

Crossing Over

by Mark Amundson

Frequency crossover networks have been around since the early days of movie theaters. Today we have active crossover networks besides the legacy passive networks for splitting out bands of audio signal to frequency-specific drivers (speakers). This installment of Theory and Practice will go backwards in history by first discussing crossovers, and working through the basics of passive crossover networks for a two-way speaker system.

Active or Passive?

With the ever dropping price of Digital Signal Processing (DSP) speaker processors, the previous argument of going active if you could afford it goes by the wayside. Even with legacy active analog crossover units, the reasons to remain using passive crossover networks boil down to simplicity and the lack of need for a dedicated high frequency driver amplifier. As of this writing, several speaker manufacturers, both professional and non-professional, are offering low- to moderate-cost DSP-based speaker processors that perform the active crossover role plus equalization and time alignment.

The principle of active crossovers is to pre-split the audio frequency bands while they still are "line levels" in order to avoid doing the same while handling hundreds of watts headed to driver voice coils. This argument for avoidance comes from a few items, the first being that the inductors and capacitors that make up passive crossover networks can absorb precious watts of power that should be pushed out to the audience instead of being wasted as heat. Another is the reduction of damping factor that impairs the driving amplifier from precisely controlling the motion of the driver's voice coils, thus blurring the fidelity of the speaker system. The last item is that active crossovers can easily create very tight filters that could not be efficiently or cost-effectively implemented in a passive crossover network. Try implementing 100Hz center four-pole (24dB) Linkwitz-Riley network with capacitors and inductors and you see my point.

So with either analog or digital-based active crossover networks, you do the frequency dividing task at line levels between the console and the power amp racks. Of course, you have now doubled or tripled the number of amplifier channels you need to implement a bi- or tri-amp speaker system. Then there is the multi-pair cabling to the speaker via Neutrik Speakons or EP connectors. And the balanced patch cords from crossover to amplifiers, and the jackplate system in your amp racks to make everything plug, power and play. And do not forget the extra power distribution breakouts for the crossovers and extra amplifiers.

I made the difficult plunge from passive to active in my entire rig, but took it in affordable chunks. The easiest, but nevertheless expensive, way was get the amplifier acquisitions done first and "make do" with low-cost analog crossovers until the DSP versions come along with the right configurations at the right prices. For example, I have a BSS Minidrive (FDS-336) for my mains speakers, and I am still using the industry renowned TDM 24CX4 quad two-way analog crossovers to create four bi-amp monitor mixes per unit. The version of 24CX4 I have also has a simple but effective adjustable limiter circuit to help protect the amplifiers and drivers from excessive signal levels. The obvious next step is to retire the 24CX4s for a DSP unit that will include time alignment and preset equalization.

"Passivation"

The reasons for sticking with the legacy passive crossover system also has to do with the fact that most purchased speakers for Music Industry (MI) and Prosumer customers already have the passive crossover network included, so why not save on cable and electronics and just leave it alone? But unless you build your own speakers already, you probably wonder what makes up a passive crossover network in speakers these days.

Whether you are building your own passive crossover network using purchased parts or just want to know what technology is inside your own cabinets, let us explore the basics using a simple two-way, two-pole, passive crossover network. Figure 1 shows schematically such a network with the drivers and cabinet jackplate interface. The two-pole description means that two filtering components (capacitors and inductors) are used to separate frequencies with each "pole" meaning a -6dB per octave slope contribution in the crossover network.

In two two-pole designs, the woofer (low frequency) circuit gets a series inductor and a shunt capacitor to reduce high frequencies and pass low frequencies. Likewise the tweeter (high frequency) circuit gets a series capacitor and a shunt inductor to reduce low frequencies and pass high frequencies. Most all two-way speaker cabinets will employ a passive crossover like this. Where things get artistic is how the manufacturer's designers choose the component values to set the crossover point and how much dip at the driver networks' intersect point. A classic example would be where a 12-inch woofer and a 1-inch throat tweeter intersect at a crossover frequency of 2.5kHz with the crossover network chosen to create -3dB (half power) for each driver at the 2.5kHz frequency. At that exact frequency, each driver shares half the reproduction burden of creating a sound wave.

Matching Magic

You may have noted the flip in the tweeter polarity in the Figure 1 example. The reason for this flip is at the crossover frequency, where both parts of the network introduce phase errors that combine nicely when one driver polarity is flipped. With active crossover systems, this flipping is not needed, and undone if there is active/passive switch on the cabinet jackplate. But where this gets proprietary with manufacturers is in the sensitivity matching part of the passive crossover network. I am not going to reveal anything specifically to any manufacturer, but I do show a basic two-power-resister "L-pad" configuration as an example of what I would do for a home-brew design.

You may have noticed in speaker specification differing woofer and tweeter sensitivity ratings, with the high frequency driver 6 to 10dB more efficient. So when using a single amplifier, passive networks must "pad" down about the same number of dBs on the tweeter network to match up these sensitivities. But no one said that you had to use power resistors exclusively for this matching. In fact, most designs for matching employ proprietary mixtures of capacitors, inductors, resistors and low-voltage light bulbs.

And then there is the raging controversy of which tweeter protection designs are best. Philosophies range from absolute circuit breakers to softer multi-step protection using things like light bulbs, poly-switches, relays and circuit breakers with standard components. I rely upon the KISS (Keep it Simple, Stupid) principle to just breaker the tweeter, but manufacturers will expend plenty of marketing dollars to let you know how much torture their products will endure with their crossover network driver protection schemes.

If all of this intrigues you to try your hand at brewing your own passive network, check out a catalog supplier called Parts Express (www.partsexpress.com). They specialize in drivers and network components for the Do-It-Yourself enthusiast. They have multiple pages of tips and techniques to help you select the best network for your drivers. My best advice is not to skimp on inductor wire size and go with film capacitors, plus do not go the "audiophile" route with esoteric components. Back in the '70s, all we had for crossovers were oilcan starter-capacitors normally used in window air conditioners.