
Stereo 3-Way Active Crossover

User Manual

Model K231, Rev 3.2

Sublime Acoustic, LLC

Features

- Stereo 3-way or 2-way Active Crossover for driving separate subwoofer, midrange and tweeter amplifiers
- Linkwitz-Riley crossover filters, 4th order 24dB/Octave or 2nd order 12dB/Octave filter slope
- For Bi-Amping or Tri-Amping your sound system, or to add a sub-woofer to vintage audio systems lacking LFE outputs
- All analog design employing only the highest quality audiophile grade components:
 - Burr-Brown audiophile grade op-amps
 - Metalized Polypropylene Film capacitors
 - Metal film resistors with 1% and 0.1% precision
 - ALPS metal film potentiometers
- Crossover frequencies are selected through pluggable 'XO Frequency Modules'
- Wide range of XO Frequency Modules are available to support any crossover frequency (see list below)
- Stereo or Mono Subwoofer Output - Optional Subwoofer channel L/R mixer
- Supports Balanced and Unbalanced audio input and output signaling
- Sub, Mid and High output gain level front panel adjustments
- Baffle Step Compensation, Adjustable Gain, Selectable baffle size ranges
- Can be configured for 3-way or 2-way active crossover operation
- Supports 4-way or 5-way operation by cascading two K231's

Specifications:

- Total Harmonic Distortion (THD): Better than 0.0005%
- Total Harmonic Distortion + Noise (THD+N): Better than 0.0028%
- Intermodulation Distortion (IMD): Better than 0.0058%
- Signal-to-Noise Ratio (SNR): 120dB
- Channel Crosstalk: Less than -83dB
- Frequency Response: Linear from 10Hz – 250KHz
- CMRR (balanced inputs/outputs): Better than 70dB
- Input Impedance: 75K ohms unbalanced, 150K ohms balanced
- Output Impedance: 50 ohms, AC coupled
- Input Signal Max: 5.5V
- Insertion Gain: Adjustable Sub, Mid and High channels -9dB to +2dB
- Filter Topology: Linkwitz-Riley, Constant Voltage, 4th Order 24dB/Octave, 2nd Order 12dB/Octave
- Enclosure: Black Aluminum Extruded Chassis
- Dimensions: 6.5"W x 6.5"D x 2.5"H
- Shipping Weight: 3 lbs

Inputs:

- Stereo Balanced: ¼" TRS Jacks
- Stereo Unbalanced: RCA jacks
- Power Supply: Internal Analog Bi-polar, +-16V with 20,000uF total filter capacitance
- AC: 115/230VAC, standard C13 plug

Outputs:

- Stereo Balanced High, Mid, Low: ¼" TRS Jacks
- Stereo Unbalanced High, Mid, Low: RCA Jacks

We support the following Crossover frequencies:

- Any multiple of 10Hz from 40Hz-200Hz (e.g. 40Hz, 50Hz, ... 200Hz)
- 250Hz, 275Hz
- Any multiple of 100Hz from 300Hz-4000Hz
- Any multiple of 500Hz from 4500Hz-12000Hz

K231 Stereo 3-Way Active Crossover Overview

The K231 Stereo 3-Way Active Crossover significantly improves the audio quality of sound systems by separating the low, mid and high frequency ranges using ultra low noise, high precision active filter circuits. This allows the use of a separate power amplifier dedicated to each speaker driver. These functions result in greatly improved clarity and lower distortion of the sound that is produced.

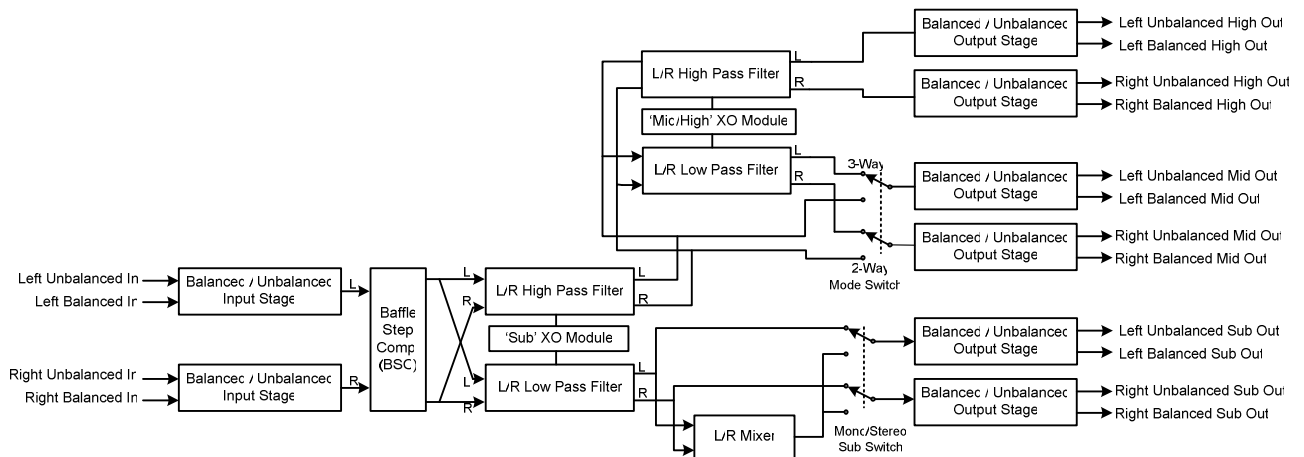
The block diagram below shows the primary functional blocks of the K231. The line-level audio signals, either balanced or unbalanced, enter from the left and are received and buffered by the 'Balanced/Unbalanced Input Stage' circuits. Note that the balanced and unbalanced inputs are both always active. Whether your inputs are balanced or unbalanced is selected simply by which jacks you plug in to. The balanced inputs are ¼" TRS jacks, and the unbalanced inputs are RCA jacks. Since this is a shared circuit between balanced and unbalanced input jacks, only one or the other can be connected at any one time.

After the input stages, the signal is processed by the 'Baffle Step Compensation' circuit, or BSC. This is simply a configurable stereo low pass shelf filter with adjustable frequency and gain that compensates for the 'Baffle Step' effect. See below for a more detailed description.

Next in the signal path is the Subwoofer crossover. This is a 2-way crossover that splits the subwoofer frequencies from the mid and high frequencies. Any frequencies below the 'Sub' XO module setting are sent to the Sub output. The low output can optionally be mixed into a mono subwoofer signal via a small switch that is accessible through an access panel on the bottom of the chassis. The high output of this crossover gets passed either to the mid/high crossover or to the 'Mid' outputs, depending on the setting of the 'Mode' switch. When set to 2-way mode, the 'Mid' outputs are actually the tweeter outputs, with all frequencies above the XO frequency.

The mid/high crossover, as the name implies, splits the mid frequencies from the high frequencies. Any frequencies above the 'Mid/High' XO module setting goes to the high output. Note that since the Sub crossover has already removed the subwoofer frequencies from the mid/high signal, this makes the mid filter into band pass filter, whose frequency is bounded on the low end by the Sub XO module setting and on the high end by the Mid/High XO module setting.

All of the crossover circuit outputs then go to six identical 'Balanced/Unbalanced Output Stages'. Again, both the balanced and unbalanced outputs are active at all times. But, again, this is a shared circuit between balanced and unbalanced outputs and only one set or the other should ever be connected at any given time.



What is an Active Crossover and Why Do I Need It?

All speaker systems employ an electronic circuit called a crossover to split the sound into frequency ranges; it sends the low frequency sounds to the woofer, and the high frequency sounds to the tweeter. This is important because each of the loudspeakers is built to produce certain frequency ranges, and they don't sound very good, or may even be damaged, if run outside of their proper range. Loudspeakers can actually distort within their natural frequency range if they are also presented with frequencies outside their natural range. In other words if you send low frequencies to your tweeter, the high frequency sound reproduced by the tweeter will be distorted by the presence of the low frequency signal.

Most speaker boxes you see employ *passive crossovers*, which are made up of large inductors and capacitors that filter the low frequencies from the highs. But passive crossovers have a number of very significant drawbacks. One big problem with passive crossovers is they don't have a very sharp *roll-off*. This means that some of the bass frequency energy will still reach the tweeter, and some of the treble energy will still reach the woofer. Another major disadvantage with passive crossovers is efficiency; they waste a huge amount of the power you're amplifier is providing. High frequency sounds are prevented from going to the woofer (and low frequencies prevented from going to the tweeter) by essentially just shorting them out; so power is wasted in the form of heat dissipated in the crossover components. In some cases up to 50% of the amplifier's power is lost to heat.

But by far the biggest problem with passive crossovers is that they significantly degrade the quality of the signals that pass through them by introducing distortion in the following ways:

- **Intermodulation Distortion (IMD):** Intermodulation distortion is a type of distortion that occurs when the passive crossover is tasked with producing two or more frequencies at the same time. The intermodulation between each frequency will produce additional frequencies at the harmonics and at the sums of the original frequencies that are not part of the original signal. This is most pronounced when simultaneously reproducing very low and very high frequencies. This type of distortion leads to a muddying of the sound created, making it harder to distinguish the individual instruments across the sound stage. Active bi-amp'd or tri-amp'd systems are much less susceptible to intermodulation distortion because the woofer and tweeter channels are driven by separate amplifiers.
- **Loss of Damping:** The caps and inductors placed in the circuit between the amplifier and the speaker coil cause a loss of damping, meaning that the amplifier is more isolated from the driver and has weaker control over the motion of the loudspeaker cones. The result is a muddier, less precise sound. In a bi-amp system the amplifiers are connected directly to the speaker coils with no capacitors or inductors to get in the way of the amplifier's ability to precisely position the cones, which gives you dramatically higher sound definition and vibrancy.
- **Back-EMF Distortion:** Back EMF, or back electro-motive force, is the voltage created by the speaker winding when the momentum of the cone causes the winding to continue moving relative to the speaker magnet. This voltage, particularly from the woofer, flows backward through the crossover toward the amplifier and into the tweeter channel. The massively chaotic interactions these voltages can cause are far too complicated to even begin to calculate. But they do cause a great deal of distortion of the sound. Active bi-amp systems are not in any way susceptible to back EMF distortion.
- **Channel phasing:** Once a passive crossover splits the audio signal, the woofer and tweeter signals can be out of phase from each other (which means one leads or lags the other) due to loose component tolerances or temperature related variations in these large discrete components. This causes distortion at and around the crossover frequency because at these frequencies both the tweeter and the woofer will be driven, but each will be in a different phase. At various points of time in the wave the woofer and tweeter will be either fighting one another or re-enforcing one another. This leads to a muddying of the sound definition.

All of this adds significant distortion to the final sound created. Audio engineers for decades have tried in vain to come up with ever more complex passive filter arrangements to try and resolve, or mask, these inherent problems.

Active crossover circuits, like those used in the K231, on the other hand, are built from the highest quality operational amplifiers (op-amps) and the filter functions are applied to the line-level preamp input signals instead of the high voltage amplifier outputs. These active filters are designed to be many orders of magnitude cleaner and more precise than the passives. Active filters have a much sharper roll-off, 24dB/octave, allowing each of the loudspeakers to perfectly focus on producing only the frequencies they are designed to handle. Active crossovers are also more efficient from a power standpoint because of the fact that the filters are applied in the line-level audio input signal; only the energy meant for a particular driver is sent to the amplifier that drives it, so there is no wasted energy. But the biggest advantage of active crossovers is the sound quality. A vanishingly small amount of noise and distortion is introduced in the op-amp filter circuits, on the order of 0.00005% total harmonic distortion. All of this results in extremely clean, precise, and well defined audio output to your amplifiers.

To learn more about the many advantages of active crossovers over passive crossovers, please read our paper on the subject:

<https://www.xkitz.com/blogs/making-the-case-for-active-crossovers-vs-passive>

Front Panel

The front panel contains four control knobs; One for BSC filter gain, and one each for High, Mid, and Low output channel gains. The panel gradients for the BSC knob are marked off in dB, from 0dB in the counter-clockwise position to 6dB fully clockwise. This allows you to control the gain of the BSC low pass shelf filter (see the BSC section for more info). The High, Mid and Low knobs have a small circle that indicates the 0dB gain point for each of these channels.

Back Panel

The back panel contains the AC input jack, the main power switch, and all of the audio input and output jacks. These are all fairly self explanatory. As previously mentioned, for any given audio channel, only connect a balanced source OR an unbalanced source, but never both at the same time.

3-Way or 2-Way Active Crossover Configuration

The K231 is primarily designed as a 3-Way crossover, but it can be configured as a 2-Way crossover by setting the 'Mode' switch inside the access panel on the bottom of the unit (see diagram below). In 2-way configuration your woofers or sub-woofer would be still be driven from the 'Sub' channel outputs, but your tweeters will be driven from the 'Mid/High' outputs. The 'High' outputs would be left unconnected and the 'High' knob on the front panel will have no effect.

Input / Output Signals – Balanced or Unbalanced

There are two basic systems used to connect the audio signal on consumer and pro audio equipment; unbalanced signals and balanced signals. Unbalanced signals use one wire for signal and the other for the shield ground. Balanced signals, on the other hand, have two signal wires and a shield ground wire. These two signal wires both contain the same audio signal, but one is 180 degrees out of phase with the other (in other words, they are differential signals). These are the (+) and (-) signals.

Unbalanced signals are most common in consumer grade audio, and are generally much more susceptible to audio noise like 50/60Hz hum than are balanced signals. Unbalanced signals will pick up any electro-magnetic noise in the nearby environment (such as computers, cell phones, microwaves, etc.) and add it to your audio signal, making it audible in your speakers. Unbalanced signals can also lead to ground loops, which are the major source of 50/60Hz hum in any sound system. Ground loops arise whenever there is more than one path from any piece of audio equipment to earth ground. Your equipment will always be grounded through your AC line. Adding another path to ground through your unbalanced audio cable adds a second path to ground, and this can cause audible 50/60Hz hum.

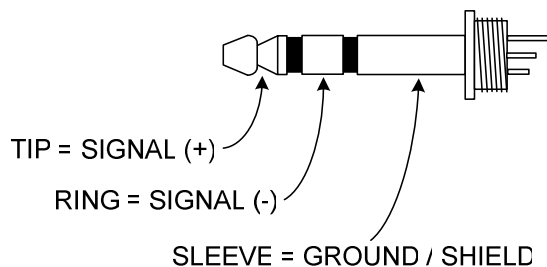
Balanced signals are more common in high end consumer and professional audio systems and are much less susceptible to noise. Balanced signals allow you to run very long audio cables without allowing electro-magnetic noise to couple into your signal. They're also not susceptible to 50/60Hz hum; there is no connection to ground in the audio signal cable (ground is only in the shield), so they can't create ground loops in your sound system. Since the signals are differential, and signal receiver circuit only measures the *difference* between them (not the absolute voltage), any noise that may couple into the signals will couple equally on both the (+) and (-) signal wires. They'll both contain the same (common mode) noise, but the difference of the two will remain the same and not contain the noise. In other words, the noise will be canceled out and won't be audible in your speakers.

Another very significant advantage of using balanced mode is you will get an extra 6dB of dynamic range, which gives you a lower noise floor and twice the slew rate of your signal for greatly enhanced signal definition.

If you have the choice, you should ***always*** choose balanced mode over unbalanced.

Both the balanced and unbalanced inputs/outputs are always active. There is no switch to select one or the other signaling mode. You select balanced or unbalanced mode by the jacks you choose to connect. The RCA jacks are all unbalanced signals, and the ¼" TRS jacks are all balanced signals.

Figure 1. Balanced Mode signal Input and Output ¼" TRS Jack Wiring



Configuring the Crossover Frequencies

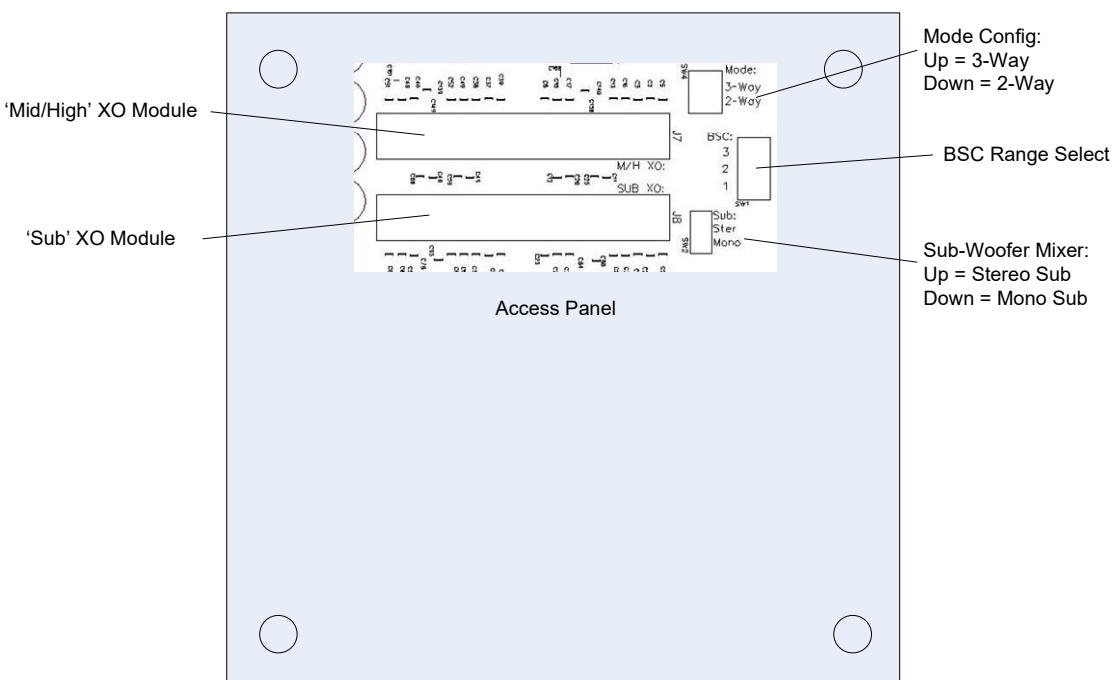
The subwoofer and mid/high crossover frequencies are controlled by the values of two 'XO Modules' inside the K231. These are accessible through an access panel on the bottom of the chassis. Normally these will be pre-installed at the factory and you may never need to do anything with regard to the XO modules. But you may want to experiment with other crossover frequencies, and this can be easily accomplished with the K231. The XO modules are nothing more than small PCBs that are inserted into two card slots labeled 'Sub' and 'Mid/High'. Changing the subwoofer or mid/high crossover points is as simple as replacing the XO module(s) with new values. Additional XO modules can be ordered from Xkitz.com.

12dB Crossover Filter Slope and Channel Phasing

If you're using XO Modules that are set for 12dB per octave filter slopes, the resulting 'Mid' output channels will be 180° out of phase from the 'Sub' and 'High' outputs. This is a normal attribute of 12dB filters. To compensate for this you will need to swap the speaker wires on the speakers that are driven by the 'Mid' output channels to put the channels back in phase. If you're using 24dB/octave XO modules, then all the outputs are in phase with each, so no speaker wire swapping is needed for 24dB modules.

Access Panel

The XO Modules and mode setting switches are located inside an access panel on the bottom of the unit, as shown in the diagram below:



Subwoofer Output – Mono or Stereo

The subwoofer output can be configured to be either stereo or mono by setting a small switch marked 'Sub:' behind the access panel on the bottom of the chassis. When set to stereo, both subwoofer L and R jacks are active. When set to mono, the L and R subwoofer channels are mixed into a single channel which is available on both Sub output jacks. When set to mono mode, you can plug your subwoofer amplifier into either of the Sub output jacks.

Baffle Step Compensation (BSC)

Baffle Step Compensation, or BSC, allows you to apply a low pass shelf filter function to the audio signal to compensate for a phenomenon where sounds above a certain frequency (determined by the size of the baffle, or the front of your speaker box) are actually reflected by the front of the speaker enclosure. Sounds that fall below that frequency do not get reflected, but instead wrap around the back of the speaker enclosure and are attenuated to a certain extent. This has the effect of reducing the magnitude of the lower frequencies. Your ear hears the primary waves plus the reflected waves on the highs, but only the primary waves of the lows. The BSC circuit, by applying a low pass shelf filter, will roll off some of the highs to restore the overall sound to a more natural, linear state. There are a number of good articles on the web with much more in-depth descriptions of BSC.

The knob on the front panel labeled 'BSC' allows the BSC filter gain to be adjusted. Turning this knob fully counter-clockwise reduces the BSC filter gain to the point of being entirely disabled. Turning it clockwise increases the BSC magnitude to a maximum of 6dB. In other words, it increases the amount of attenuation of the higher frequencies to 6dB below the lower frequencies. This compensates for the theoretical 6dB attenuation of the low frequencies due to the baffle step effect.

There is a small switch that is accessible through the access panel on the bottom of the chassis labeled 'BSC:', and each position is labeled '1' through '3'. The position of this switch controls the frequency of the low pass BSC shelf filter. Set this switch to best match your speakers' baffle size (use the smaller of the two speaker height and width dimensions).

Table 1. Baffle Step Compensation – Recommended Switch Setting

Baffle Width (in Inches)	Baffle Step Freq.	BSC Switch Setting
Less than 9"	507Hz	3
9" - 13"	350Hz	2
Greater than 13"	253Hz	1

System Power-up Sequence – Important!

The K231 can sometimes send a loud 'thump' to the amplifier when you power it up or power it down. To protect your speakers, be sure to power up the K231 *before* you power up your amplifiers. And power down your amplifiers first, then power down the K231.

Initial Power-up and Calibration

Ideally you should use a white or pink noise generator and a spectrum analyzer to accurately balanced the High, Mid, Low and BSC settings, but you can just as well balance your system 'by ear'.

To balance your system, first set the Sub, Mid and High levels to unity gain by setting the knob indicator lines to point to the small circles on the panel gradients. For simplicity, set the BSC to fully OFF, or counter-clockwise to start with. Turn on the power to your system and the K231. The initial sound will most likely be way too bright, as tweeters often have a higher sensitivity than woofers. Drop the level of the 'High' knob until you get to a natural mid/high balance. Then balance the 'Sub' channel (assuming you're running in 3-way configuration). Lastly turn up the BSC knob until the bass sounds natural.

Amplifier Wiring

The wiring diagrams below show the amplifier wiring for 2-way, 3-way, 4-way, and 5-way configurations. The diagrams show both balanced and unbalanced connections, but for each channel you should use only one or the other. For 4-way and 5 way operation, two K231's are cascaded to create the additional channels. Always use balanced 1/4" TRS patch cables to connect the two K231's as shown.

Figure 2. 2-Way (Bi-amp) wiring

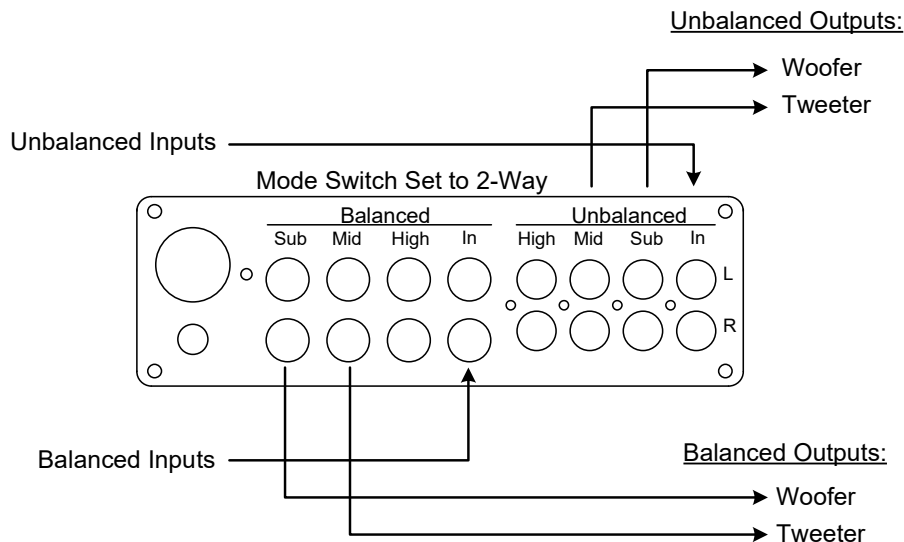


Figure 3. 3-Way (Tri-amp) wiring

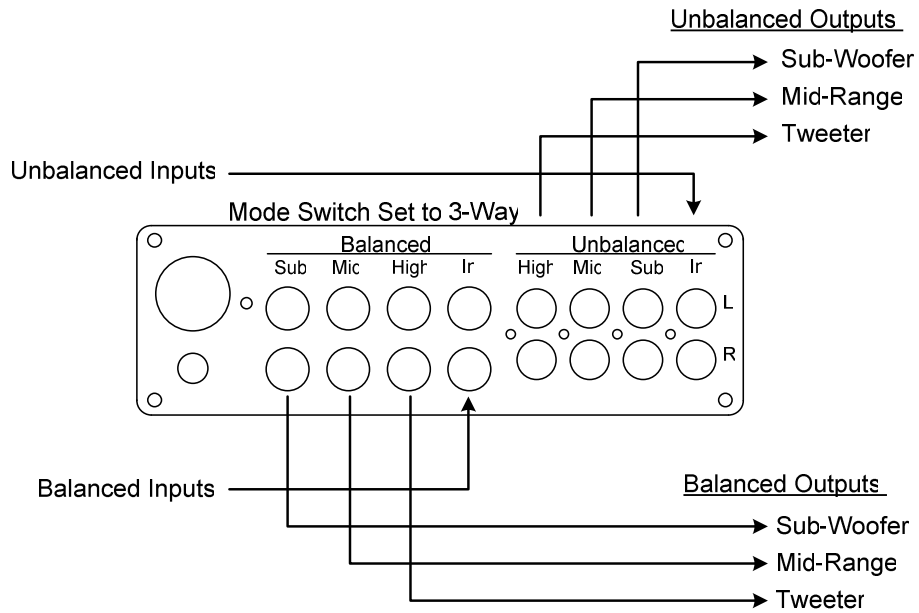


Figure 4. 4-Way (Quad-amp) wiring

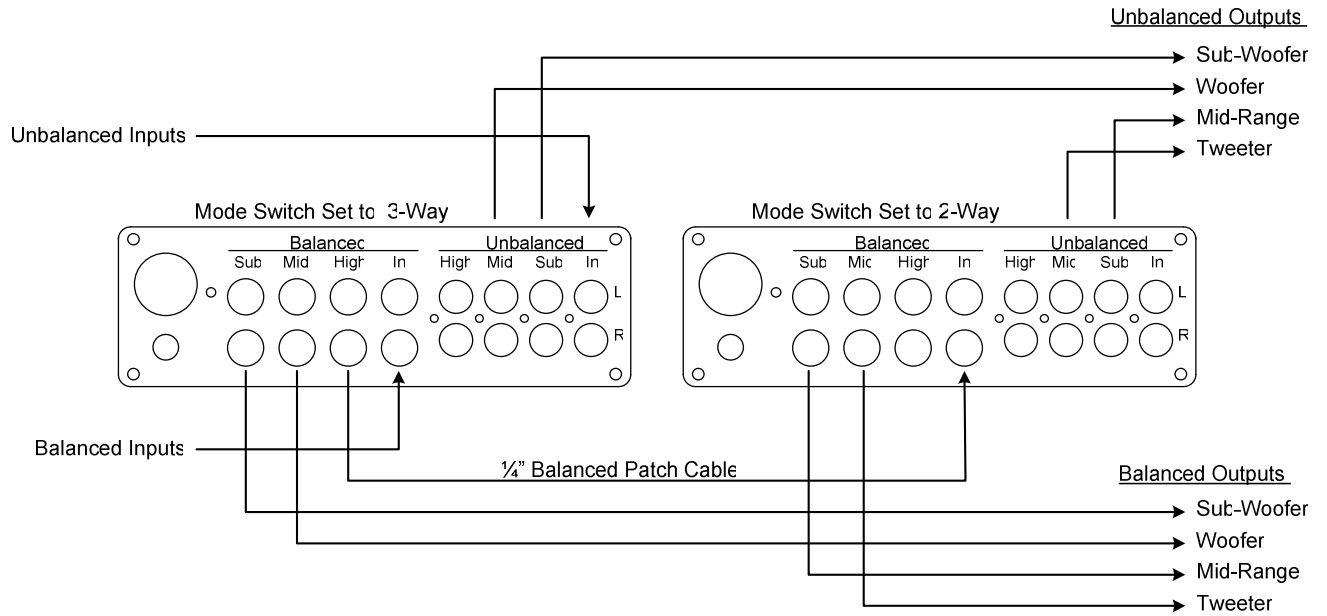


Figure 5. 5-Way (Hex-amp) wiring

