Damping factor

The *damping factor* is a technical term defined as the ratio of the loudspeaker nominal impedance Z_L to the power amplifier output impedance Z_{out}.

$$D = \frac{Z_L}{Z_{out}}$$

For example, suppose that $Z_L = 8$ ohm and $Z_{out} = 0.1$ ohm. The damping factor of the amplifier is D = 8/0.1 = 80. Regarding this parameter we usually hear that more is better. This is justified by the fact that the amplifier controls the movement of the drivers cone and to do this it must have a low output impedance. Let's examine if this hypothesis is true or not.

In the part of electroacoustics that studies the operation of a loudspeaker driver an important parameter is the *quality factor* Q. It is a dimensionless parameter that determines how damped an oscillation is. A value higher than 1 signifies an underdamped oscillation whereas a value less than 1 a damped oscillation. In electroacoustics we define the *mechanical quality factor* of a driver as

$$Q_{MS} = \frac{1}{R_{MS}}\sqrt{\frac{M_{MS}}{C_{MS}}}$$

where M_{MS} is the moving mass, C_{MS} is suspension compliance (how soft it is) and R_{MS} is the mechanical resistance (any type of losses converted to heat). The amplifier plays no role here; everything is determined by mass and compliance. Typical values for the parameter Q_{MS} are between 3 and 15.

The other important parameter is the *electrical quality factor* defined as

$$Q_{ES} = \frac{R_E}{(Bl)^2}\sqrt{\frac{M_{MS}}{C_{MS}}}$$

where R_E is the voice coil resistance, B the magnetic flux density and l the length of coil wire immersed in the magnetic field. Typical values for Q_{ES} are between 0.2 and 0.4. The voice coil resistance for an 8 ohm driver is about 5.6 ohm. A high R_E value increases Q_{ES}, which results in less control on the cone motion, but the major role here plays the magnetic system. Increasing Bl (the magnet strength or the wire length) lowers Q_{ES} and we obtain more control. Where does the amplifier come into play? Well, the output impedance adds to the R_E value increasing it. However, assuming $R_E = 5.6$ ohm adding another 0.05 to 0.1 ohm will not make much of a difference. Moving on the total quality factor for a driver is defined as

$$Q_{TS} = \frac{Q_{MS}Q_{ES}}{Q_{MS}+Q_{ES}}$$

Assuming $Q_{MS} = 7$, $Q_{ES} = 0.35$ we get $Q_{TS} = 0.333$ a value close to Q_{ES}. What does this mean? It means that it is the Q_{ES} that is really important, in other words the diaphragm motion is controlled by the magnetic system, not so much by the suspension or the output impedance of the amplifier.

Is there anything else to say about the damping factor? Yes, there is. In the output impedance of the amplifier we should add the impedance of the interconnecting cable. In addition, we should not forget that the amplifier output stage operates in conjunction with the power supply. The capacitors have some resistance called the *equivalent series resistance* (ESR) that is essentially in series with the loudspeaker. As you can see from figure 1 the power supply is outside the feedback loop, therefore feedback does nothing to lower ESR. When the amplifier output impedance is low enough the control of the drivers is left to the capacitors. Therefore, the quality of capacitors matters.

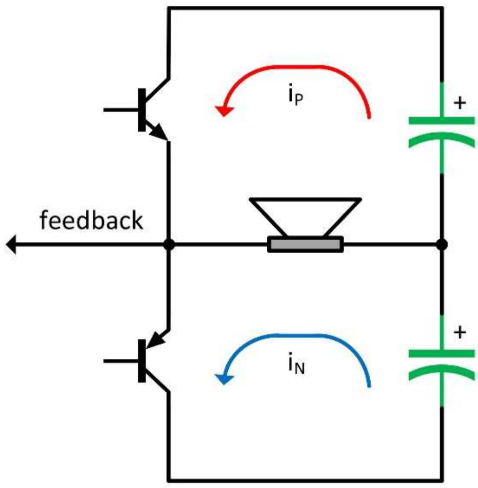

Figure 1. The amplifier output stage works in conjunction with the power supply

From what we have discussed so far, someone may have reached the conclusion that the damping factor is not an important parameter. However, there is another issue where high output impedance plays a negative role. A high output impedance can alter the frequency response. Ear is very sensitive to frequency response variations provided they occur over a wide frequency range. Variations as low as ±0.1 dB can be heard if they occur in a range that covers more than one octave. In figure 2, the blue line represents the frequency response of an amplifier with an output impedance 0.01 ohm plus 0.1 ohm for the cable. The deviation from a perfectly flat response is ±0.07 dB and can be considered innocuous to the listening experience. The red line represents the frequency response of an amplifier with 1 ohm output impedance plus 0.1 ohm for the cable. The deviation is ±0.7 dB and this is certainly audible.

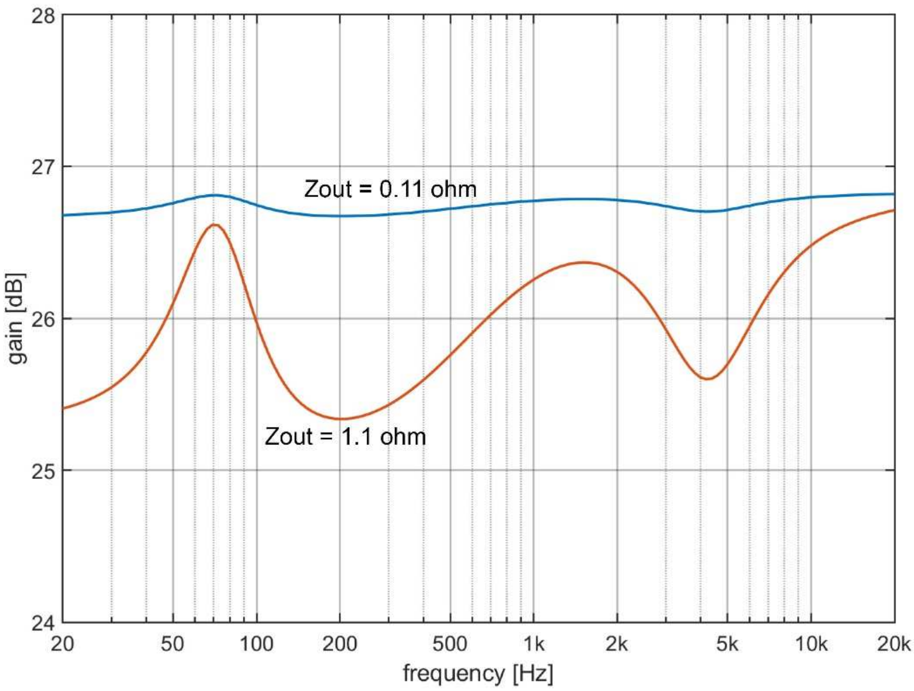

Figure 2. Frequency responses: Blue line, an amplifier with 0.01 ohm output impedance. Red line, an amplifier with 1 ohm output impedance. The cable resistance is 0.1 ohm in both cases

This amplifier works as an equalizer! The result may be pleasant or not; this is dependent on the loudspeaker impedance characteristics across the audio spectrum. You may get more body in the bass, more "air" at highs, however you should know that this is an alteration of the frequency response from a high output impedance and not some magic from the amplifier.

For Echo Diastasis

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