The Damping Factor Debate

What do the numbers really mean and do very high amplifier damping factors have any noticeable effect on performance?

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SOME amplifier manufacturers have introduced circuits that have much higher damping factors than conventional units. A high-quality "traditional" vacuum-tube amplifier can be expected to have a damping factor ranging from 10 to 20, but some of the newer transistorized units boast of damping factors greater than 100. Moreover, advertising and promotional literature for these models explains that the damping factor is a sort of figure of merit indicating the degree of control which the amplifier has over the loudspeaker. The higher the damping factor, the more accurately the speaker is controlled and the better the performance. Is this right?

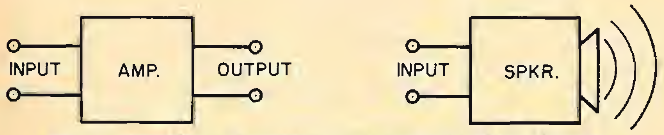
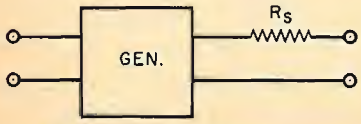


Fig. 1. Amplifier and speaker represented as "black boxes".



INTERNAL IMPEDANCE VS DAMPING FACTOR FOR 8Ω OUTPUT

R_S	DF
8Ω	1
1	8
0.1	80

Fig. 2. The amplifier acts like a generator with resistance.

R_{VC}	RATED IMP.
3.2Ω	4Ω
6.4	8
12.8	16

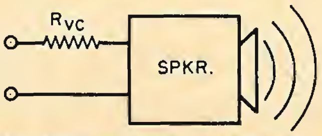
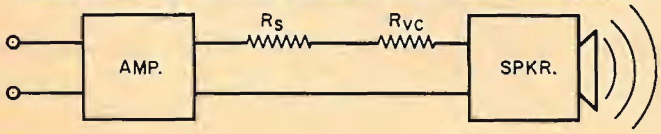


Fig. 3. Speaker resistance is about 80% of rated impedance.

Fig. 4. R_s and R_{vc} are in series between the amplifier and speaker.



The subject is really pretty simple, but not quite *that* simple. To get started on the right track, let's go back and look at a few of the more basic things about audio power amplifiers.

We can represent an amplifier as a black box with a set of input terminals on one side and a set of output terminals on the other, as in Fig. 1. And we have indicated a loudspeaker in the same way, except that instead of output terminals there are some sound waves emanating from the far side of this particular box.

The Loudspeaker Load

The next step is to connect the speaker to the output terminals of the amplifier. As far as the speaker is concerned, when it "looks back" at the amplifier, it "sees" a generator of audio signals which acts as though it has a certain effective internal impedance. This can be represented as a resistor connected in series with the output terminals. Don't be misled by the fact that the resistor is imaginary—the behavior of the amplifier is exactly the same as if there were a resistor in plain sight on the back of the chassis. (Of course, generator impedance includes reactive characteristics too, but for our purpose here, a simple resistor will do nicely.)

By taking the internal impedance of the amplifier (R_S) and bringing it outside the black box, we arrive at Fig. 2. R_S may be relatively large or it may be small. It may even be non-existent (zero internal impedance is not too hard to achieve in practice).

We assume that the black box itself produces a constant output voltage regardless of load. Nevertheless, a certain load impedance is required for a certain output power at minimum distortion. This is the impedance that the amplifier must "see" when it "looks" at the speaker load and is the *rated load impedance* usually indicated at the amplifier output terminals. We will assume that the rated load impedance is 8 ohms in this case, no matter what the value of R_s.

If we were going to use the amplifier to drive a constant-resistance load, it wouldn't matter whether the internal impedance was one ohm or 10 ohms or 10,000 ohms. But because the amplifier is used to drive a loudspeaker, the value of its internal impedance becomes a most important factor.

For one thing, a loudspeaker does not present a constant load to the amplifier. An 8-ohm loudspeaker may measure 6 ohms at some frequencies and 60 ohms at others. If the amplifier has a high internal impedance, the voltage at the loudspeaker terminals will go up as impedance goes up and go down as impedance goes down.

Secondly, a loudspeaker cone has inertia. It has to be stopped and started and moved back and forth in very complicated patterns. If the internal impedance of the amplifier is too high, the speaker will move the way it wants to move instead of the way that the amplifier tells it to move.

The Damping Factor

Rather than specify the value of R_s, it has become common to translate this into a figure which is called the *damping factor* (DF) of the amplifier. As we have seen, it really has more to do with coupling than damping. One definition of damping factor is the ratio of rated load impedance to the amplifier's own internal impedance.

For our 8-ohm black-box amplifier, an internal impedance of 8 ohms gives a damping factor of one. An internal impedance of one ohm gives a damping factor of 8. And if R_s is only 1/10 ohm, the damping factor is 80. These factors are shown in Fig. 2.

This being the case, common sense leads us to believe what the proponents of high damping factors say in their sales literature, namely, that the damping factor is a numerical indication of coupling between amplifier and loudspeaker and the higher the figure, the better off we are.

Unfortunately, we cannot always rely entirely on common sense. For one thing, a particular loudspeaker may not require a high damping factor to accurately follow the signal from the amplifier. Some loudspeaker systems give smoothest performance if the amplifier has a damping factor somewhere between one and three.

But there is another property of dynamic loudspeakers, *all* dynamic loudspeakers, that has to be appreciated to really understand how the damping factor works. It is this other half of the *actual* damping factor which so many people seem to ignore.

A dynamic loudspeaker has a voice coil, and the voice coil has electrical resistance. In most practical cases, the d.c. resistance of a loudspeaker is about 80% of its rated impedance. This is not always the case because different manufacturers use different impedance-rating methods, but such variations will not affect what we are talking about. Let us suppose, therefore, that our 8-ohm black-box speaker has a d.c. resistance of about 6.4 ohms.

The voice-coil resistance is effectively in *series* with the "working" parameters of the loudspeaker, just as is the internal impedance of the amplifier. And this time it isn't even an imaginary resistor; it is a real coil of wire that measures 6.4 ohms with a v.o.m.

Instead of the circuit of Fig. 1, what really happens is shown in Fig. 4. The resistance that isolates the loudspeaker from the amplifier is not just R_s, but rather R_s plus R_{vc}. When the two are connected together, neither the speaker nor the amplifier can distinguish between R_s and R_{vc}. The actual damping factor depends upon the *sum* of these two resistances, not upon one or the other.

Amplifier R_s (ohms)	Amplifier DF	Actual Over-All DF
8	1	0.57
4	2	0.80
2	4	1.0
1	8	1.14
0.5	16	1.23
0.25	32	1.28
0.125	64	1.30
0.05	160	1.32
0.025	320	1.33
0.0125	640	1.33
0.0000	Infinity	1.33

Table 1. The actual damping factor (with loudspeaker connected) is limited by the speaker voice-coil resistance. Figures are for 8-ohm output terminals to which speaker having nominal 8-ohm impedance and 6-ohm voice-coil resistance is connected.

Table 1 shows the specified damping factor of an amplifier against the actual over-all damping factor for a wide range of generator impedance values when the amplifier is connected to an 8-ohm speaker. The actual damping factor values are computed by adding R_s and R_{vc}, then dividing by the rated load impedance. In this instance we have used an 8-ohm loudspeaker with a d.c. resistance of 6 ohms to prepare the chart. The exact figures are not particularly significant—the point is that the resistance of the speaker voice coil is the limiting factor.

Note that changing the amplifier damping factor from unity to 8 makes a substantial change in the actual damping factor, though it is not a 1:8 change but a 1:2 change. But changing the damping factor from 8 to 16 makes very little difference in the actual damping factor, and anything more than 16 has very little effect indeed. If we increase the damping factor from 16 to 160, the change is effectively less than 10%, not 10 to one.

Conclusions

It should be obvious at this point that the quoted damping factor of an amplifier is important only if the figure lies somewhere below 20 or so. Changing the damping factor from 2 to 20 does change the performance of the loudspeaker system (for better or for worse, depending upon the speaker). But trying to prove that a damping factor of 200 is somehow better than one of 20 is pretty unconvincing because the effective difference in the particular case cited is only that between 1.25 and 1.32.

But someone is bound to insist that exhaustive tests have been made with such and such an amplifier and that a very high damping factor *is* better than one down around 10 or 15. "The bass is just a little cleaner, just a little more natural and open," is the way the argument usually runs.

In a given situation, this may very well be true. R_s is a byproduct of negative feedback. The more such feedback that is thrown into a power amplifier circuit, the lower the generator impedance and the higher the damping factor. The point is simply that if a lot of feedback has to be used to lick the distortion in a particular circuit, fine—use it. But don't believe that the reason it sounds good is *because* of some astronomically high damping factor.

When I get a letter from someone who is worried about buying a certain amplifier because it has a specified damping factor of "only" 15 or 16, I can't help but remember an old, old joke. It goes like this:

A scientist is giving a public lecture. During the course of his speech, he predicts that in 100 billion years human life will become extinct. A man in the audience, obviously upset, asks the lecturer to repeat the statement.

"I said," quotes the professor, "that in one-hundred billion years, human life will no longer exist."

"Oh, thank goodness," replies the man, much relieved. "I thought you said one-hundred *million!*" ▲