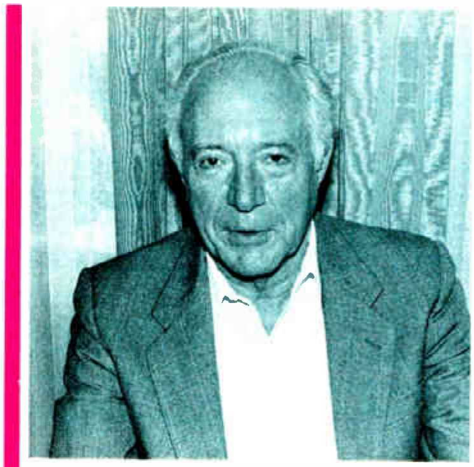

THE DESIGNER SERIES

David Hafler introduces a listening test for amplifier distortion

INTERVIEW

THROUGHOUT THE HISTORY OF sound reproduction there has always been uncertainty as to what degree of distortion and what types of distortion were audible. At one time it was thought that 5% total harmonic distortion was the threshold of audibility. Later, 2% was considered to be the goal to be reached to make distortion inaudible.

Now, high quality amplifiers routinely specify distortion of less than 0.1% over the 20Hz to 20kHz band. Despite this low distortion, many critical listeners claim to hear differences in performance which, if correctly identified, show that conventional distortion measurements are inadequate for indicating whether an amplifier's distortion is audible. This has led researchers to seek other forms of distortion than THD and IM, and some emphasis has been placed on transient distortions. However, this has still not given us the possibility of making a measurement and assigning a numerical value above which distortion may be audible, and below which it is inaudible.

What is clearly needed is a method of determining whether distortion is audible in a given piece of equipment. This determination should be made using music as a source, and not limiting the investigation to steady state signals such as sine waves or square waves.

If one could compare the reproduced sound with the *original*, one could judge for oneself whether the degree of distortion is detectable. This, however, is a test of the entire audio chain, including microphones and loudspeakers. One could not separately determine whether the amplifier had audible distortion or not. To listen for an amplifier's distortion, one must have a reference for comparison. The most accurate and convenient reference is the traditional straight wire. A straight wire has infinitesimal distortion and must by its nature be more accurate than any active device such as an amplifier. It immediately opens up the possibility of A-B comparison between it and the amplifier being tested. This can be done by putting two amplifiers in series, with the gain of the second one reduced to unity (to match the gain of the straight wire); then the test amplifier can be bypassed by switching the straight wire across it.

Fig. 1 (overleaf) illustrates the simple setup for making this A-B test. One half of a stereo amplifier can be used as the driving source for either the other half or for the straight wire. Two subtle points must be observed in this experiment. First, there should be a loudspeaker load on the driving amplifier in the 'A' position. If that speaker load is not used, the test is less stringent as the effect of the speaker on amplifier performance is not taken into consideration. As we shall see later, a change in loudspeaker load can change the performance of an amplifier. Fig. 1 shows the driving amplifier with its own speaker load in the 'A' position and with the test amplifier's load in the 'B' position. Naturally both loudspeakers should be identical. A second requirement in this test is that the speaker load for the driving amplifier must be isolated by putting it in a separate room. Otherwise, sound from that speaker will mask the sound of the amplifier *vs.* wire comparison.

A-B testing is a valid and scientific method of comparison. However, it requires judgement, and it has been criticized as being confusing, fatiguing and artificial. There is no question that what one person hears on an A-B test is not necessarily what another hears. There is considerable dissension as to the merits of A-B testing. Since it is not universally accepted, there is, fortunately, a more sensitive listening test for distortion.

The preferred way to listen for distortion is what I call the straight wire differential test (SWDT). This arrangement is illustrated in fig. 2. Here again, one half of the stereo amplifier can be used to provide a low impedance driving source. The gain of the second half is set to unity to match the straight wire. In practically all power amplifiers, the input and output are in the same phase, so a transducer such as a loudspeaker can be connected from input to output in a differential mode. It is obvious that if input and output are identical, there will be no signal in the loudspeaker. Any sound audible after careful adjustment of the level will be distortion.

What is done here is to remove the original signal by subtracting the output from the input; this unmasks the distortion generated in the second (test) amplifier. This remainder includes non-linearities such as THD and IM. It includes all types of transient distortions, and it includes amplitude and phase aberrations. It includes not only all known distor-

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DAVID HAFLER

The American designer David Hafler, a recipient of *HFN/RR*'s Lifetime Achievement Award in December 1984, is regarded by many as the Henry Ford of hi-fi. His work at Dynaco in the 1950s and 1960s made superlative-sounding products available at realistic prices, and he championed the concept of kit-building – augmented by the most lucid instructions imaginable – to further reduce prices. This attitude has been caried over to the products now available under the Hafler name, and he continues to offer high-value-for-money products in the face of escalating price thresholds. British consumers, in particular, have perpetuated his name by labelling his ambience-retrieval configuration the 'Hafler circuit'. We met with him in London to discuss his new 'Straight Wire Differential Test' method and 'Excelinear' amplifier fine-tuning circuit; he saved our interviewer's batteries by presenting us with this article, which explains the process. In addition to this, he even provided us with sheets discussing the questions most likely to be asked about Excelinear, to which we have added a few questions of our own.

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tions, but also any which may be identified in the future. What it does not do is separate the types, so no weighting can be given to more obnoxious forms of distortion.

When this test is performed on most amplifiers, one can hear grunge, harshness, edginess, grain, and other irritating sounds. One can also hear some relatively clean sound which comes mainly from amplitude and phase errors. These are inaccuracies, but not necessarily of an annoying type. However, the best designs should minimize them as well as the irritating factors.

The SWDT is elegantly simple, requiring no instruments. Its merits are obvious, but it is extremely difficult to apply because of its great sensitivity. A few minutes of phase shift, or some millibels of amplitude variation will show up as significant sound. This test shows most amplifiers to be audibly inaccurate. When a similar approach to amplifier testing was discussed in the past*, the experimenters found relatively high levels of sound due to phase and amplitude variations. They did not consider these to be important, and they compensated the straight wire to minimize such variations. They made the assumption that phase variations were inaudible. This is disputable and controversial. We prefer to correct the amplifier to eliminate these aberrations rather than to eliminate them from the signal source.

The SWDT gives the amplifier designer a tool for improving the sonic performance of his designs. He can test and adjust the amplifier to excel on this test. The first amplifier to be designed with the aid of this technique was the Hafler XL-280. The approach was very conservative, while still innovative, aiming at a wideband, low distortion design before the application of overall negative feedback and before trying to 'tweak' the final elements for minimum phase shift simultaneous with minimum distortion and adequate stability margin. Components were selected, bias currents were tested, phase compensation was added – all to get minimum sound output with the SWDT. The amplifier is symmetrical throughout, from a pair of J-FETs in the input to power MOSFETs in the output. The low level class A stages use a separate power supply to isolate them more effectively from the Class AB output devices.

The XL-280 uses a *moderate* amount of negative feedback in an overall loop, plus local feedback such as in the source follower output stage. There are some who unjustly accuse negative feedback of being detrimental. However it is safe to say that NFB *properly* applied is always beneficial. However, proper application involves applying it to a very linear amplifier and assuring an adequate stability margin. Used in that way, NFB will reduce distortion, widen bandpass, and most important, it will stabilize operating characteristics so that performance will not drift in use; and production units will have negligible variation from one to another.

Phase compensation is used in the XL-280 to achieve minimum phase shift in the audio band in order to get maximum sensitivity from the SWDT. Achieving the goal of very low phase shift at high frequencies precludes the use of the customary output coil found in most amplifiers. To carry the control of phase to the ultimate, a phase 'tweaker' is positioned so that it is accessible from outside the amplifier.

In testing the amplifier under many conditions, it was observed that the optimum

*Testing Amplifiers With A Bridge, Andrew R Collins, Audio, March 1972.

FIG 1 A-B TESTING, AMP VERSUS STRAIGHT WIRE

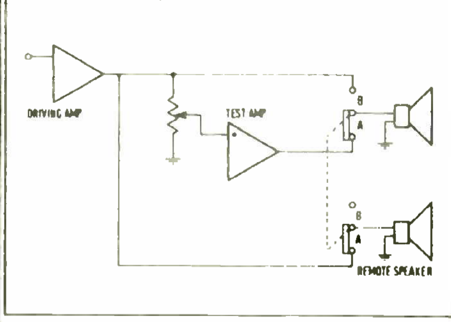
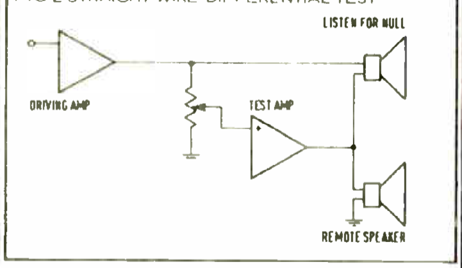


FIG 2 STRAIGHT WIRE DIFFERENTIAL TEST



point of operation, as determined by the SDWT, shifted with a change of loudspeaker. This was due to variations in loudspeaker impedance and the fact that the amplifier internal impedance increased at high frequencies. A change in loudspeaker impedance made a small change in amplitude response. These small variations may be the cause of some of the sonic differences which are heard by 'golden ear' testers. Fortunately, these small deviations can be readily compensated with the phase shift adjustment built into the amplifier. The result is that by using the SWDT, it is practical to compensate the individual system for the specific type of loudspeaker in use.

For most listeners, the minute difference due to the final 'tweaking' is unimportant; and a check with the A-B test confirms this. Most people can be satisfied with an adjustment based on any conventional speaker load, rather than the specific speaker they are using. However, for the perfectionists and the most critical 'golden ears', the XL-280 amplifier can be adjusted to its ultimate capability with specific loudspeakers using the Straight Wire Differential Test as the measuring tool.

When applying the SWDT test with the XL-280, we have found that when playing music above normal listening levels, or when seated at less than the usual distance from the loudspeakers, there may be slight whispers of residual sound which are clearly identifiable as phase and amplitude distortions. These are sufficiently minor to be completely masked by normal musical content, and this can be verified with the A-B test procedure which confirms the SWDT results. After trimming for the individual speakers being used, test results show up to 70dB of nulling in the midband, and about 60dB over most of the rest of the audio spectrum. This means that the *total* distortions do not exceed 0.1% over the audio band and are essentially inaudible.

When the SWDT gives a substantial null on musical material at normal listening levels, the sound of the amplifier cannot be improved in accuracy. Any other amplifier which does not produce as deep a null on the SWDT, or which sounds different from one which does, is less accurate, regardless of whether its sound is pleasing or euphonious. Once this level of amplifier performance is reached, further improvements in sonic quality must be obtained from other elements of the hi-fi chain that the power amplifier, although of course, designers will still face the continuing challenges of reliability, efficiency and economy in amplifier designs.

HAFLER Q&A

Q: How do you account for amplifiers with near-perfect specification but inferior sonic performance?

A: I think that accuracy must be the goal that is sought; this must be the ultimate. If these amplifiers sound dreadful, then they're not being measured by all possible techniques. This method includes all distortions that are possible. Any difference between input and output of an amplifier represents a distortion. It has something which is not being measured by conventional measurements, but still shows up as being inaccurate on this test. Inaccuracy doesn't mean necessarily that it's objectionable sound. You could put your sound through a filter and maybe improve it, but you wouldn't want to sell such a filter as a power amplifier.

Q: What about distortion in the driving amplifier?

A: It does not affect the procedure. It merely delivers a distorted signal to the test amp; and if the test amp is accurate, it will pass this distorted signal without further distortion. The test is not affected.

Q: If this technique is so good, how come nobody thought of it before?

A: It is not a new idea. However, amplifiers in the past looked very bad on this test which shows up all the flaws. The XL-280 may be the first amplifier to offer a good null with the SWDT.

Q: Why does a change of loudspeaker load make a change in amplifier performance?

A: The output impedance of an amplifier tends to rise with higher frequencies. Therefore, at higher frequencies, a change in load will produce a small change in amplitude, and this change will not be constant with frequency. The changes in amplitude are associated with changes in phase. In the XL-280 we provide for compensation of these phase and amplitude shifts so that their effects are below audibility.

Q: But if your amplifier shows up best on this test, it must sound best against any competing units. Is that so?

A: The amplifier which produces a null in the SWDT cannot be improved in sound quality. Any amplifier which sounds different from it, must be *wrong*. This applies regardless of price. We expect that the amplifiers which will show up worst on this test will be the tube amplifiers with output transformers. Thus, another myth will go down the drain.

Q: Is there anything you feel that this test doesn't reveal, anything that sneaks by?

A: Prejudice, perhaps. A $600 amp can never be considered as good as a $6000 unit regardless of how they sound.

Q: Basically, you're calling everyone's bluff here, putting every subjectivist on the spot.

A: I'm giving them a chance to substantiate their viewpoints. We're taking into account distortions which can't even be measured.

Q: But what will you say to the subjectivists who prefer amplifiers which do not do as well as the Hafler on the Excelinear test?

A: I'd have to say 'You prefer inaccuracy'. We are not going to sell inaccuracy; we're going to sell accuracy. The Excelinear technique strips away the music and leaves the residue. If you like that residue, that's your privilege. I think that everyone will agree that power amps are supposed to deliver the signal with the minimum of distortion; it's hard to justify anything else.