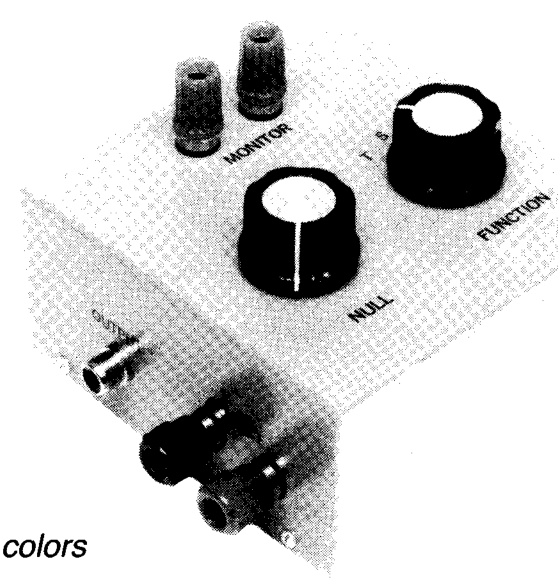
DIFFERENTIAL AUDIO-DISTORTION ANALYZER



This device tells you why an amplifier that passes all conventional tests with flying colors can still sound bad.

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THE GREAT LEGENDARY PLUMBER, Stilson Hammerknock, (yes, *plumber*, as in "Get someone to fix the pipe!") used to tell customers that "If the rate of evaporation exceeds the rate of drip, your pipe isn't leaking." The audio-testing corollary to Stilson's rate-of-evaporation theory is that "If you can't hear any distortion there *is* no distortion, regardless of what the instruments show." On the other hand, it also means that the listener might hear an irritating, annoying distortion, even if the distortion can't be measured by conventional test equipment.

David Hafler, one of the pioneers of high fidelity, developed the first truly low-cost high-performance FM-stereo tuner and the highly respected *Dynaco* amplifiers. Hafler observed that conventional audio-amplifier distortion tests do not indicate all possible distortions because the measurements are made under static conditions: a specified input and output, a resistive load, etc. He believes that amplifiers should also be evaluated by a listening test that compares an amplifier's output signal to the input signal under *dynamic* conditions—meaning, a *program* signal source and a speaker load.

The Hafler test—one that differentially compares an amplifier's input and output signals—was discussed in Larry Klein's "Audio Update" column in the September 1988 issue of **Radio-Electronics**. This month, we'll show you how to build a switching device so you can make your own Hafler-type distortion tests.

There are many reasons why there is a continuing debate over amplifier-distortion tests: what test parameters to use, what the parameters represent, and what the results actually mean. A goodly number of test and measurement specialists claim, and have proven, that by using the same set of parameters they can come up with valid tests that prove an amplifier is either good or bad. How the amplifier actually *sounds* is something else; it might have no relationship to the test results.

Amplifiers behave differently to a dynamic signal and load than they do to a resistive load and a fixed or pulsed input signal. Actually, it's the resistive load that's the major problem because it does not truly represent the loudspeaker; that is the reason why Amplifier A might sound terrific with Speaker X yet sound rotten with Speaker Z, while Speaker X sounds so-so with Amplifier B, and an absolute disaster with Amplifier C.

The reason for disparities in performance when an amplifier drives a speaker is due to the fact that a speaker's impedance is not resistive; it is a reactance that varies with the signal frequency. It would be very nice if we could assume that amplifiers are not sensitive to the load, a condition that some manufacturers imply when they claim their amplifier has a "zero-output impedance." But the truth is that amplifiers are load-sensitive, and speaker systems are somewhat sensitive to the output impedance of the driving amplifier. Again, that is why amplifier A sounds good with Speaker X, but Speaker X sounds rotten with Amplifier C.

Another problem is the kind of distortion being measured, which is why many audiophiles and sound purists still argue that even when the amplifier is deliberately driven into distortion, tubed amplifiers always sound better than solid-state amplifiers. In other words, a tubed-amplifier's distortion is less displeasing to listen to than the distortion from a solid-state amplifier. Let's look at why that might be so.

Assume that we have tubed Amplifier A, which—under the exact same signal, power, and operating conditions as solid-state Amplifier X—is producing 3% THD (*T*otal *H*armonic *D*istortion). Solid-state amplifier X is producing under 0.5% THD. Yet, without knowing the measured distortion, listeners claim that tubed Amplifier A sounds cleaner. How come?

Harmonically related

The reason why the higher-distortion tubed amplifier sounds better is that it has even-order distortion: second, fourth, etc. Tubed amplifiers, even when driven well into distortion, produce primarily even harmonics, which are musically (harmonically) related. For example, the second harmonic of 440 Hz (the musical note A_4) is 880 Hz; still A (A_5), but an octave higher. The fourth harmonic is 1760 Hz, again A (A_6), but two octaves higher. Because the distortion is primarily even-order, even the intermodulation products are harmonically related. If the user can't hear the input-signal source, the output signal—even though distorted—can sound good, acceptable, or, at worst, still pleasing to the ear.

On the other hand, a solid-state amplifier's distortion products are odd-order: third, fifth, etc. Now the third harmonic of 440 Hz is 1320 Hz, which falls somewhere between the notes E (E_6) and F (F_6). The fifth harmonic of 440 Hz is 2200 Hz, which falls between C (C_7) and D (D_7). As you can see, the distortion products are not harmonically related. For the same reason, the intermodulation products are all over the musical scale. Because harmonic relationship is absent, it's possible for a solid-state amplifier having measurably low distortion to have an edgy, annoying sound.

Not heard at all

It is to avoid discussions about which distortion is caused by what, and what it all means, that Hafler takes the position that no distortion of any kind is tolerable under dynamic conditions, and that the best way to determine whether distortion of any kind exists—even distortions not yet quantified because there's no way to measure them—is to listen *to the distortion itself* by differential comparison of an amplifier's input and output signals. That can be done by connecting a monitor speaker across the input and output. Because the output signal is in phase with the input signal, nothing will be heard from the monitor speaker if the amplifier is free of distortion.

However, if the amplifier introduces any kind of distortion—amplitude, frequency, phase, ringing, whatever—there will be no cancellation of the output distortion because there is no corresponding input signal. And *something*—some kind of sound—will be heard in the monitor speaker. As yet, there is no way to quantify what's heard, so the rule of thumb is: "The less you hear, the less the distortion."

Obviously, one cannot connect a monitor speaker from a voltage-sensitive amplifier input to the amplifier's power output; but, as shown in September's "Audio Update," Hafler gets around the problem by using a power amplifier as the signal source. That way, the monitor speaker can be differentially connected from the speaker output of the signal-source amplifier to the speaker output of the amplifier being tested.

Because a stereo amplifier has two independent channels, the signal source can be one channel, while the amplifier being tested can be the second channel. The only restrictions on the Hafler-type test setup are that both amplifiers must have a grounded output terminal, and the amplifier being tested must not invert the phase of the signal from the input to the output.

Because a power amplifier might have a relatively high distortion, it is logical to question how it can function as a signal source for distortion tests. The fact is that the amount of distortion in the signal source makes no difference; the signal source can be 100% distortion because the Hafler test is concerned only with distortion that is *added* to the signal source. Regardless of the input signal's distortion, if the output of the amplifier being tested is an exact reproduction of the input signal then nothing will be heard from the monitor speaker.

PARTS LIST

R1–R4—10,000 ohms, ½ watt, 10%
R5—220 ohms, ½ watt, 10%
R6—1000-ohm potentiometer
J1–J8—5-way binding post
J9—phono jack
S1—4P3T rotary switch, see text
Misc:—cabinet, wire, hardware.

A Hafler tester

A device for making the Hafler distortion test is shown in Fig. 1 and Fig. 2. It is an experimenter's version—in that it uses readily available parts—of the commercial *Excelinear* unit developed by the David Hafler Co.

Almost anything can be used as a cabinet. The circuit can even be assembled on a piece of wood. Jacks J1–J8 can be anything that will hold a wire, but the 5-way binding posts shown on the prototype are suggested. If each pair of jacks is spaced on ¾-inch mounting centers, you will be able to easily connect wires and cables that are terminated with conventional dual banana-plugs.

Function-switch S1 is a 3P3T (triple-pole, triple-throw) switch, which is somewhat unusual and is not likely to be found in local stores. The switch used in the prototype was a conventional 4P3T type, with one pole left unused. Be very careful when making connections to the switch. Although it looks easy enough from Fig. 1, the contact-jumpers can be confusing, and you might end up with the connections reversed on two of the three sections.

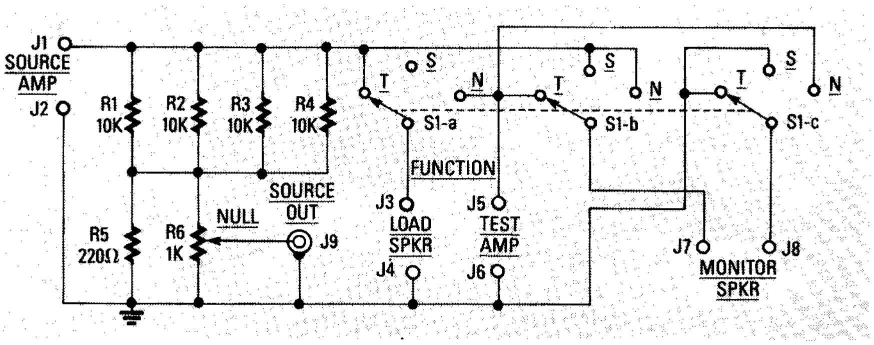

FIG. 1—THE CIRCUIT LOOKS SIMPLE ENOUGH, but take extreme care when wiring S1 because it's easy to get the wiring reversed on two of the three sections.

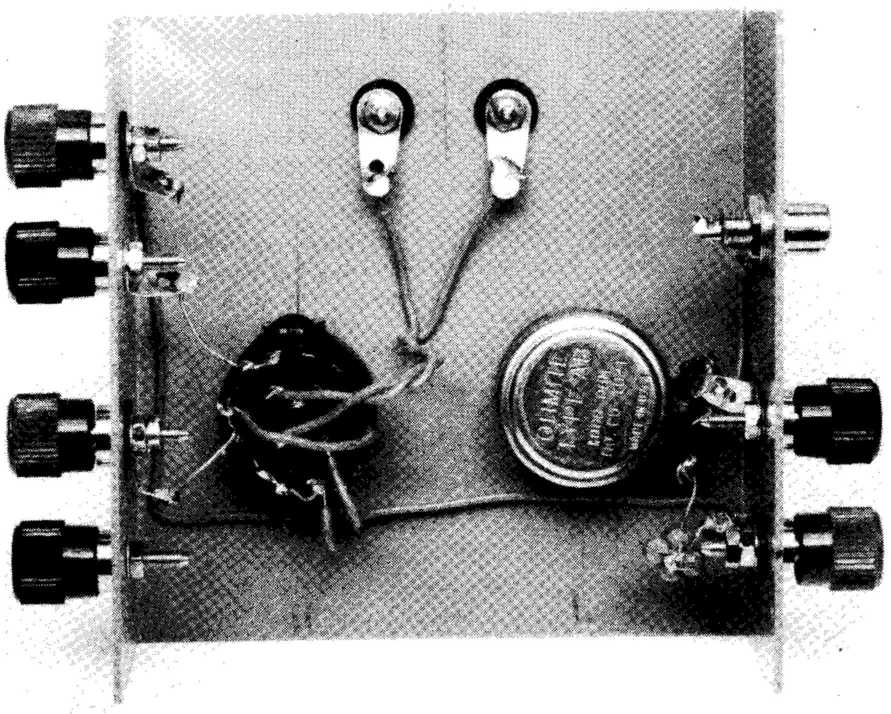

FIG. 2—THE PROTOTYPE TESTER is built in a small metal enclosure. To prevent shorting of uninsulated wires, position the parts so the wiring is as direct as possible between the jacks, the switch, and the null control.

Resistors R1–R4 equal a 2500-ohm, 2-watt resistor. A 2200-ohm, 2-watt resistor is used in the commercial version of the tester. Unfortunately, 2-watt resistors aren't the easiest parts to come by. Because there is no practical difference between 2200 and 2500 ohms, by using four parallel-connected ½-watt resistors, we attain the necessary 2-watt rating with easy-to-get parts.

Theoretically, R5 could be eliminated if R6 was a 200- or a 250-ohm potentiometer, but your chances of finding a 200/250-ohm carbon potentiometer are almost non-existent. The R5/R6 arrangement shown in Fig. 1 allows the use of a 1000-ohm potentiometer—a value that's often available locally.

Hook-up

Jacks J1 and J2 are connected to the output terminals of the signal-source amplifier. Jack J3, the *source output*, connects to the auxiliary (AUX) input of the amplifier being tested. The output of the amplifier being tested connects to jacks J5 and J6. The monitor speaker—which should be of high quality, such as one of your hi-fidelity stereo speakers—connects to jacks J7 and J8.

The load speaker, which connects to jacks J3 and J4, should be the speaker that is usually driven by the amplifier being tested. As stated earlier, an amplifier's characteristics can be determined by its load, so you want your amplifier to be working into its usual speaker. But there is a problem in that: You will not be able to hear the weak differential sounds in the monitor speaker if the load speaker is pounding away. So locate the load speaker a long way from the test site—preferably in a closet.

Making the test

Just so you understand what's going on, refer to Fig. 1 as we walk through the functions of switch S1. We will refer to the amplifier being tested as the *test* amplifier.

When S1 is set to the T (TEST) position the source amplifier is connected to the load speaker through S1-a, while the monitor speaker is connected to the test amplifier through S1-b and S1-c. When S1 is set to the S (SOURCE) position, the load speaker is disconnected, and the monitor speaker is connected to the source amplifier so that you can hear the test signal. When S1 is set to the N (NULL) position, the load speaker is switched in as the load for the amplifier being tested, and the monitor speaker is connected differentially to the outputs of both the source and the test amplifiers.

After all connections are made, set null-control R6 to *off* (full counterclockwise), set S1 to the S position (monitor speaker to the source amplifier), connect J3 to the test amplifier's AUX input, and set the test amplifier's volume control almost full open. Using any signal source—disc, tape, radio, even interstation noise—advance the volume of the source amplifier until the sound in the monitor speaker is the maximum volume you usually use.

Then set S1 to the N position (monitor speaker differentially connected to both amplifiers) and advance R6. The sound in the monitor speaker will increase and then start to decrease (null). Very carefully, adjust R6 around the null for the *minimum* sound from the monitor speaker. Anything heard in the speaker will be distortion of some kind: amplitude, frequency, or "only heaven knows." A really good amplifier should produce a bare pipsqueak of sound, usually caused by slight variations in the amplifier's frequency response.

The nulling should also result in equalized gain in the test amplifier. In other words, the sound level of the test amplifier should be the same as that of the source—a perfect condition for an A-B listening test.

Taking care not to disturb R6, rock switch S1 between the T and S positions, which will switch the monitor speaker between amplifiers. (It will also switch the load speaker between amplifiers to keep both of them loaded at all times.) If the test amplifier truly has low distortion, there should be no discernible difference in sound quality as you switch the monitor speaker between the source and test amplifiers.

You may find that the device has uses that you hadn't thought of. Now you can quickly settle an argument with your friend as to whose stereo has less distortion or better sound reproduction. One thing though—if you have an amplifier that you've held in high regard for many years because of its excellent sound quality and precision craftsmanship, then it's probably not such a good idea for you to perform the Hafler distortion test. You may come to an upsetting conclusion that your unit doesn't sound as good as you thought. **R-E**