AUDIO TALK

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Damping Factor & loudspeaker damping

Following last month's discussion on so-called high definition loudspeaker cables and their mythology, it is now appropriate to discuss "damping factor". The significance of an amplifier's damping factor is widely misunderstood, which when you come to think about it, is not surprising. After all, the damping factor of an amplifier bears little or no relationship to the damping actually applied to a typical loudspeaker system.

Well what is "damping factor" and why does it cause such confusion? We can answer these questions in two steps. First, we shall define what damping factor is, and then define what it is not.

Damping factor is merely the ratio of an amplifier's output impedance to its nominal load impedance. So if an amplifier has a damping factor of 50 with a nominal loud impedance of 8 ohms, then the output impedance of the amplifier is 8/50 or 0.16 ohms.

Normally though, when measuring damping factor, one does not go to the bother of measuring and calculating the output resistance and then dividing it into the nominal load value. All that is done is to measure the difference in amplifier output voltage between no-load and normal load (8-ohms) conditions, and divide this difference into the load voltage. This is done at a convenient power level, usually one watt.

Actually this method is the same as that used for measuring the regulation of a power supply. And really, an audio amplifier can be regarded as a voltage source with low output impedance.

Damping factor is normally measured at a frequency of 50Hz. This is right in the piston range of all wide range speakers, and it is also close to the fundamental resonance of many loudspeakers, ie, just where they need damping the most.

Another practical reason for measuring damping factor at 50Hz or a similar low frequency is that this parameter is normally reduced at low frequencies, compared to that obtainable at mid-frequencies. This is often the case with amplifiers which have output coupling capacitors; the rising reactance of the capacitors at low frequencies increases the amplifier output impedance. Thus the damping factor is reduced.

As an illustration of this phenomenon, consider an amplifier with a mid-frequency (1kHz) damping factor of 50, which has an output coupling capacitor of 1000uF. At 50Hz, the reactance of a 1000uF capacitor is 3.18 ohms. Add this to the almost negligible output impedance of the amplifier (which is 0.16 ohms) and, by vector addition, the output impedance becomes 3.184 ohms. When divided into the load impedance of 8 ohms, the damping factor is a mere 2.5!

Before we can consider whether or not a damping factor of 2.5 is inadequate or not, we must define damping as it is applied to loudspeakers.

The concept of damping (in the electrical sense) first arose out of the losses inherent in tuned circuits. A tuned circuit in an oscillator may have high or low losses. If the losses are high, oscillation will tend to die away quickly when excitation is removed; the tuned circuit is said to be highly damped. If the losses are low, the oscillation will tend to decay slowly; the circuit is said to be lightly damped.

Damping was also used to describe the mechanical and electrical methods applied to indicating meters, to stop the pointer swinging about wildly with changes in the current being measured. Similar thinking lies behind the concept of damping as applied to loudspeakers.

The voice coil of a loudspeaker is situated in a powerful magnetic field. When a voltage source is applied to the loudspeaker, current flows through the voice coil, causing the speaker cone to move. In that mode the loudspeaker can be thought of as a motor,transforming electrical energy to mechanical energy. But this process is reversible and the loudspeaker is also a generator, producing a voltage which is proportional to the velocity of the voice coil in the magnetic field. In conventional terms, this voltage may be thought of as the "back-EMF".

Now consider a situaton when the voltage applied to the loudspeaker is suddenly reduced to zero. Instead of the speaker cone ceasing its forward (or reverse) motion, it will tend to keep going in the same direction and to keep generating the same "back-EMF" as it was before the applied voltage dropped to zero. Now, if the "back-EMF" could be shorted out, the speaker cone would come to an abrupt stop.

This would be because the electrical loading placed on the voice coil "generator" by the short would be transformed to a mechanical load on the speaker cone. This is what actually happens in practice. The low source impedance provided by a typical good quality amplifier tends to short out the "back-EMF" and thus provides a degree of control over the speaker cone motion. This is the concept of damping.

The damping described above should be categorised as electrical damping and is but one component of the total damping applied to a typical loudspeaker system. The major component of loudspeaker damping is mechanical, made up of the total air loading exerted on the speaker cone by the listening room, the enclosure and its venting system and the filling material in the enclosure.

It is generally true to state that loudspeakers with sealed enclosures have more mechanical damping than vented enclosures. As a consequence, vented enclosures often have a boomier and more uneven bass response than sealed enclosures.

Having defined what damping is, we should note that it is only effective in the frequency region where the cone behaves like a true piston, ie, where the voice coil is tightly coupled to the cone. For a typical woofer, the piston range will span several octaves above its fundamental resonance, ie, up to several hundred hertz.

At higher frequencies, the speaker cone tends to "break-up" and no longer behaves like a piston. The voice coil progressively decouples from the cone and the effective radiating area of the cone is reduced till, at some relatively high frequency, the cone hardly moves at all and the voice coil dust cap alone radiates, if at all.

To return to the main argument, I stated above that the electrical damping provided by an amplifier is only a portion of the total damping applied to the loudspeaker.

Even with the above proviso, there are a number of factors which may substantially reduce the efficacy (and thus importance) of the electrical damping which can be provided by an amplifier. All of these factors depend on the magnetic circuit of the speaker. For a start, if the speaker has a large magnet structure and provides a high flux density in the voice coil gap, then the back-EMF generated by the speaker, for a given drive current, will be proportionately higher. This will mean that the amplifier will be more effective in providing electrical damping.

Second, if the speaker has a long-throw voice coil, then only part of the voice coil will be immersed in the magnetic field at one time. This means that the voice coil will generate proportionately less back-EMF and amplifier damping will be consequently reduced.

But the most important factor of all, which greatly reduces the efficacy of the damping provided by the amplifier, is the resistance of the voice coil itself. In a typical 8-ohm loudspeaker, the voice coil resistance is about 6 or 7 ohms. Against this, we can see that the fraction of an ohm output resistance of a typical amplifier is negligible. So, by comparison, if an amplifier has a relatively high output impedance at 50Hz of, say 3 ohms, the overall change in the electrical damping is not large. For the electrical damping provided by the amplifier to be really effective, the voice coil resistance would have to be considerably smaller with respect to the total loudspeaker impedance.

We might conclude then, that the electrical damping provided by the amplifier is not of major importance. Whether or not that is the case depends on the particular loudspeaker system, and whether the designer has relied on electrical damping to achieve the specified performance. Whatever the conclusion, it would be wrong to assume that an amplifier need not have a low output impedance.

Ideally, the amplifier should have zero output impdance. If not, when driving a loudspeaker system with typical large variations in load impedance, the amplifier will be unable to provide constant voltage drive. This would be undesirable, because loudspeaker designers normally assume that the driving amplifier is a constant voltage source.

If we decide that for an amplifier to be a constant voltage source with less than 1dB (or ±0.5dB) total variation over the whole frequency range when driving typical loudspeakers, then the source impedance must be less than about 0.3 ohms.

Our conclusion is therefore a paradox; High damping factor is not of great relevance as far as damping of loudspeakers is concerned. But as an indirect indicator of low output impedance, high damping factor is desirable. Confused? Well never mind. Most amplifiers have a high damping factor anyway, as a spinoff of normal design procedure.