An Advantage of Active (Digital) Crossovers

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The discussion of an active cross-over's advantage over the more common passive units entails a familiarity with an amplifier's figure of merit, Damping Factor (DF), and the Output Impedance (Z_{OUT}), accumulated from the amplifier itself, through the wires and any electrical components in the crossover.

The DF (Damping Factor) relates inversely to the amplifier's Output Impedance relative to an agreed-upon nominal value of 8 ohms of speaker resistance (to standardize matters). The DF is a measure of how well the amplifier can *damp* the back ElectroMotive Force (EMF or voltage) generated by the speaker in response. You may interpret this as a good thing - that is, how well the speaker driver's motion is controlled by the amp's Z_{OUT}. Think of it as how quickly a woofer can be started and stopped in accord with the driving signal.

Here's an example with typical numbers to illustrate this.

If the solid state amplifier specification says it has a damping factor of 200, that has been computed by its manufacturer from the equation:

DF = 8 Ohms/(Z_{OUT} in ohms) Note: DF is a pure number without units

Turning the defining equation around,

Z_{OUT} = 8 Ohms/DF

So for the amplifier in this example:

Z_{OUT} = 8 /200 = 0.04 ohms

Now, as I said, the full meaning of output impedance accumulates, beginning with the amp, adding in the effect of speaker wire and passive cross-over components, if any. Let's use 14 awg stranded speaker cable. According to the wire DC resistance tables it is 2.31ohms/1000 ft, or 0.00231 ohms/ft. Since there are 2 wires, it sums to 0.00462 ohms/ft. Assuming a typical 12.5’ length of speaker wire, the total resistance is now 0.05775 ohms per cable, so the output impedance the 8 ohm speaker load sees driving it is the sum of the contribution from the amp (.04 ohms) plus that from the wire (.0577 ohms), yielding .09775 ohms. If we now say that this is the modified output impedance of the amp and wire combo, the effective damping factor is now considerably reduced from 200 down to [8 ohms divided by .09775 ohms], or 81.2.

That's not all in the context of a passive cross-over. In the simpest example, let's say we have a single electrolytic capacitor in series with the tweeter circuit and a single inductor in series with the woofer, a very simple single-pole crossover. The electrolytic capacitor may have an equivalent series resistance (ESR) around 30 milliohms. And the inductor may have a series resistance of 0.1 ohm. Looking back through the crossover to the amp, the woofer sees a damping factor of

8/(.09775 + .1) or, 8/.19775 = 40.5,

and the tweeter sees

8/(.09775 + .03) or, 8/.12775 = 62.6.

The simplest passive crossover thus reduces the DF even further than just the effect of the wire.

Now if we use a more realistic, standard version of a multi-pole passive speaker crossover you'll find that the damping factor the drivers see is considerably lower yet. If any level-changing series resistors are used, it is easy for a realistic crossover damping factor to be driven down to less than 10.

With an active digital cross-over, there are, of course, no additional degradations to the damping factor beyond any effect of the wiring.

This all goes to show one reason to use a crossover *before* the speaker amplifier to keep the damping factor to the combination of just the amplifier output impedance and the speaker cable's DC resistance. Some folks call this an active speaker system.

Now a word from our sponsor regarding the use of active crossovers with a complex line array speaker.

The use of an active cross-over has a special value when directing frequency bands in a speaker with multiple planar drivers, as used in line arrays. If you series connect the drivers, the damping factor is now everything already considered, including the resistance of the planars themselves, whichcan be less than 4 ohms per driver . Very low indeed with lots of planars. To minimize this baneful effect HAL decided to make active speakers in which every planar midrange has its own amplifier. The amp-per-driver concept is only slightly compromised by arranging the tweeter array in series pairs, to minimize the number of amplifier modules needed. This is justified by the tweeters not undergoing the large woofer-like excursions that create large back EMFs.

The HAL Pulsing Quasar and Megalith line arrays use ChipAmps with DC coupled inputs, and outputs without Zobel or Thiel stabilizing networks, as the nearly purely resistive planar load only "sees" the component of the PC board wiring impedance and speaker cable impedance. This was tested during design for full amplifier stability with these driver and cable loads.