DAMPING, DAMPING FACTOR,

by Floyd E. Toole*

The first, and perhaps the most important, observation to be made regarding damping factor in amplifiers is that it has really rather little to do with the damping of anything. Having made that pugnacious remark let me now back off to 'square one' and try to explain why.

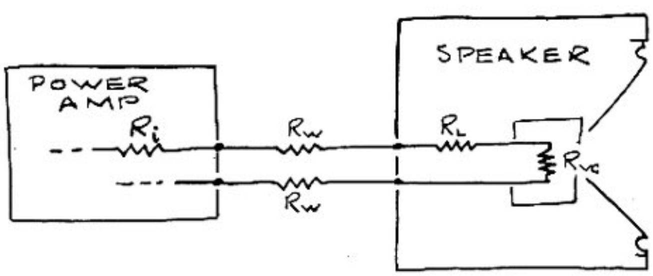
The damping factor (DF) which appears in the spec sheets of hi-fi amplifiers is an expression of the ratio of the nominal amplifier load to the internal impedance of the amplifier (in reality this impedance is complex but normally it is blindly assumed to be resistive). For example, taking a nominal load of 8 ohms, an amplifier with an internal impedance of 0.08 ohms would be said to have a damping factor of 100. In practice one finds DF's in the range 10 to 1000, implying a wide range of amplifier internal impedances. Damping is a 'good thing' in hi-fi, implying, as it does, tight, controlled bass, incisive, taut middles, and crystal-clear high-frequency transients. What sane-minded person would not be attracted to amplifiers claiming higher damping factors?

Damping in any electrical, mechanical, or acoustical system refers to purely *resistive* elements. The damping element dictates how much 'hangover' occurs after a transient event. In a car, the shock absorbers damp the mechanical system and prevent uncontrolled bouncing after every pothole. In a speaker the diaphragm motion is damped in three ways: mechanically, by the friction in the cone material and suspension; acoustically, by the air load resistance; and electromagnetically by the voice coil moving in the magnetic field circulating a current through the amplifier output. The first two are dictated by the speaker type and design. The third, since it involves the amplifier, is the one over which we like to think we have some control.

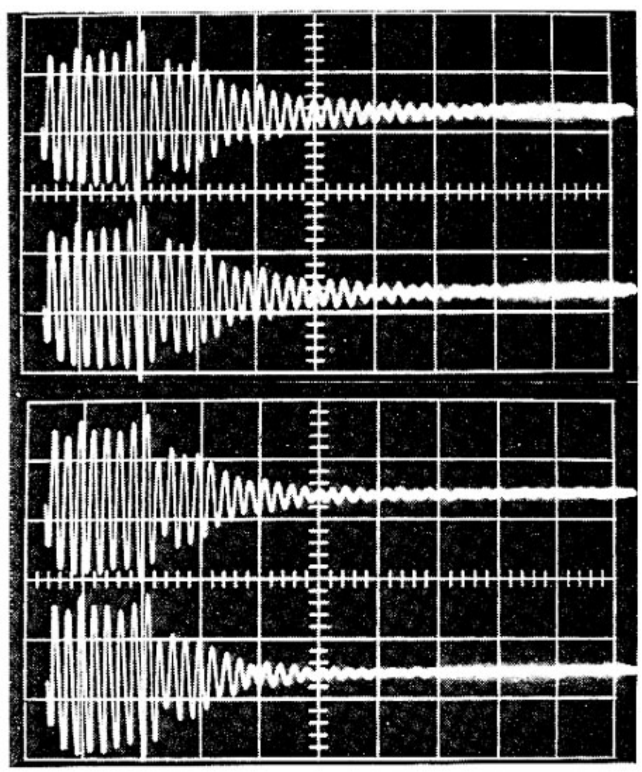
To see for yourself that there is something to this business, you can do a simple experiment. A speaker — preferably a woofer — that is electrically disconnected should, by this definition, have no electromagnetic damping. Gentle pressure on the diaphragm will move it easily back and forth. Now, with a piece of wire or metal bar, short circuit the terminals of the speaker and try again. This time the diaphragm will offer a kind of 'viscous' resistance to motion. An amplifier with low internal resistance (high damping factor) is a reasonable equivalent to this electrical short circuit. A higher internal resistance (lower damping factor) reduces the amount of damping due to this mechanism. The key question is 'by how much and does it matter?'

Figure 1 shows a simple amplifier-speaker hook-up. The internal resistance (Ri) of an amplifier ranges typically from about 0.04 ohm to 0.4 ohm (DF = 200 to 20). A few really exotic machines claim DF's of 1000 (Ri = 0.008 ohm). If this were the only resistance in the system, one could perhaps work up some enthusiasm for high DF's. The speaker, however, must be connected to the amplifier by wire. The resistance of the wire (2 Rw) will not likely be less than 0.1 ohm; so that, by the time we get to the speaker, our expensive DF of 1000 has dwindled to 8/.108 = 74.

The first requirement of a crossover network is an inductor in series with the woofer. The resistance of an indicator (RL) may be about 0.5



Above: Figure 1 — A simple resistance diagram of a power amplifier and woofer (ignoring mechanical and acoustical elements).



Right: Figure 2 — 8-cycle toneburst response of Speaker A at 85 Hz, with *amplifier* damping factors of (top to bottom) 0.5, 1.0, 4.0, and 200.

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ohm. The system DF as we approach the woofer is now 8/.608 = 13.2. Including the speaker itself, we must add the resistance of the wire in the voice coil (Rvc). This may be 5 ohms or more in an 8 ohm speaker. The damping resistance is now no less than 5.608 ohms, and the 'system' DF cannot be greater than *1.4*! Obviously, increasing amplifier DF beyond about 20 cannot significantly alter the electromagnetic damping of a conventional speaker.

So far, we have ignored the damping due to all other factors. Mechanical and acoustic equivalent resistances would normally be added in series with those in Figure 1 so that the significance of amplifier internal impedance is even further reduced. In some speaker designs, acoustic damping predominates.

Figure 2 shows the effect of DF on the transient behaviour of a speaker that uses tuned pipes to enhance low-frequency output. While ridiculously low DF's aggravate the ringing slightly, even the highest DF has little effect in controlling the energetic bass ringing of this system.

Figure 3 shows what happens with a straightforward acoustic-suspension speaker that is well-behaved at its low end. Clearly the amplifier DF is not the major factor in the excellent transient response of this system.

At middle and high frequencies, one finds much the same thing. Figure 4 shows the amplifier unsuccessfully attempting to control ringing at 12 kHz. In contrast, at a frequency away from that resonance, tone-bursts were as uniformly good as those of Figure 3. The explanation is fairly straightforward in these cases. The amplifier and speaker motor system may have the voice coil under near perfect control; but an acoustical or mechanical resonance may be excited by the transient signal and, because of a 'loose' coupling to the voice coil, these elements may continue to radiate sound after the voice coil has been brought to rest.

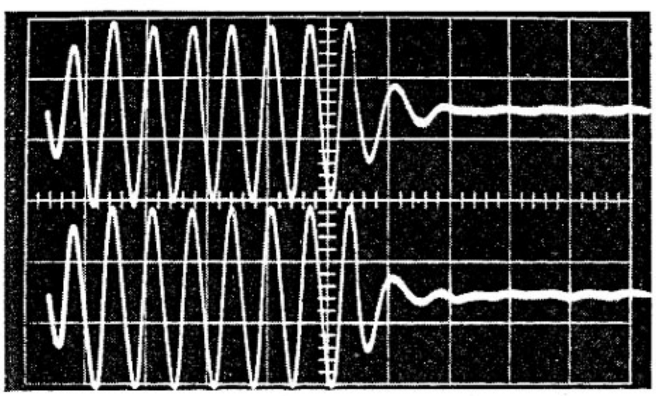
Another way of saying all this is that tight, incisive, well-damped sound is the result of good speaker design not a high amplifier damping factor.

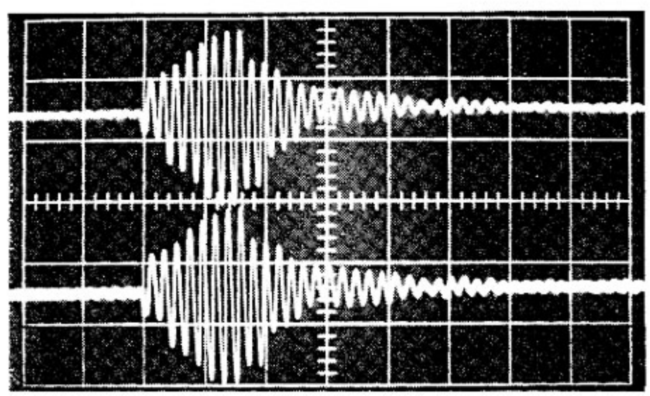
In terms of amplitude response, one finds typically that series resistances up to 2 ohms (DF down to about 4) do not alter speaker output more than about 1 dB, see Figure 4. Here the additional series resistance is preventing the amplifier from behaving as a proper constant-voltage source. The lower the speaker impedance the greater will be the effect.

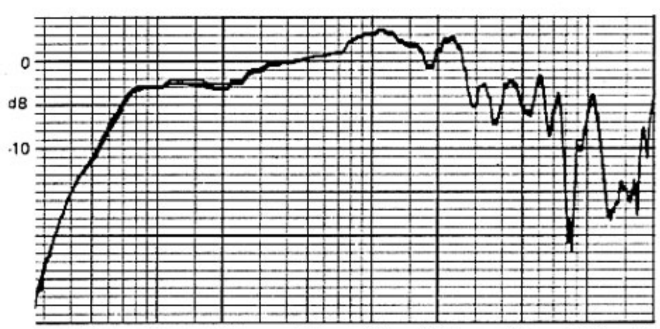
At this point, one may well wonder, what is the value, if any, of a high damping factor? Hopefully it has not *all* been wasted effort on the part of amplifier designers.

I think it is fair to say that, for most amplifier designs, damping factor is an almost incidental factor. The feedback necessary to achieve low distortion often leads directly to a low internal impedance, which in turn results in a high damping factor. So far as the damping of speaker transients is concerned, a DF of 20 or more will ensure that everything possible has been done — the rest is up to the loudspeaker.

Choosing an amplifier on the basis of damping factor would be like choosing a high-performance car because it is red rather than black. It may result in the right choice, but for the wrong reason. It happens that many sports cars are red and many limousines black. ■







Above left: Figure 3 — 8-cycle toneburst response of Speaker B at 85 Hz, with *amplifier* damping factors of 0.5 (top) and 200 (bottom).

Above right: Figure 4 — 8-cycle toneburst response of Speaker A at 12 kHz, with *amplifier* damping factors of 200 (top) and 0.5 (bottom).

Left: Figure 5 — Frequency response of Speaker B with *amplifier* damping factors of 200, 1.0, and 4.0 (superimposed).