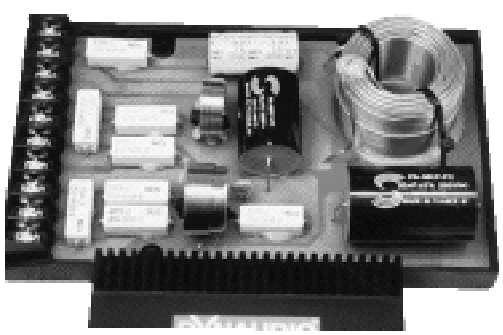
all about crossovers

TYING IT ALL TOGETHER FOR IDEAL SQ

By Chris Lewis   Photography by Chris Lewis

IT IS NOT enough to have great bass, great midrange and great highs, and understand where those echoes are coming from. You still have to blend those elements together to achieve ideal sound quality, and that is where crossovers come in. Crossovers handle multiple responsibilities, namely protecting the driver from receiving too much power and protecting the driver from over excursion. Crossovers also match the relative levels of the drivers so that they sound good, but that is perhaps the least important of its goals. After all, if you're constantly destroying your midranges and tweeters, how good they sound will always be a fleeting experience.



For starters, let's discuss the power handling limits of the speaker. Plow too much power into any driver and the voice coil will burn. My shop repairs speakers and manufacturers require that I cut out the voice coil and inspect it for charring. Guess what happens to your warranty if your voice coil is burned? That's right - no warranty repair.

Your typical tweeter can only tolerate about five watts of RMS power for an extended time. Woofers on the other hand can handle anywhere from 60 to 1000 watts. I read recently that clipping your amplifier causes tweeter damage because the squared-off top of the waveform is DC that gets to the tweeter. While this is not entirely accurate, Richard Clark offers a much better explanation: clipping turns music into square waves. Then, as we learned in the SPL segment (Feb., 2000), a square wave delivers twice the power of the equal amplitude sine wave. Take a 30-watt amplifier and drive it to clipping with a lead guitar solo and instead you've delivered 60 watts of power to the mids and tweeters. Suddenly there's no more sound and no more warranty. Your speaker didn't just die - it was murdered.

As mentioned earlier, one of the purposes of the crossover is to protect the driver from over-excursion. Sending highs to the woofer does nothing but sound bad, while sending lows to a midrange or tweeter can damage them quickly. Force the diaphragm too far backward and the voice coil will be damaged when it slams into the bottom of the gap. Force the diaphragm too far out and the tensile leads or suspension will be torn loose. Remember, tweeters and midranges do not have the kind of excursion that a woofer does.

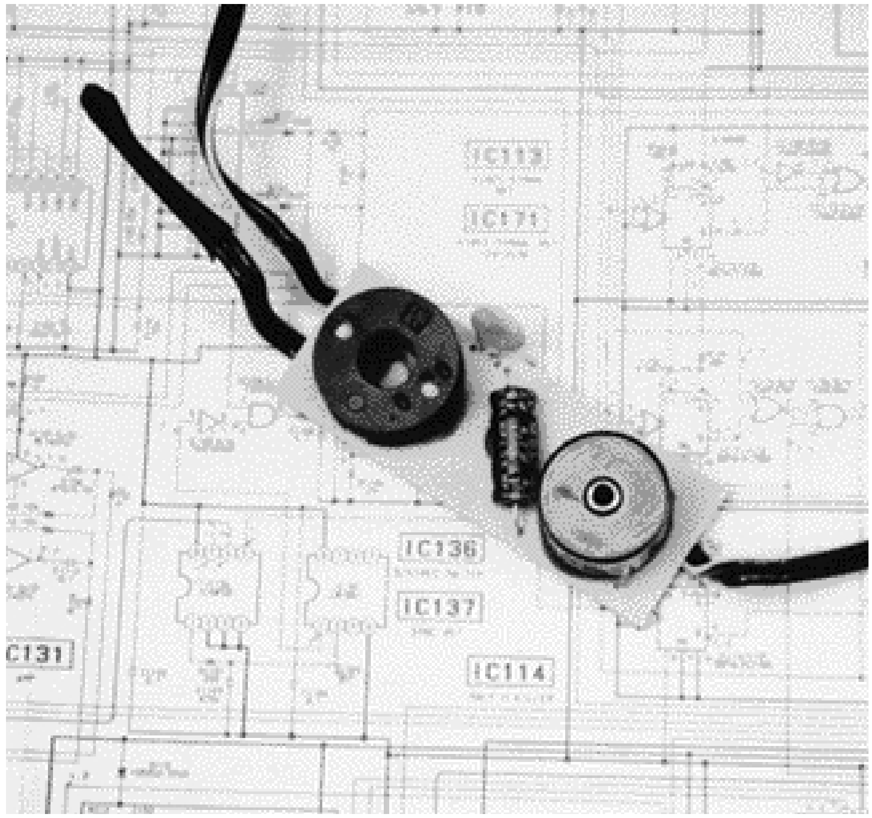
There are four basic electrical components that make up a crossover: Capacitors, inductors, resistors and wire. Capacitors block low frequencies, while inductors block high frequencies. These are the reactive elements. Resistors are used to waste power, thereby matching the efficiency of different components. The fourth component is commonly overlooked: wire.

Naturally the cheaper components are not the best. Your typical electrolytic capacitor is not made with any great accuracy. Most electrolytic capacitors are designed to operate with a variable DC voltage that is never reversed. This makes them unsuitable for the AC values encountered in music. Another downside to the common electrolytic is the tolerance of -20 percent to + 80 percent. Music has an average DC value of zero. Effectively the voltage across the capacitor is AC, which requires a bipolar electrolytic capacitor. Naturally the bipolar 5 percent capacitor is more expensive. The best (and most expensive) crossovers are made with Mylar or other film capacitors with 5% tolerance and hundred-volt ratings.

Inductors come in two types as well: air-core and iron-core. The iron-core inductors wind wire around a powdered iron or iron-ferrite core, while air-core inductors use, surprise, air. The iron-core allows the inductors to be made with less wire, a cost-saving measure as copper wire is expensive. Unfortunately, iron does not always behave like an inductor should. The air-core inductors behave the best. They are, however, larger and more expensive.

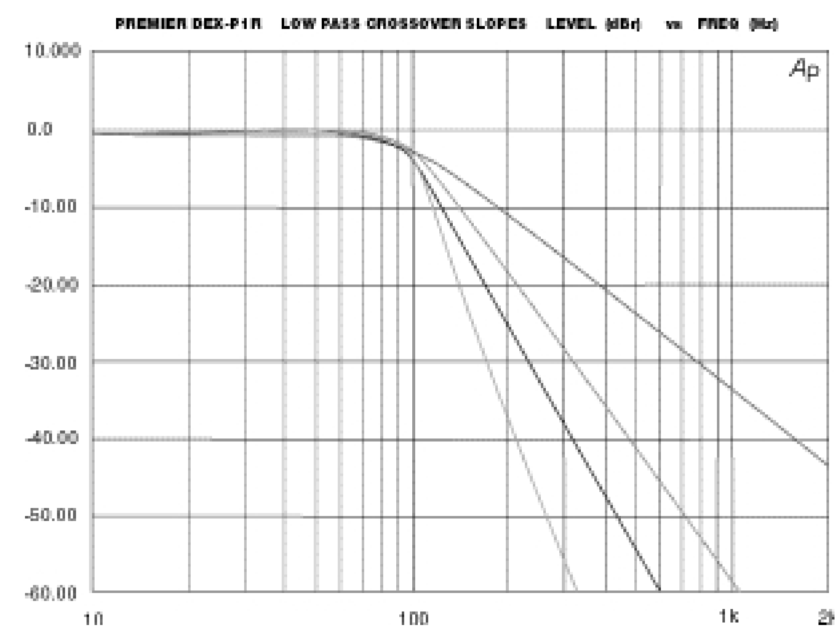
An unexpected downside to the air-core inductor is that it behaves like half of a transformer. One of the worst engine noise problems I have ever had to solve was engine noise in the tweeter. Almost by chance, we found the noise was present even with the stereo turned off. It turned out that the air-core inductors in the crossover were located too close to some factory wiring. Wrapping the crossover in a metal foil shield solved the problem. (Accele carries metal foil under part number CMS.)

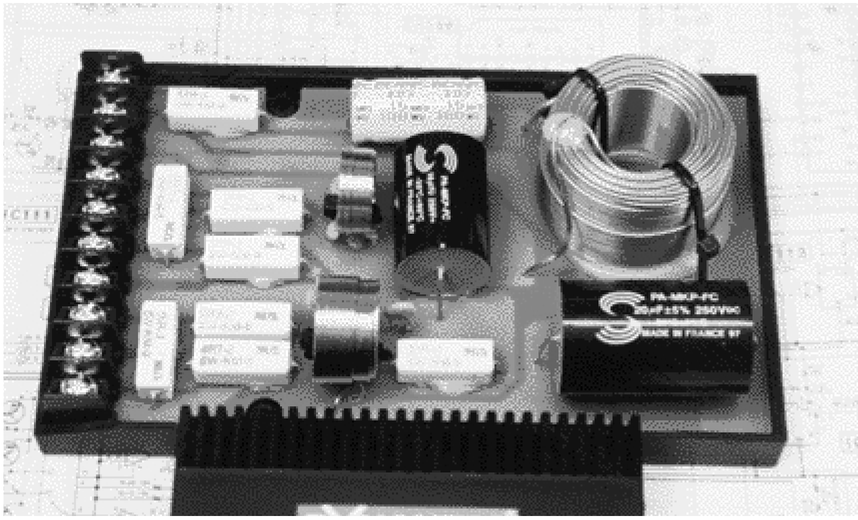
Shown in the photographs are two rather well-made crossovers from Dynaudio and Diamond Audio, and one El Cheapo. All of them use air-core inductors except for El Cheapo. The variation in size of the inductors relates to two variables: power handling and crossover point. The larger wire gauge allows for higher power handling. The lower the crossover point, the more turns are need-



We fondly refer to this crossover as El Cheapo, for obvious reasons.

For the Premiere DEX-P1R (reviewed June 2000), the crossover point is where the signal has dropped off by three decibels, in this case 100 Hz. One octave higher at 200 Hz the slope is easily read as 12, 18, 24 and 36 decibels. These results correspond to second, third, fourth, and sixth order.





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ed in the wire to increase induction. The very large inductor in the Dynaudio crossover is the result of a low crossover point from a bass to midrange and the high-power handling ability. Almost every capacitor is a high-quality film type except for El Cheapo. The apparent use of an electrolytic capacitor in the Diamond Audio crossover is made acceptable by the inclusion of a small, high-quality capacitor in parallel with the electrolytic.

Usually, the efficiency of the midrange and tweeter are different. Therefore, it is necessary to waste the efficiency of one component in order to match the other.

You may have noticed a number of large white rectangular components in these crossovers. These are resistors, capable of dissipating five to 10 watts. After all, a three-decibel adjustment would require the power resistors to waste as much power as is delivered to the tweeter. Additional resistors allow the user to select the relative level. The large white components in the Diamond Audio crossover are a particular brand of high-quality capacitor, and it is hard to tell them apart from the power resistors.

Recently a customer came to my store complaining that half of his tweeters were shutting off. Two of the speakers were connected to the 35-watt deck. Two more speakers were connected to an outboard 35-watt amplifier. The tweeters connected to the larger amplifier were shutting off when the music contained lots of highs. A quick read of his owner's manual revealed that Eclipse installs a solid state protector on every tweeter. The difference in power between the 35-watt "deck power" and a 35-watt amplifier was enough to trigger the protector. Commonly known as a poly-Silicon switch, it's a good thing to look for in a crossover. The small, tan object in each crossover that looks like a cheap ceramic capacitor is actually the poly-Silicon switch. The nice thing about the poly-Silicon switch is that it resets when it cools off. An alternative is to use a 1-amp fast blow fuse.

By the way, there are no legal limitations to specifications of car audio power. Your typical high-power car deck is 12 watts per channel. Over the years, this number has been inflated to 25, then 35, and now 45 watts per channel. Everyone tells similar lies, but the truth is 12 watts.

Not including the two-way speaker with a simple capacitor on the tweeter, the most common passive crossover is 12 dB per octave. Higher-order crossovers are difficult to build for two reasons: quality components are expensive and the specific values may be difficult to find. But like an engineer at Recoton once said, the capacitor manufacturers build what Recoton wants. If you order enough, you can get any value. Amateurs are on their own.

The best alternative is the electronic crossover. When used in a multi-amplifier system, the performance and ease of adjustment is worth the cost. Active components like transistors and opamps are relatively inexpensive, as are low-power precision resistors and capacitors. Even precision inductors can be realized using opamps, capacitors and resistors. Now crossovers of almost any order can be built inexpensively. The 12 dB per octave crossover is easily built as an adjustable crossover. Higher order adjustable crossovers are more expensive because of the adjustable element.

Before continuing, an explanation of the usage of "order" is necessary. Crossovers are specified by order, usually first, second, third, fourth, etc. Order is always an integer and you can multiply the order by six decibels per octave to obtain the crossover slope. When I reviewed the Premiere DEX-P1R (June

2000), a picture-perfect graph was generated. The crossover point is where the signal has dropped off by three decibels, in this case 100 Hz. One octave higher at 200 Hz, the slope is easily read from the graph as 12, 18, 24 and 36 dB. These results correspond to second, third, fourth, and sixth order. Multiply order by 90 degrees and you get the phase shift difference at the crossover point for Butterworth filters.

A quick check for order is to count the quantity of reactive elements per driver. If the crossover claims 12 dB per octave and there is just a capacitor on the tweeter or just an inductor on the woofer, you know the manufacturer is lying.

There are audible and mathematical differences between different order crossovers. The first order crossover is mathematically perfect. If speakers were perfect, the first order crossover would be your choice. Unfortunately, first order crossovers may not protect the driver properly. You can always use more expensive/rugged drivers, or you can replace your tweeter on a regular basis.

The second order crossover (12 dB per octave) is your worst-sounding choice. At the crossover point, there will be a cancellation notch. This is caused by the 180 degrees of phase shift between the low-pass and high-pass outputs. Or you may invert the tweeters, but then the high pass and low pass will be out of phase and this is an audible problem also. There is also another problem: If the driver opens up, the amplifier will be driving only the series inductor and capacitor. At the crossover frequency, the magnitude of the inductor impedance is equal and opposite to the magnitude of the capacitor impedance. The results add up to zero, which is a short circuit (very bad) on the amplifier.

One recent customer blew up not one, but two perfectly good receivers. After some investigation, it became clear that the midrange in one cabinet was open. This type of problem cannot be found at the enclosure terminals with your ohmmeter. You must physically remove each speaker from the enclosure and disconnect the wires to make sure you are measuring just the speaker.

Third order crossovers sound good with 270 degrees of phase shift difference. They protect the driver quite well, but third order and higher adjustable crossovers are difficult to build. You pay more, you get more.

The fourth order (24 dB per octave) crossover provides very good protection for the individual drivers. The phase shift, however, increases to 360 degrees. There is no cancellation notch, but there is a timing problem. Moving pole locations slightly results in the Linkwitz-Riley configuration. The Linkwitz-Riley configuration has no phase shift between the high-pass and low-pass outputs and sounds excellent.

Since there is no phase shift between the high-pass and low-pass output when using the Linkwitz-Riley configuration, you could time align the speakers. Practical analog time delay circuits that cover a couple of octaves are easy to build. If you are not using a coaxial speaker, crossover time delay works very well for the short path length errors involved. Furman Sound and Rane offer this feature on their pro sound crossovers, while AudioControl makes similar car crossovers. For more information, try their Web sites: www.furmansound.com; www.rane.com; and www.audiocontrol.com.

So what kind of performance should you expect with the electronic crossover? Since the circuitry is relatively simple, the signal-to-noise ratio should be better than 110 dB. The distortion should be less than 0.01%. Poor choices of capacitor type and component values can introduce significant distortion. The low-pass output should be down less than one dB at 10 Hz. The top end should be flat well past 20 kHz.

There are significant differences in power supply design. My own preference is for a fully-isolated, switch-mode power supply. This allows for a continuous signal ground from input to output. A common alternative is to combine the power ground and output ground, then use a balanced or differential input. This causes ground loops and relies upon the differential input to reject noise. Both work well when properly used. Maybe next time I will tell you what to listen for in setting up your own car stereo.

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