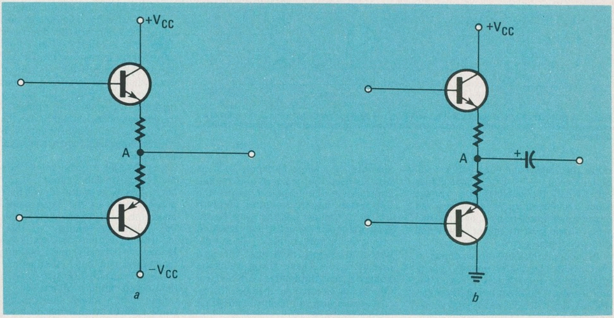

FIG. 1—THE OUTPUT STAGE of most modern audio amplifiers uses the direct-coupled configuration shown in *a*. Earlier amplifiers mostly used the capacitor-coupled configuration shown in *b*.

IMPROVE AUDIO AMP PERFORMANCE

You haven't finished repairing that audio amplifier until you've made these two simple, yet often-overlooked, adjustments. Here is what they are, and how to do them.

KIRK VISTAIN

DOES YOUR HI-FI POWER AMPLIFIER sound as good to you as it did the day you bought it? Components drift with age and when they do, so do the specifications and performance. Or, suppose an output transistor shorted and you just replaced the shorted output, a transistor driver, and a handful of burnt resistors. If you replace the cover without adjusting the bias and symmetry, you've left out one of the most important steps. Sure, maybe thermal runaway won't occur. Maybe there won't be any DC-offset at the speaker terminals. Maybe the crossover notch won't be too bad. But that's too many maybe's. Let's see how two simple adjustments can improve performance.

For reasons of efficiency, the most popular audio-output configuration these days is the Class B, push-pull direct-coupled design shown in Fig. 1-a. A few years ago capacitor coupling (shown in Fig. 1-b) was the norm; that's because it needed only a single-ended power supply and speaker damage, in the event of output failure, was unlikely. After a while though, those amplifiers gained a reputation for poor low-frequency response and instability; that is why direct-coupling is now so popular. But, with that technique, dual-polarity power supplies are needed, as well as complex circuits to protect the speakers in the event that one of the output transistors shorts (dumping the full supply voltage across the speaker's voice coil).

With either design, there are only two basic adjustments to be made, although different manufacturers may use different terminology for one or the other. They are:

1) Quiescent (low, or no-signal) bias through the output transistors.

2) Output symmetry.

A source of bias is provided in Class B audio-amps to reduce crossover distortion to an acceptable level (see Fig. 2). That actually makes them Class AB, since collector current flows for more than 180 degrees of the input waveform.

Output symmetry refers to how equally the positive and negative halves of the input waveform are reproduced. A misadjustment of that usually results in asymmetrical clipping and reduced output power for a given distortion rating. Usually, that adjustment is labeled BALANCE in capacitor-coupled units. In direct-coupled amps, it is called OFFSET and determines the DC potential across the speaker terminals; that potential, of course, is ideally zero. Regardless of what it's called or exactly where in the circuit it is, that control does the same thing, trim circuit values so that the output transistors conduct equally. If that is

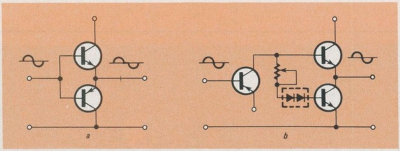

FIG. 2—A SIMPLE CLASS-B AMPLIFIER (shown in *a*) will produce some distortion in the form of a crossover notch. That amplifier is made Class AB (shown in *b*) by using a bias source to reduce distortion.

done, the voltage at point A in Fig. 1 will equal $(+V_{CC} - -V_{CC})/2$. That comes out to half the power-supply voltage when a single-ended power supply and capacitor coupling is used, or zero volts when a dual-polarity power supply and direct coupling is used.

It is important that you remember to check both bias and symmetry in any high-fidelity amp that is serviced for any reason. Those control settings can drift as the unit gets older, and sometimes they're not set right to begin with. Certainly, whenever any output part fails, especially if general-replacement semiconductors are used, bias and symmetry checks are essential.

How it's done

I developed the following method while doing quality assurance for an importer of Japanese high-fidelity equipment. We ended up with a shipment of receivers whose distortion figures did not meet the manufacturer's specifications; not at full power, but at around 250 milliwatts. That is the bottom of the power band for FTC ratings, as well as a common listening level for headphone users. We traced the problem to crossover distortion, noting that the problem was more severe at higher frequencies. Adjusting the quiescent bias solved the problem. That incident showed me the importance of using dynamic methods to "fine tune" the quiescent bias.

The instruments required include a harmonic distortion meter, an AC voltmeter (many harmonic-distortion meters also include that instrument), a triggered scope (preferably dual-trace), a low-distortion sine-wave generator, and an attenuator (a sine-wave generator and attenuator are also often combined in the same instrument). A DMM with 200 mV and 200 mA ranges is also needed. An eight-ohm standard, non-inductive load-resistor completes the list. Be sure that its power-handling capacity is adequate for the amplifier under test. The setup is shown in Fig. 3.

The output of the attenuator is fed to the power-amp's input. If the unit-under-test is a receiver or integrated amplifier, a high-level input, such as AUX, is used. Set the BASS and TREBLE controls for flat response, center the left-to-right BALANCE control, and turn the BIAS trimmer all the way down. Now's a good time to use your DMM to check the current in the V_{CC} line to the output transistors. Sometimes there's a fuse here, so it's easy. If not, watch the voltage across the emitter loads and use Ohm's law to calculate the bias. In any case, make sure you're only reading one channel at a time.

Plug the amp into a variable auto-transformer (such as a Variac), and increase the supply voltage slowly, watching the bias current. It shouldn't be much more than 10 mA with a full 117-volts AC input. If it exceeds that level, make sure that you have the BIAS trimmer set for minimum and that no signal is at the input (or output). If that isn't the problem, look for defective parts. One that many technicians miss is the bias trimmer itself. If it opens up the bias current goes sky-high.

Assuming you made it up to full line voltage with no problems, let the amplifier stabilize. That takes five to ten minutes, depending on the ambient temperature.

There are two types of adjustments you can make—static and dynamic. Static adjustments are made with no input signal to the amp; an input signal must be present for the dynamic adjustments. Turn the amplifier's volume control to maximum. Turn on the sine-wave generator, set the frequency to 20 kHz, and increase the signal level to bring the amp to full power while checking the output waveform for any gross distortion. After you've done that, turn off the sine-wave generator and set the amp's bias trimmer for a current equal to the manufacturer's specification. Then, turn the signal generator back on, but only bring the signal level up high enough to produce a 250-milliwatt output across the eight-ohm load. Readjust the bias, if necessary, to reduce the total harmonic distortion to below the manufacturer's rating. Remove the test signal and check the quiescent bias again. It should be close to that specified in the service manual, and, in any case, no more than 50 mA. Of course, always make sure that the harmonic-distortion meter is not reading spurious noise or ground-loop hum.

The next thing we want to do is to adjust the symmetry. On direct-coupled amps, that is called "offset"; it is best adjusted by measuring the DC voltage across the speaker outputs (those outputs should be properly terminated with a load resistor) and setting the trimmer for minimum voltage. The minimum voltage should be less than 60 millivolts. That adjustment is made with no input signal; there is no dynamic adjustment.

In capacitor-coupled amps, the symmetry adjustment is often called "balance," not to be confused with the front panel control of the same name. To make the static adjustment, simple set the symmetry trimmer so that the input to the output-capacitor is ½ V_{CC}. However, I usually don't bother with that adjustment, but do the dynamic one instead. Using a 1-kHz sine wave, drive the amp to clipping. Monitor the amp's output with a scope, and trim the balance control so that the positive and negative peaks are clipped equally. You can also use a harmonic-distortion meter for that if you reduce output to just the point at which clipping begins. In that case, adjust for minimum distortion.

A word of caution—some earlier amplifiers don't take kindly to being driven into clipping, and may be damaged. I've never had that problem with a unit that was operating properly, but it's good policy not to keep any amp in the clipping region longer than is absolutely necessary.

When you've completed the bias and symmetry adjustments, you should go back and do them again. That is necessary because those adjustments sometimes interact.

No specifications

So far, we've assumed that the specifications needed to make those adjustments are available. As most of you know, that is not always the case. Fortunately there are some rules of thumb that can be used when the exact specifications are not available. First of all, the bias should almost never exceed 50 mA. As a matter of fact, 30 mA is a safer figure for most mid-powered amps. For the dynamic adjustment, simply trim the bias for a minimum crossover notch. Use the scope to find that, and remember to take into account those maximum bias figures we just stated. Don't use the harmonic-distortion-meter/voltmeter here to avoid any distortion caused by the output stages of those instruments.

Symmetry adjustments are straightforward. You don't need any service data for them, assuming, of course, that

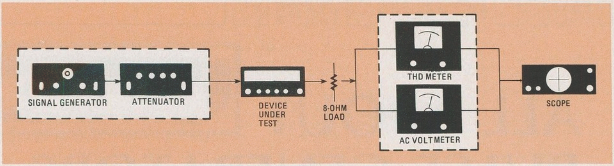

FIG. 3—THE SETUP USED for dynamic bias adjustments. Note that the devices grouped together by the dashed boxes are often found in a single instrument.

you can identify the trimmers. If you can't, remember that the bias trimmer usually has a low resistance, around 500 ohms, while the symmetry trimmer is generally more than 5000 ohms.

When all adjustments have been completed satisfactorily, let the device burn-in for a while to insure that thermal runaway or excessive heat-dissipation does not occur. At idle, the output transistors should get warm, not hot.

A simple technique

The method I have outlined is the best way to make those adjustments. However, the hobbyist or technician who only occasionally repairs audio gear is not likely to own, or have access to, that equipment. If that is your situation, here is an alternate method that requires only a service-grade audio generator and an oscilloscope.

Fortunately for us, the type of distortion produced by the typical service-grade audio generator is not crossover distortion, since most of them don't have Class-B output sections. That means we can obtain a quick, relative measurement of the crossover notch using a scope, and adjust the bias for the minimum distortion that is commensurate with a practical bias level.

The same test frequency and power level—20 kHz at 250 milliwatts across an 8-ohm load—are used, but this time the output of the terminated amplifier is fed directly to the scope. Vertical scope-gain is set to give a trace that excludes the tips of the sine wave. That allows us to concentrate on the zero-crossing point, where crossover distortion occurs. With the quiescent bias set at a minimum, you will see the notch in most cases. As the quiescent bias is increased, the notch will become smaller, or disappear. Just remember the guidelines for maximum bias outlined earlier. Sometimes you won't see a notch—that's great! Crossover distortion is no problem then, and quiescent bias can be set using the static technique.

While the method outlined here cannot give absolute measurements, it is quite effective, it certainly is useful for those not equipped with expensive, high-quality test gear.

The bias and symmetry adjustments that we've covered here are useful and important procedures. It does not take much time to make those adjustments, and, in any case, they should be done to retain high-fidelity performance. **R-E**

What's News

Supreme Court asked to protect videotapers

Sony Corporation of America has petitioned the Supreme Court to review the widely criticized decision of a California court that would make it an offense for videotape-recorder owners to tape TV programs in their own homes. According to the decision of the U.S. Court of Appeals for the Ninth Circuit, that would be a violation of Federal copyright law.

The decision resulted from a suit brought in 1976 by Universal City Studios and Walt Disney Productions. Up to the time of the decision, the right of the home recorder to copy anything off the air was unchallenged, as long as no attempt was made to sell or otherwise commercialize the recordings.

Universal has sued 43 manufacturers, distributors, and advertisers of home videotape equipment—in effect, the whole home-video recording industry.

Since the main object of the buyer of a videocassette recorder is to tape programs off the air, the ruling might ruin the industry. Sony says: "Billions of dollars in sales and thousands of U.S. jobs will be threatened if the decision stands." Furthermore, Sony pointed out in its petition, "Universal and Disney admitted that they had suffered no damage, and they could not show that home recording would reduce the potential market for their productions."

3-degree spacing urged between satellites

RCA American Communications, Inc. (Americom) has come out in favor of a three-degree spacing between communications satellites in stationary orbit. That is in response to widespread discussion of the subject, and specifically, to an FCC request for comment.

Americom also stated that it supports positioning satellites 2 degrees apart eventually.

Reducing the distance between orbiting spacecraft will provide a larger number of "slots" to accommodate the satellites expected in the near future. The present spacing of satellites serving the United States is 4 degrees—approximately 1,800 miles apart. Those are spaced on an arc 22,300 miles above the equator, between 70 and 143 degrees West longitude.

To achieve the long-term objective of 2-degree spacing, RCA Americon recommends:

1. Adoption of uniform standards, to apply to all satellites authorized for future construction;
2. Adoption of uniform standards for earth stations, to permit them to operate in a 2-degree environment.
3. A strong inter-carrier cooperative effort aimed at a phased reduction to 2-degree spacing.

New silicon MESFET's operate at 3 GHz

General Electric scientists report that they have achieved output of 0.6 watts at three gigahetz with silicon-on-sapphire MESFET's (*M*etal *S*emiconductor *F*ield-*E*ffect *T*ransistors).

Efficiency was 50 percent. That is the highest power and efficiency recorded for a silicon device of that type that can be used in a monolithic microwave circuit.

Such microwave circuits are now being developed actively in many laboratories. But most of the work centers around gallium arsenide as the semiconductor material. Gallium arsenide is expensive, and its processing is complex. The GE scientists believe that silicon can perform well up to at least four gigahertz.

MESFET performance is determined—in addition to its intrinsic semiconductor properties—by the device structure. The gate length and width are important factors. The shorter the gate, the higher the frequency with useful gain; the wider the gate, the greater the power handling capability. In the new silicon-on-sapphire MESFET, the gate length is only one micron; the width more than 3200 microns. The gain is 7 dB at 3 GHz. The researchers believe that silicon MESFET's with even wider gates may be practical, offering outputs of several watts while retaining their high efficiency.