germanium!* The circuit was a stacked transformerless output.

The characteristics of the two transistors were pretty close. However, you can see what happened. Silicon transistors need a 0.6 volt bias to start conducting; germanium, 0.2 volt. The silicon transistor was in the lower half. So, it didn't begin to conduct for quite a while, causing the output to go along the baseline until it reached the conduction level before it went into conduction.

Incidentally, as an experiment, I tried two germanium transistors, then two silicon, in this unit. The results were mildly astonishing; both sounded pretty good. The originals were germanium. A bit of bias adjustment made the silicons work.



Fig. 6-12. Crossover distortion caused by unlike transistors in output pair.

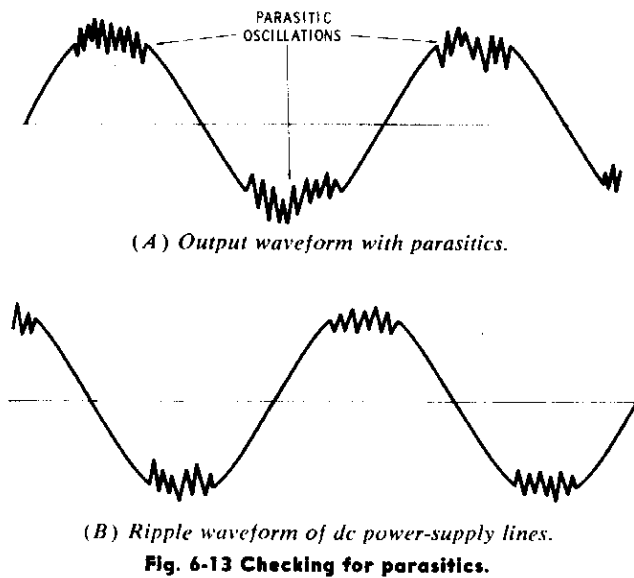
### CHECKING FOR PARASITIC OSCILLATION WITH A SCOPE

Fig. 6-13 shows another fault that's hard to find without the scope. The small "bursts" of high-frequency signal on the low-frequency signal waveform are parasitic oscillations. These take place in some of the amplifier circuits, usually due to a bad electrolytic filter capacitor somewhere. This allows the power supply to develop a "nonzero impedance" to ground, and unwanted signals can build up on common voltage supply lines, etc.

To find out, scope the power supply lines with a good sized signal being fed through the amplifier. If



## Output Stage—Transformers and Speakers



you find anything at all on the dc voltage supply lines, such as the waveform of Fig. 5-11B, look out! This is **WRONG!** Connect the scope to the point where the ripple waveform is the largest, then start substituting filter capacitors until you get rid of it. **NEVER** bridge an electrolytic filter capacitor across a dc supply line in a transistor amplifier without turning the power **OFF**. The resulting surge can blow transistors. Since these amplifiers come back on instantly, this is no trouble. Just turn it off, clip the substitute capacitor across the circuit, and turn it back on.

### REPLACING OUTPUT TRANSFORMERS IN TUBE AMPLIFIERS

In better tube amplifiers, you will notice that the output transformer is almost as big as the power transformer. This is absolutely necessary to get good quality. As has been said before, the output stage dissipates about 95% of the power used in the whole amplifier. To be able to handle this kind of power without distortion, a big transformer with lots of iron is needed. This eliminates the core saturation that is responsible for distortion.

When an output transformer is replaced, check the schematic and the parts list. The type of tubes used and their operating voltages determine the wattage rating of the output transformer. For example, two 6V6s, with 250 volts on both plate and screen, are rated at 10 watts output. Two 6L6s, with 360 volts on the plates and 270 volts on screens, have an output of up to 45 watts. Check the tube manual to see what power you need.

To find a suitable replacement output transformer, you must have other information besides the wattage

rating. Its primary winding impedance must match the load resistance (sometimes called load impedance) of the output tubes used, and the secondary winding must match the voice-coil impedance of the speakers. The 6V6s mentioned have a plate-to-plate load impedance of 10,000 ohms. With these tubes and a 16-ohm speaker the rating would be "push-pull plates, 10,000 ohms, to 16-ohm voice coil, 10 watts." Replacement transformers are available from many different manufacturers, all of whom publish very detailed catalogues with lists of output transformers of all sizes, shapes, and variety of ratings. Standard pa-type output transformers can be used; the only difference between them and the regular guitar-amplifier output transformers is in the number of extra taps on the secondary winding. They have provision for hooking up 4-, 8-, and 16-ohm speakers, a 500-ohm output, and so on. Simply use the leads you need and leave the rest open.

### INVERSE FEEDBACK

Most of the larger amplifiers use inverse feedback in order to reduce distortion and give a better tone. The feedback voltage is often taken from one side of the output-transformer secondary winding at a speaker connection. (Fig. 6-14 shows how this can be connected.) The voltage that is fed back must be of the right polarity; it should produce degeneration instead of regeneration. (Regeneration causes oscillation, and degeneration stops it.)

If you replace an output transformer and turn the amplifier on, only to get a deafening howl, turn it off and change the polarity of the feedback voltage—move the feedback connection to the other end of the voice-coil winding. This reverses the polarity; opposite ends of a transformer winding are 180° out of phase with each other. In Fig. 6-14 note that a ground

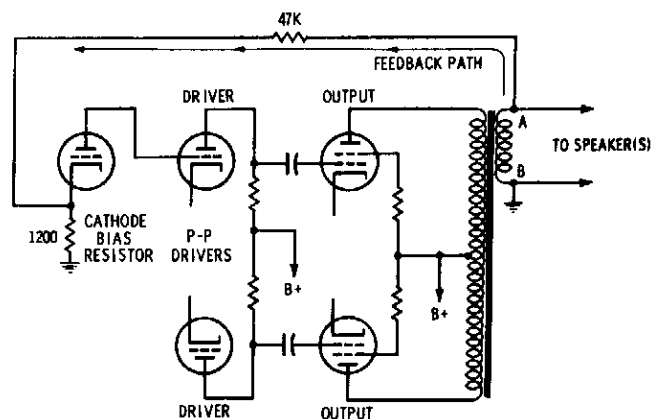


Fig. 6-14. Inverse-feedback connection on output-transformer secondary.

## Service Procedures and Techniques

is shown on the end of the voice-coil winding marked "B." To reverse the feedback connection, move the ground to A and the feedback to B. The voice coil, being nonpolarized, can be left where it is. Do not move only the feedback lead; this grounds out all inverse feedback, and the tone will suffer. You might notice a little increase in volume with this arrangement; inverse feedback cuts the gain but helps the tone quality.

As a final precaution, never turn on an amplifier for testing without some kind of load hooked to the output-transformer secondary. If you do, the impedance in the power-output stage will be so far off that you may burn out the output transformer in just a few seconds. The stage is set up to work with an 8-ohm or a 16-ohm load across the secondary so that the primary winding will have the proper loading.

### CROSSOVER NETWORKS WITH MULTIPLE SPEAKER SYSTEMS

Many of the better amplifiers will use "speaker systems" instead of a single or double speaker of the same size. Very large speakers (woofers) are most efficient in the low-frequency range. However, they're not too good for the very high frequencies. So, smaller speakers will be added; a medium-sized one, say 5 to 8 inches in diameter, for the "midrange," from about 2000 Hz up to 7000 Hz, and a very small speaker, sometimes a horn type, for the frequencies above this, up to a maximum of 20,000 Hz. This one, because it handles only very high frequencies, is sometimes called a "tweeter."

To get the best results with a multiple-speaker system, the various frequencies must be divided up among the different speakers. The lows go to the woofer, midrange to the medium-sized speaker (sometimes called a squawker) and the highs to the tweeter. Fig. 6-15 shows a simple circuit used to accomplish this frequency distribution. This is called a "crossover network." At a low frequency most of the sound energy goes to the woofer. When it reaches a certain frequency, it is transferred automatically to the tweeter; it is said to "cross over" from one to the other, hence the name. Only two speakers are

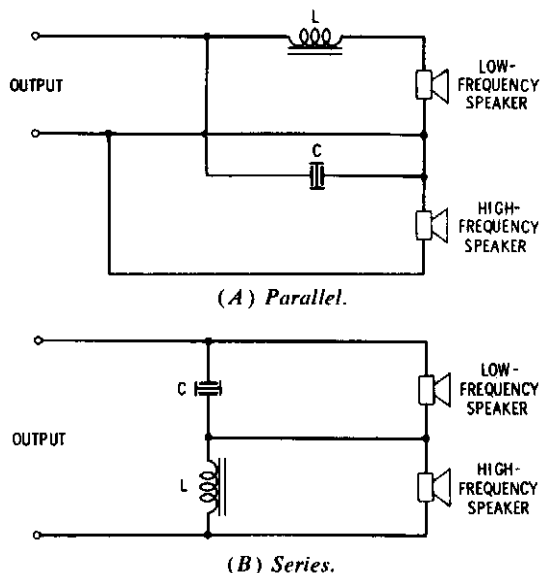


Fig. 6-15. Crossover networks.

shown; to use three, an additional part is added. Works just the same, though.

Here we take advantage of the basic characteristics of inductance and capacitance. A capacitor has a very high impedance at low frequencies that gets smaller as the frequency increases. The inductance has exactly the opposite effect—high impedance at high frequencies, very low at low frequencies. If components are hooked up as shown in Fig. 6-15A, the capacitor will let the lows go only to the woofer while feeding the highs through to the tweeter. In the series circuit (Fig. 6-15B) the high frequencies are bypassed around the woofer by the capacitor so that they appear across the inductance. Reverse the action for lows; the lows are bypassed across the tweeter by the inductance and blocked by the capacitor so that they have to go through the woofer.

### TROUBLES IN SPEAKERS

All speakers are dynamic types. A voice coil, which is a hollow cylinder with a small coil wound on it, fits over a magnetic pole piece so the coil is suspended in a magnetic field (Fig. 6-16). The voice coil actually moves back and forth in a very narrow slot. If the cone warps or the voice coil touches the sides of the

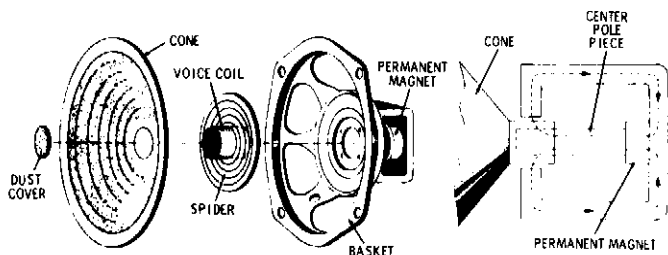


Fig. 6-16. Construction of a pm speaker.

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at any point, a distorted, harsh, scraping sound comes from the speaker.

To test for this, place your fingertips on both sides of the cone at once, and push straight in and out. Listen to the sound: you shouldn't hear anything at all if the voice coil is floating freely. If it is dragging, you will hear a scraping sound. Trouble is usually caused by dampness that warps the cone or voice-coil form. There is no cure for this: modern speakers can not be realigned, as the old ones could. However, you can always have the speaker reconed at far less than the cost of a whole new one. This is especially true in the case of the heavy-duty speakers in high-powered amplifiers. Magnets never wear out, so if you replace the cone and voice-coil assembly, the speaker is as good as new. Usually radio parts houses do this kind of work.

Since speaker cones are basically paper, they deteriorate with age and then crack, especially under high volume. This can cause a crackling or buzzing sound on certain notes. If the crack is caught in time, it can be patched with cement. Don't use the so-called "speaker cement"—this dries out, turns hard, and usually breaks loose at one edge. After a while the speaker buzzes worse than it did before. The best cement the author has found for repairing speaker cones is rubber-to-metal cement. It stays flexible indefinitely and sticks very well. Never use scotch tape for patching cracks—it will dry up, come loose, and buzz horribly. If you must make emergency repairs to a speaker, use surgical adhesive tape; this has very sticky adhesive and is flexible.

### FALSE SPEAKER TROUBLES

Now and then you will find an amplifier that will buzz when certain chords or notes are played on the guitar. This may sound like speaker trouble, and in some cases it is, but not always. The most common cause of this kind of trouble is something loose in the cabinet; this hits a harmonic resonance on certain frequencies, and buzzes.

The fastest way to find the trouble is to feed an

audio signal generator into the amplifier and run the whole range of audio frequencies from 20 Hz up to 20,000 Hz. Somewhere in there you will hear the buzz loudly and clearly. If an audio signal generator isn't available, get out the record player and put on an audio test record with the same range of frequencies; there are several of these available. They do an excellent job in finding this kind of trouble. Loose bolts on the speakers or on the amplifier itself are common causes of buzzes; loose cabinet hardware—latches, clamps, etc.—may cause it, too.

### CURING SPEAKER AND Baffle RATTLING

When you do find a rattle or buzz in a speaker baffle or cabinet, it can be cured without too much trouble. These rattles are due to something that is *loose*—a cracked piece of plywood, a brace, door, mount, or even the speaker frame itself, that isn't tightly mounted. Locate the cause of the rattle then bolt it down very tightly. Tighten all bolts and screws on the speakers themselves. If this is caused by a loose brace, shelf or mounting bracket, take the screws out and see if the whole piece is loose.

If it is, coat both the underside of the bracket and the mounting on the cabinet with a good grade of wood glue, then screw the bracket back down very tightly. If there weren't enough screws in it originally to hold it very firmly, drill small holes and add a few.

If the speaker cabinet is made of plywood that's just a little bit too thin, you may get "cabinet resonances" or funny sounds actually due to the sides of the cabinet acting as "cones" moving in and out with the sound. This shows up most often in the bass-amplifier speaker cabinets, which use tremendous amounts of audio power.

The cure for this is to "beef them up" by gluing pieces of heavy plywood inside the cabinet to make the walls thicker. These cabinets should be made of plywood no thinner than  $\frac{1}{2}$  inch, and  $\frac{3}{4}$  inch is better. In some cases, you can cover the inside with the goop sold for damping metal-resonance in automobile bodies. Butter this on the walls, pretty thickly.