THE PA BIBLE

ADDITION NUMBER SEVEN
CROSSOVERS AND BIAMPING

In the original "PA Bible" we discussed the crossover and some aspects of biamplifying. In this supplement we will take a more in-depth look at crossovers and the whys, hows, and advantages of biamplifying.

A crossover is a device which separates full-range program material (electrical signal) into appropriate low- and high-frequency ranges for two-way systems, or into low, mid, and high frequencies for three-way systems. A crossover is necessary to separate and direct the electrical signal from the power amplifier to the various speaker components in a speaker system. Different size speakers are best able to reproduce different parts of the frequency spectrum. Large cone speakers (usually 12, 15, or 18 inches in diameter) are designed to reproduce the low bass frequencies. Their relatively large cone areas and cone excursion abilities are necessary to produce high-level bass. Smaller speakers, such as tweeters or compression drivers on horns, are better able to reproduce the high frequencies. They are also capable of providing wider dispersion of these high frequencies. Since different speakers are necessary to properly reproduce the total frequency spectrum, the crossover is necessary to direct the appropriate frequencies to each speaker.

If low-frequency energy is applied to a small fragile tweeter, the tweeter will try to make the large excursions needed for low-frequency production – and disintegrate. If high-frequency material is applied to a woofer, no damage to the speaker will occur but you won't get many highs. The large, heavy woofer cone simply cannot move fast enough to reproduce the high frequencies.

CROSSOVER FREQUENCY AND SLOPE RATE

Figure 1 shows the frequency responses associated with three typical crossover response characteristics. The "high-pass" responses are for the crossover section which lets the high frequencies through. The "low-pass" responses are for the low-frequency section. The "crossover frequency" is the frequency where the low-pass output and high-pass output cross over one another. In Figure 1 the crossover frequency is 800 Hz.

Figure 1 also shows three different "slope rates." The slope rate is the degree to which the low-pass (or high-pass) section rejects the unwanted frequencies above (or below) the crossover frequency. For instance, a "6-dB-per-octave" slope rate means that the crossover reduces the speaker's signal level by 6 dB every time the musical tone is one octave (or one more octave) removed from the crossover frequency. A one-octave change is two times or one-half the reference frequency, e.g., 800 to 1600 Hz or 800 to 400 Hz.

The other two slope rates shown are 12 dB and 18 dB per octave. These slopes cut off more rapidly, which provides better low-frequency-overdrive protection for the high-frequency speaker components and reduces the interaction between the low- and high-frequency components in the frequency range around the crossover point.

TYPES OF CROSSOVERS

"Passive" Crossovers. A "passive" (or "high-level") crossover is what you would probably find in most multi-way speaker systems (such as P.A. and hi-fi systems). These "high-level" crossovers are made up of capacitors, inductors and resistors. The circuit requires no auxiliary power to operate (such as 120 volts ac) which makes it "passive." Because these crossovers are usually inside the speaker system, they must handle the high power levels delivered by the power amplifier (thus the name "high level"). See Figure 2 for a depiction of a simple high-level crossover.

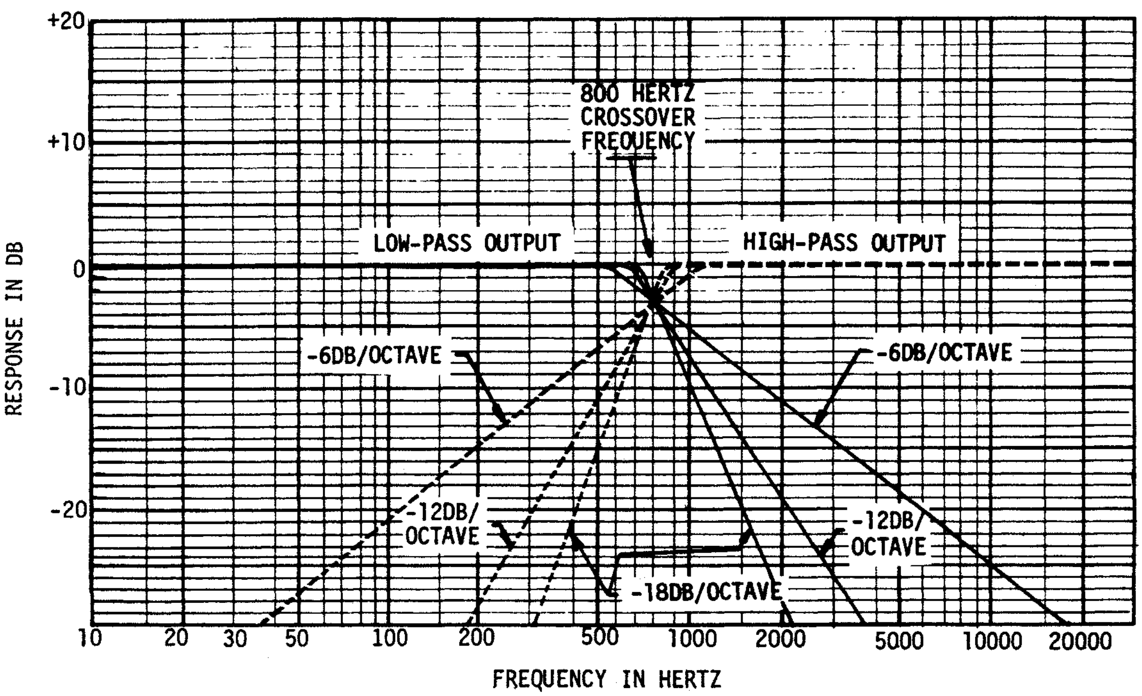

FIGURE 1 – Ideal Three Crossover Frequency Response Shapes

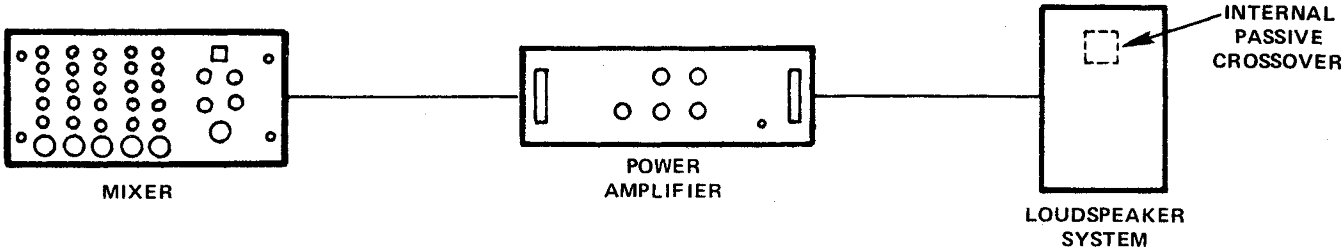

FIGURE 2 – Depiction of Passive Crossover

"Active" Crossovers. The "active" (or "low-level") crossover is placed ahead of, and feeding power amplifiers connected to, each loudspeaker channel (see Figure 3). The low-level crossover works on just a volt or so out of the mixer (thus the term "low-level"). The crossover still performs the frequency separating function, but each output of the crossover feeds its own amp, and the amp feeds its own speaker. (More on that later.) Since the "low-level" crossover drives two (or more) amps, the term bi- (two) amp is used. If an active three-way crossover were employed, the term would be tri-amp. The low-level crossover is usually composed of transistors, op-amps, and associated electronic parts that require an auxiliary voltage to operate (thus the term active crossover).

WHAT TO USE – ACTIVE OR PASSIVE?

When small sound systems are used and high sound pressure levels are not required, the economy of a passive crossover is attractive and the performance very acceptable. Speaker systems such as the E-V S15-3 have an integral passive crossover specially tailored to yield the best overall performance from the component speakers it utilizes. Passive crossovers are a useful and practical approach to many speaker systems. An active crossover, in many instances, would offer no advantage and be quite a bit more expensive.

When a larger number of components are used (such as high-frequency horns, drivers, bass bins, etc.), the active crossover may yield superior performance and better cost. One crossover can be used to drive many amplifiers and, therefore, many loudspeakers.

WHY BIAMP?

Biamping means driving your low-frequency speaker with one channel of a power amplifier and using the other channel to feed the high-frequency driver (i.e., using one amplifier for the low end and a second amplifier for high end). A biamp setup requires a low-level crossover connected between the mixer and the power amplifier. It doesn't have to handle large amounts of **power.** Since the amplifier's input is almost purely resistive, there is no interaction between the network and its load. (If interaction would occur, the crossover point or slope rates may change.)

Active crossovers are generally easier to use and adjust than passive units. Some recent units (such as the TAPCO EX-18) even have continuously variable crossover frequency controls, so you can adjust frequency coverage of different high-frequency (HF) and low-frequency (LF) drivers for different situations. LF and HF speakers can differ in efficiency by factors of two to ten (3 to 10 dB) or more. In a conventional system this difference in efficiency works against you. The usual way to get equal level from the drivers is to resistively pad (attenuate) the more efficient driver (usually the HF driver). This is really a waste of power, because the pad or attenuator merely converts the power, according to its setting, into heat. To get around this problem, the Electro-Voice XEQ808 and XEQ804 passive crossovers use capacitors to attenuate the high-frequency driver. This capacitor method also provides equalization of the driver on the horn and since it is **not** resistive it does not waste power like resistive padding methods do. Transformers can also be used to step the voltage down, but this is usually very expensive in comparison to resistors.

In a biamped system, the difference in driver efficiency can be balanced where it should be, at the level controls in the system in front of the power amps, so the signal delivered by the power amplifier is making music instead of heat.

To illustrate the difference between conventional and biamped operation, let's start with a conventional two-way speaker system with high-level crossover and one channel of a power amp. (You don't necessarily have to do the following, just read about how it works.) With the system connected as shown in Figure 2, send a low-frequency tone through the system. Note C below middle C on a piano will do nicely. It is about 126 Hz. Turn the level up until the amp clips. (It will sound just terrible!)

The harsh buzzsaw sound is amp clipping and all the loudspeaker system can do about it is to reproduce it the best it can: the fundamental (wanted) plus the harmonics which are produced by the clipping (unwanted). The clipped waveform is on its way to becoming a square wave, which is an infinite series of odd-order harmonics. If you have less clipping, you get less harmonics, which means the buzzsaw isn't as loud.

Something else happens when the amp clips. The average power delivered to the HF driver can be increased dramatically due to the addition of the harmonics. On a long-term basis, this can mean early diaphragm failure, and it costs money. Even though the tone is quite low, 126 Hz, you can get high-frequency driver damage because the tremendous number of harmonics produced can overpower the horn driver. When the amp clips, it doesn't care what is coming through, it clips everything.

Changing the input signal from a tone to music does little to change things, except the percentage of time the amp spends clipping. Because of the energy distribution in music, and the lower efficiency of the bass driver, the lower frequencies demand, and get, most of the amp's power. The high frequencies, which by their nature are faster transient spikes, don't need all that much continuous power. But added to the low frequency requirements, they can easily push the amp into clipping on peaks. For this you get harsh sound.

Recorded music usually has a peak-to-average ratio of at least 10 dB. Some program sources, like the unlimited signal from a mixing console, may have considerably more. The crash of a cymbal can easily generate transients 20 dB greater than the average signal level. For a 100-watt amp, a 10-dB peak-to-average ratio means that the average power delivered will be 20 watts, with peaks going to 200 watts. (You get 200 watts, instead of 100 watts, because the top of the sine wave signal used to rate a power amp is twice that of the average or "RMS" level.) The difference between the average level and peak clipping is called headroom. You want as much headroom as you can get.

Obviously, one way to get more headroom is to buy more watts – the most powerful amplifier you can get your hands on. But once you have it, and have reverently connected the monster to your speaker system with the power off (always off), you turn it on, sit back, and listen. You probably get a cleaner sound, and everything's fine until the amp clips because you turned the volume up too much, or worse yet, something happens in the line that sends a high-level transient (POP, SCREECH, HONK) through the system. What happens? Well, all of a sudden the poor HF driver, which may have only a 10-to-40-watt rating on peaks, sees a several-hundred-watt transient and does the only thing it possibly can do in this instance: BLOWS UP! The silence following is deafening. Later, when you can get around to it, the guy who recones your drivers takes your money and puts a little of it aside for his trip to Hawaii. And at $50 a throw, it won't take him long to get there.

We sort of got off the track, but there are really two points to all of this. Don't feed your drivers more than they can handle, and use some means of speaker protection. If you don't know the power rating of the speakers in your system, find out, and refer to "PA Bible" Addition No. 2 to refresh your understanding of power handling capacity.

So much for conventional operation; on to biamping. Connect a low-level crossover as shown in Figure 3. Hook your power amp into the crossover; channel 1 for the bass and channel 2 for the treble. Finally, connect the LF speaker or speakers to the bass channel and the HF speaker to the treble channel. Be certain the power is OFF while making the connections.

Okay, again put in the C below middle C on the piano and crank up the level the same as before. The sound stays relatively clean and just gets louder and louder. If the low-frequency amplifier clips, only the low-frequency speaker is fed harmonics instead of the high-frequency speaker, and it isn't very good at reproducing these harmonics. The high frequencies will be reproduced cleanly by the un-clipped high-frequency power amplifier, and the overall sound will be much cleaner. That's what you want, isn't it? Try **that** with a high-level crossover! No – don't do it. Save your money.

If you were now (in the same circumstances as above) to strike two notes on the piano, one low note and one high note, the combination would sound much better than the same signal through a high-level crossover system because even though the bass note may be clipped, the high note comes through clean and tends to mask it. In test setups where system components are operated near their design limits (that probably means **you**), biamp operation delivers a really transparent sound.

To sum up, there is minimal interaction between low-level crossover and amp, thus reducing distortion. The amp for the HF driver can be properly sized, thus minimizing the driver's exposure to high-level transients. The net result is a biamped system that can deliver somewhat higher sound pressure levels, lower distortion, and greater reliability. Yes, it may be somewhat more expensive in the short run, but compared to driver repair and downtime, it is a drop in the bucket. System expansion is easier – all you do is add more speakers and amps.

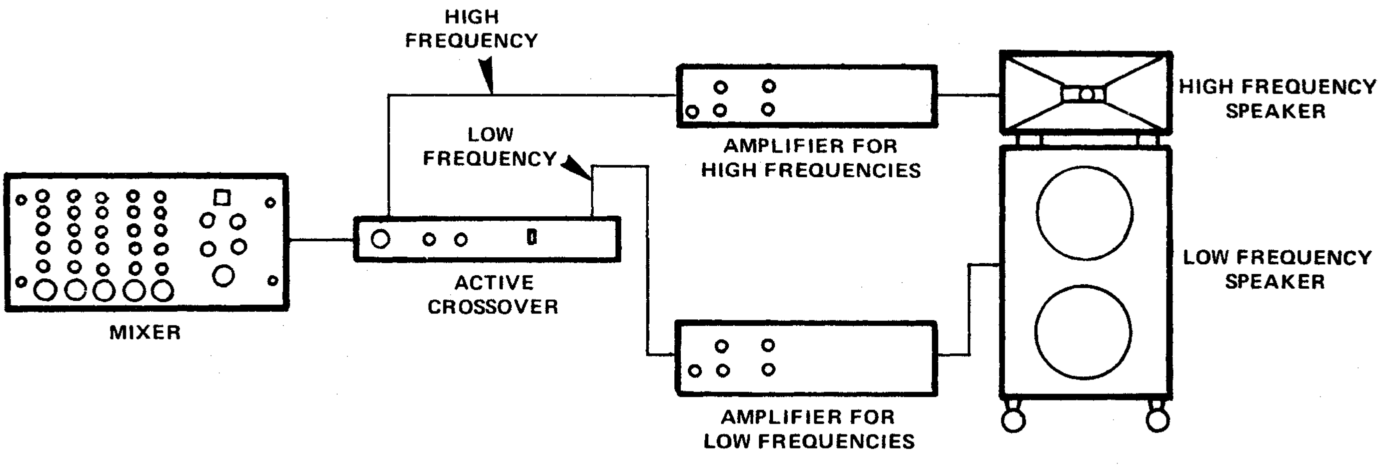

FIGURE 3 – Application of Active Crossover

POINTERS FOR SPEAKER SYSTEM BIAMPING

Many types of electronic components and speakers are available for constructing complete systems. Speakers should be picked to complement each other's characteristics. Amplifiers of the appropriate size for each speaker should be carefully chosen (see "PA Bible" Addition No. 2). The crossover should have crossover slopes suitable for the speakers being used, and should be electrically compatible with the other electronics in the system. Be certain the crossover will cover the crossover frequency you desire and beware of variable crossover dial markings so you don't accidentally set one for 100 Hz when you want 1,000 Hz.

The original "PA Bible" discussed initial balancing of high-frequency horn levels to low-frequency levels. Be certain to consult the HF driver manufacturer's specifications for the safe, permissible lowest crossover frequency or recommended crossover frequency. Higher than recommended crossover frequencies will not damage anything, but less than desirable results might be obtained.

Do not try to use an equalizer to make up for poor balance between highs and lows. This adjustment should be done at the crossover or power amplifier. Equalization is great for room tuning and performer enhancement, but over "EQ-ing" for a poor system will probably be so demanding that some part of the system will go to Hobart Tasmania for a long rest. This is particularly true of the very low and very high-frequency ranges (below and above system capability).

In a biamplified system high-frequency drivers end up being connected directly to the amplifier which drives them. This is great for most things, but if the amplifier has turn-on or turn-off transients, or if the amplifier ever fails, so might the drivers. Protective capacitors which will help minimize this problem are highly recommended. The manufacturer may be of help for type and value but if not, the following can be used. Non-polarized type capacitors (such as motor starting capacitors) with a voltage rating higher than the amplifier is capable of producing (70 volts to 120 volts) are recommended. The addition of the capacitor provides an additional 6 dB per octave roll-off and will also block any dc voltage that might appear. To calculate the appropriate value a frequency of one-half the crossover frequency should be used in the following formula so the protective roll-off will not affect normal operation. In the following formula "C" is the value of the capacitor in microfarads, "π" is 3.14, "f" is the frequency as discussed above and "Z" is the impedance of the driver $C = \frac{500000}{\pi \times f \times Z}$.

In passive, high-level crossovers this protection is an integral part of the crossover.

Be cautious when setting up so the low-frequency amplifiers aren't accidentally connected to the high-frequency transducers. The results are probably obvious. During initial sound check, turn the level up to a very **low** SPL, and listen to each speaker to be certain highs are coming from the place they should be and lows are coming from their associated speaker. (This is also a good thing to do, just to be certain all speakers are working.) If all is well, then proceed with your normal sound check.

CONNECTING THOUGHTS

By now you should be aware of the different types of crossovers and the role they play in making a speaker system function. Passive crossovers offer cost effectiveness while doing a good job whenever high-power inputs and multiple speakers are not being utilized. Biamping, on the other hand, with an active crossover, is desirable when multiple speakers and power amplifiers are used and is very flexible from a user standpoint. The choice is not always clear cut, and you must decide which will do the best job in your own application.

SPECIAL NOTE TO THE READER

The E-V "PA Bible" has been prepared to help you solve your PA problems. In addition, we have begun a series of supplements which will expand upon and add to the basic "Bible". Let us know if you have any specific subjects in mind for us to tackle. If you are reading a friend's copy of the "Bible" and would like to get your very own

You may call, write or E-mail any comments to:

E-V "PA Bible"
Electro-Voice, Inc.
600 Cecil Street
Buchanan, Michigan 49107

Outside the USA: 616/695-6831
Fax: 616/695-1304
E-Mail: www site: http://www.eviaudio.com

Electro-Voice®
600 Cecil Street, Buchanan, Michigan 49107
8234 Doe Avenue, Visalia, California 93277
Electro-Voice Div., 345 Herbert Street,
Gananoque, Ontario • Electro-Voice, S.A.,
Romerstrasse 3, 2560 Nidau, Switzerland