

Classic Crossovers

Linkwitz-Riley, Butterworth, and Bessel crossovers are provided through the Dolby[®] Lake[®] Controller interface. The Dolby Lake Processor provides Linkwitz-Riley crossovers, from 12 dB per octave up to 48 dB per octave. Butterworth and Bessel crossovers are available from 6 dB per octave up to 48 dB per octave. This document describes the details of these crossover implementations.

1. Linkwitz-Riley Crossovers

Linkwitz-Riley (L-R) crossovers are the most common crossovers used in conventional professional loudspeaker systems. The L-R crossover provides a number of useful attributes, including optimal polar and magnitude responses¹. Typically the fourth-order L-R crossover is utilized, which provides a 24-dB-per-octave transition slope.

Linkwitz-Riley crossovers are created by cascading Butterworth filters. Cascading two first-order (6 dB per octave) Butterworth filters produces a second-order (12 dB per octave) Linkwitz-Riley. Cascading two second-order (12 dB per octave) Butterworth filters creates a fourth-order (24 dB per octave) Linkwitz-Riley, and so on.

Constant Magnitude Response

One of the key attributes of the L-R crossover is that the crossover pairs electrically sum to provide a constant magnitude response. In other words, if you electrically sum the low pass and high pass channels of a Linkwitz-Riley crossover pair, the magnitude response will sum to flat.

Figure 1 illustrates this attribute. The low pass of the L-R crossover is shown in dark green, the high pass of the L-R crossover is shown in red, and the summation of the two channels is shown in blue. The summed magnitude response is constant, and the phase response shows a 180 degree phase shift at the center frequency of the L-R crossover pair (in this case 1 kHz).

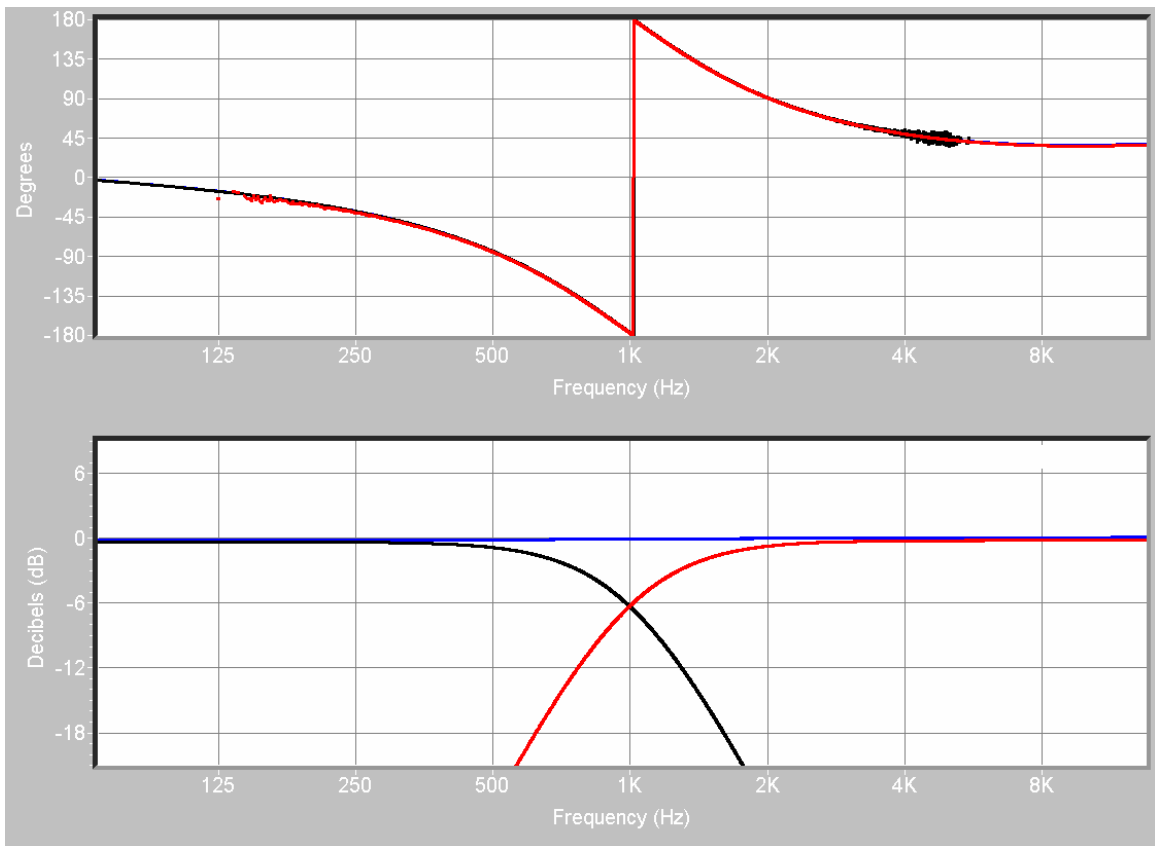


Figure 1 24 dB L-R Low Pass, High Pass, and Sum

In order to provide the constant magnitude attribute required by the L-R crossover, the phase response of L-R low pass and high pass pairs must be identical. This means that some of the L-R crossover pairs may require a polarity reversal of either the low pass or high pass channels.

Polarity Inversion Requirement

The Dolby Lake Processor provides 12 dB, 24 dB, 36 dB, and 48 dB L-R crossovers. When using 24 dB and 48 dB L-R crossovers, there is no need to reverse the polarity of adjacent crossover channels. However, the 12 dB and 36 dB L-R crossovers will require polarity reversals.

Figures 2 and 3 show the low pass and high pass channels of a 36 dB L-R crossover:

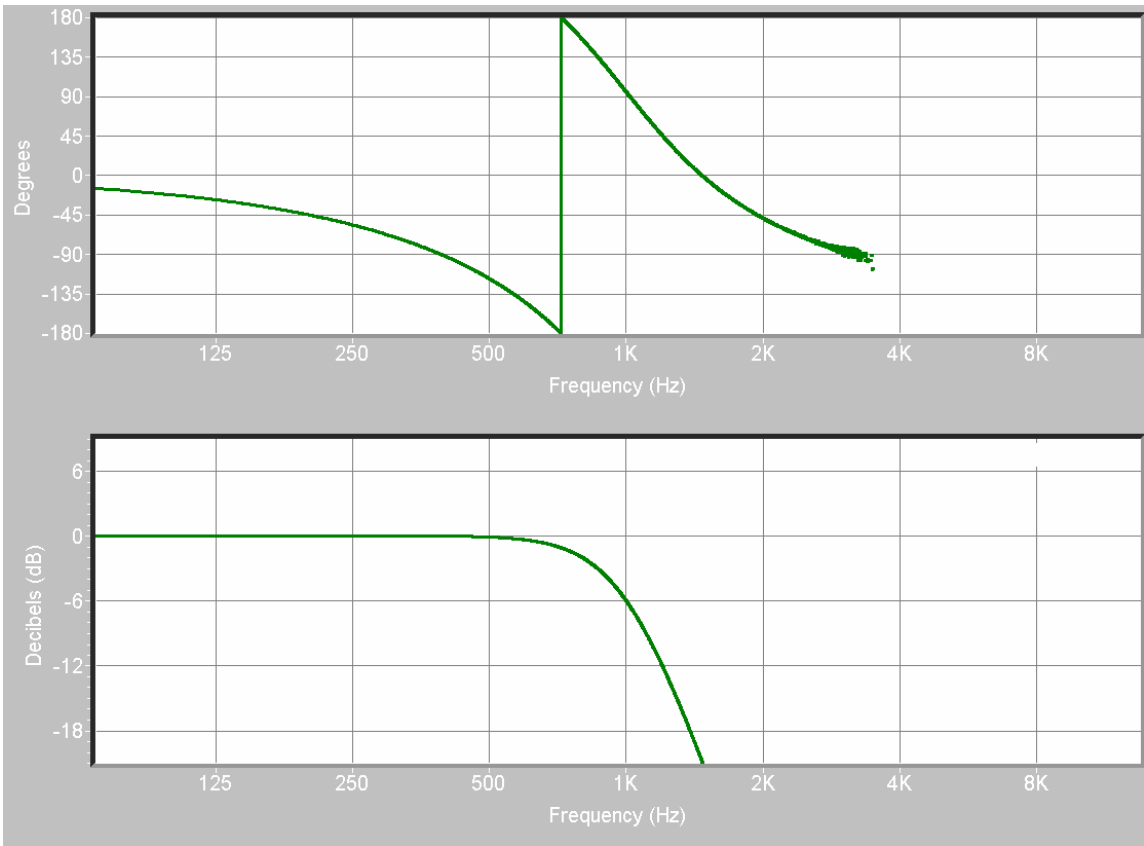


Figure 2 36 dB L-R Low Pass

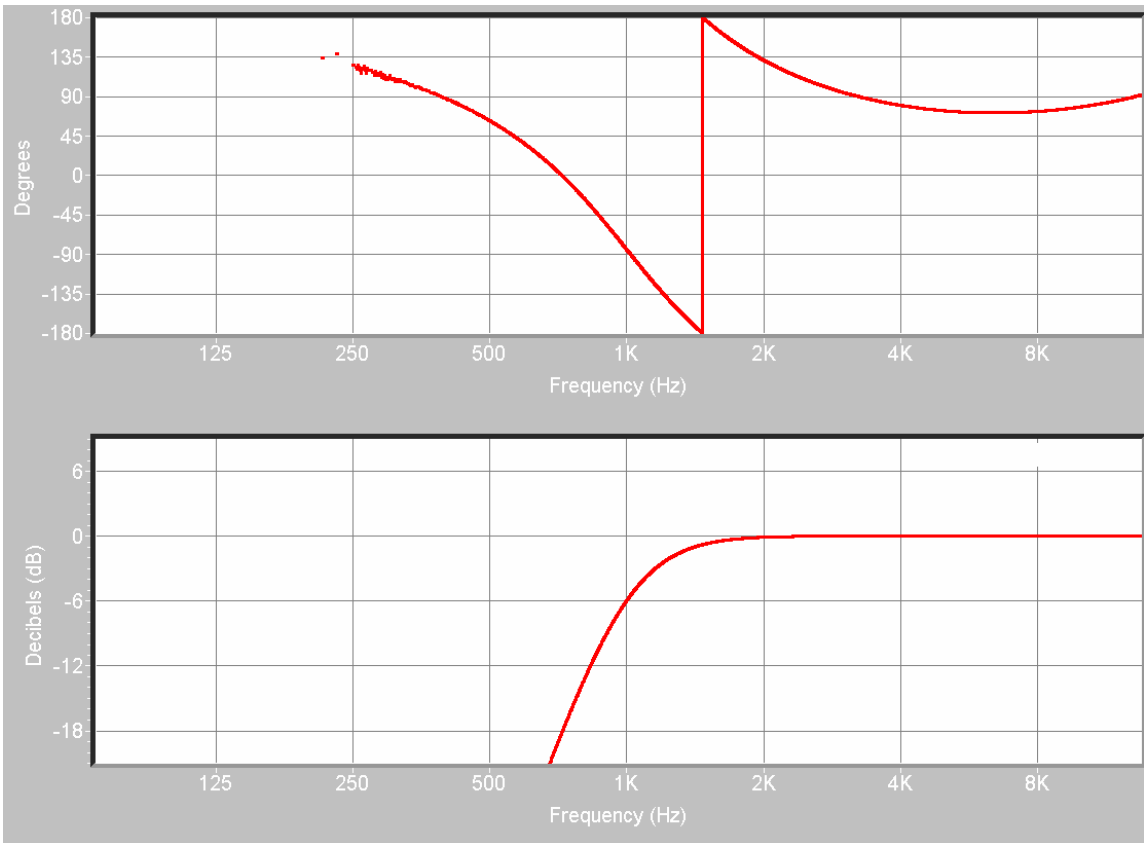


Figure 3 36 dB L-R High Pass

Looking at these figures, you can see that the phase response (shown in the top of each figure) is not the same. When these two crossover channels are electrically summed, a cancellation occurs at the center frequency. The summation of the two crossover channels is shown in Figure 4 in blue.

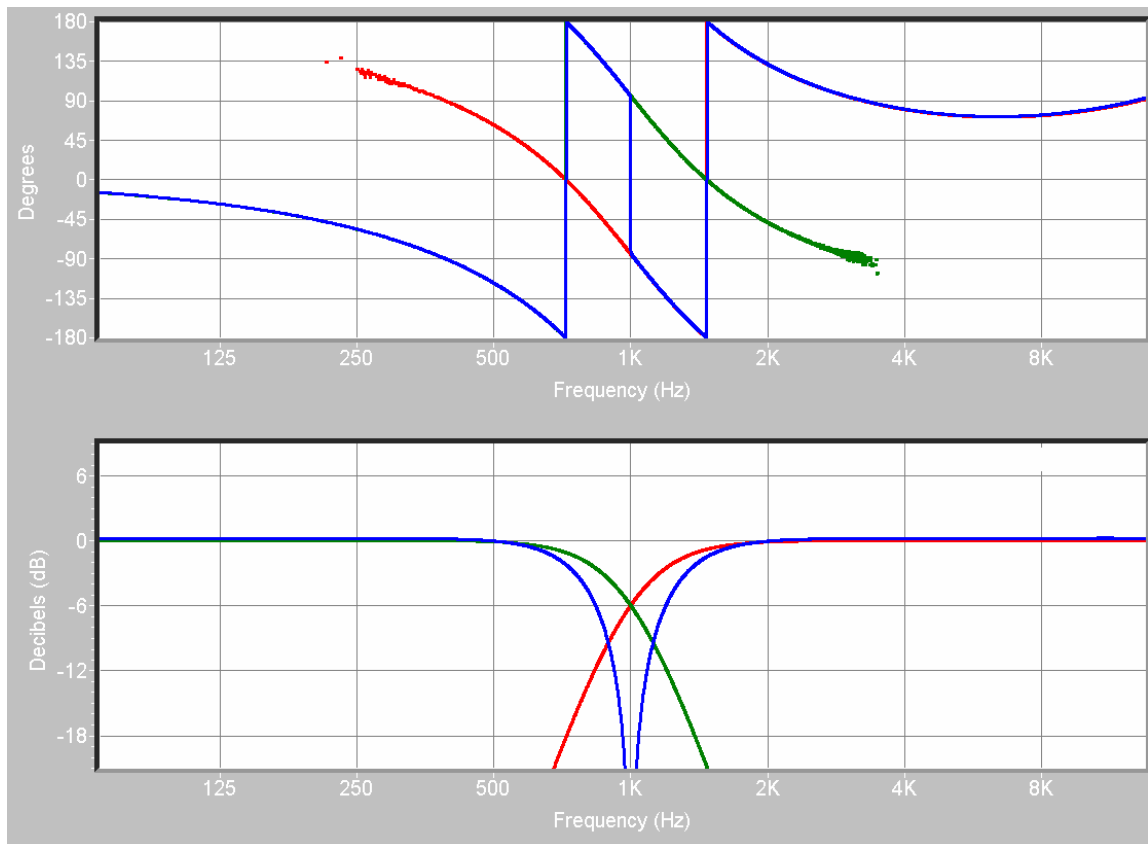


Figure 4 Low and High Channels Summed, Same Polarity

In order to provide the desired constant magnitude summation, the polarity of an output channel must be inverted. You can invert the polarity of an output channel using the Controller while in Designer Mode.

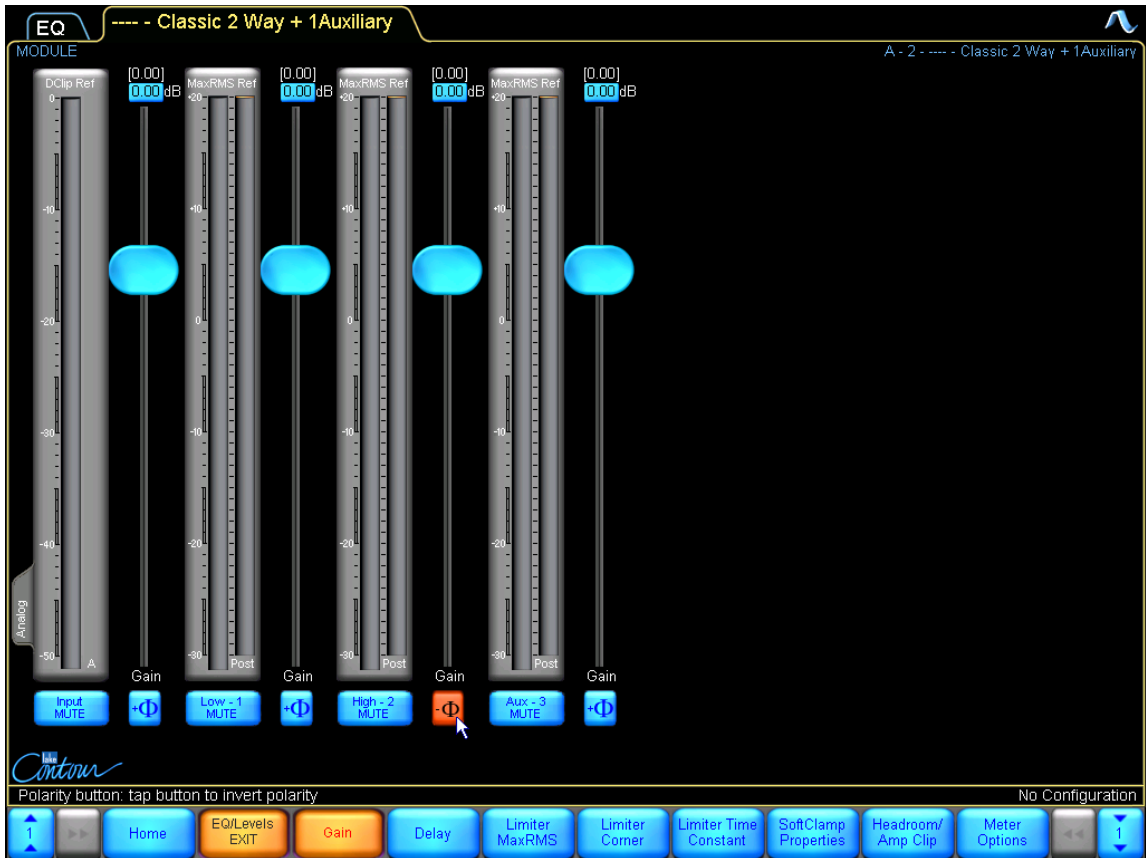


Figure 5 Invert Polarity of the High Pass Channel in the Dolby Lake Controller

Please refer to the *Dolby Lake Controller Manual* for further details.

By inverting an output (in this case we have inverted the high pass output channel), the 36 dB L-R now exhibits the required constant magnitude summation attribute as shown in Figure 6.

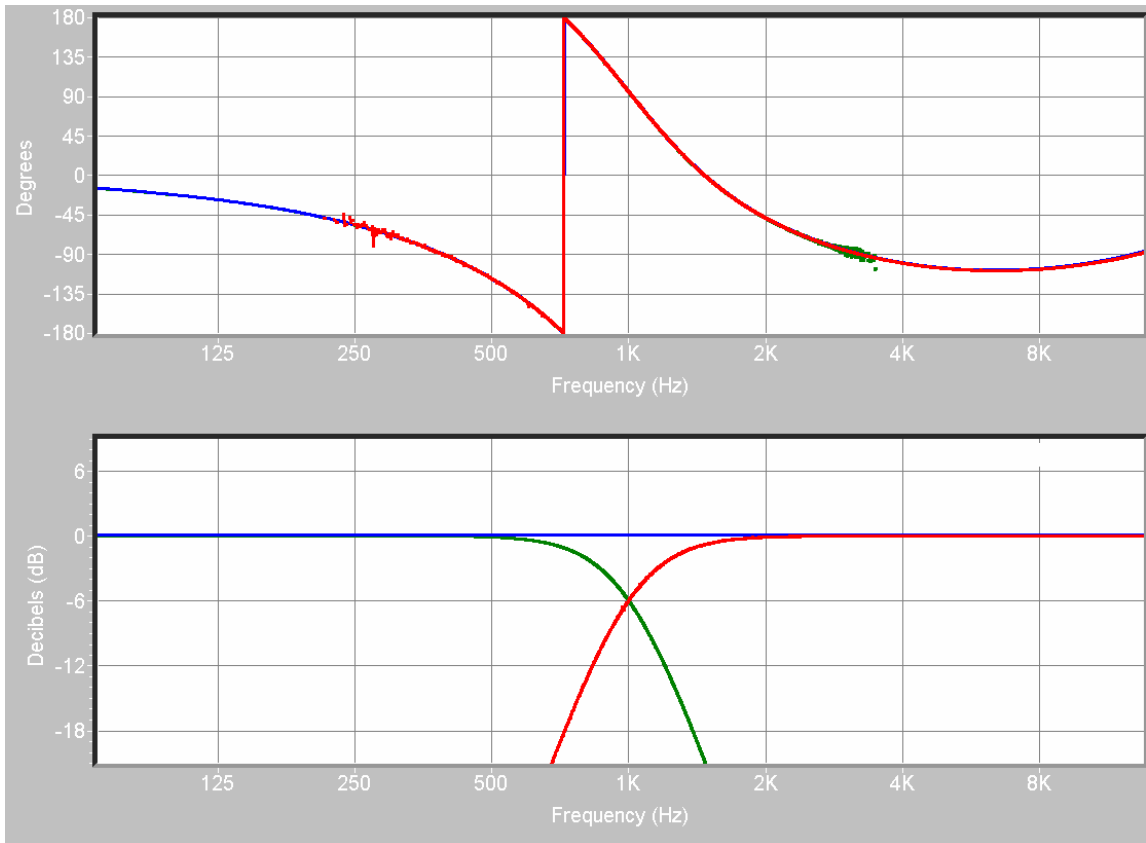


Figure 6 Low and High Channels Summed, Opposite Polarity

The polarity inversion requirement only pertains to 12 dB and 36 dB L-R crossovers.

When you select a 12 dB or 36 dB L-R crossover in the Dolby Lake Controller, a dialog box will be displayed reminding you of the polarity inversion requirement.

2. Butterworth Crossovers

The Dolby Lake Processor provides Butterworth crossovers with transition slopes of 6 dB to 48 dB per octave. The Butterworth filter is specified to provide a Maximally Flat Magnitude (MFM) response. The design of the Butterworth filter constrains the magnitude response to be -3 dB down at the crossover center frequency regardless of filter order².

Since there is not a constant magnitude constraint on the Butterworth crossover pair, the summation of crossover channels does not result in a constant magnitude response.

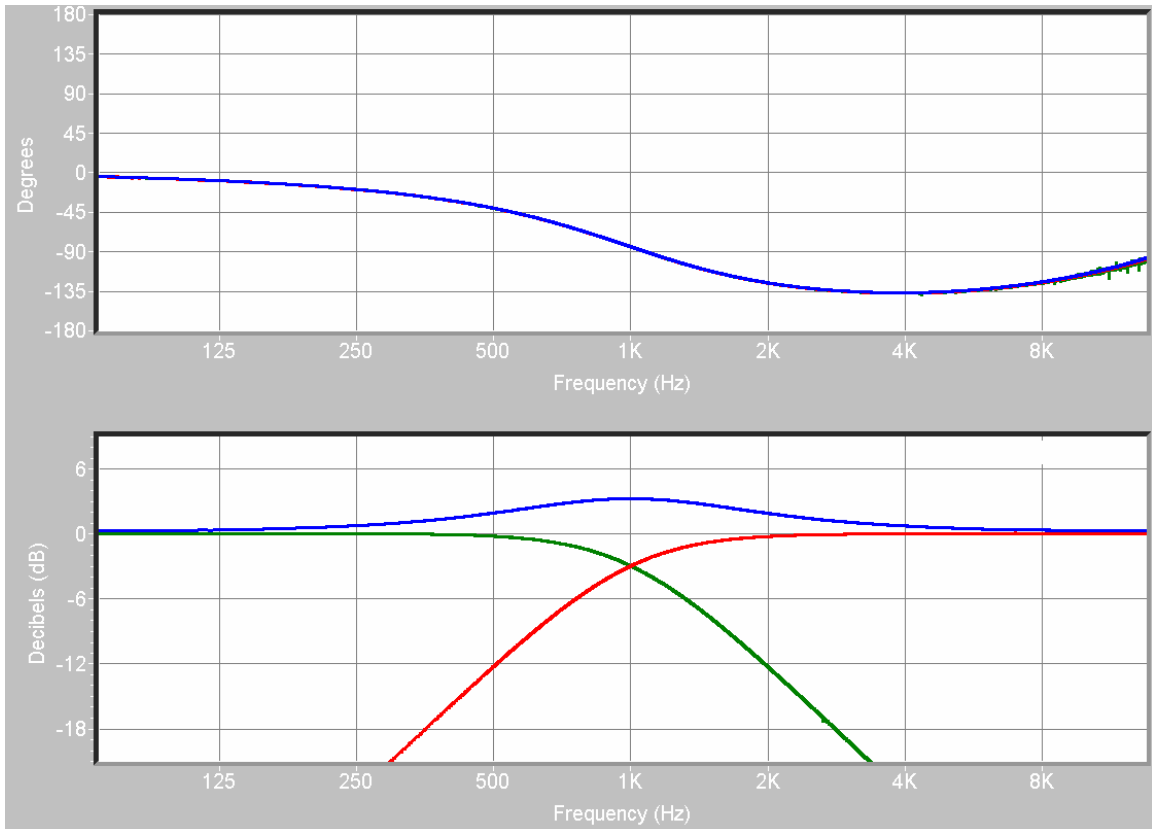


Figure 6 12 dB Butterworth Low and High Channels Summed

3. Bessel Crossovers

The Dolby Lake Processor provides Bessel crossovers with transition slopes of 6 dB to 48 dB per octave. The Bessel filter is specified to provide a Maximally Flat Delay (MFD) response. The design of the Bessel (also known as Thomson) filter constrains the time domain response of the filter. Although the Bessel filter provides poor frequency domain selectivity, it exhibits excellent delay characteristics, resulting in an optimal time domain response².

Since the design constraint for Bessel filters is in the time domain, the frequency domain magnitude specification is undefined. This means that the design of a Bessel crossover filter pair may vary.

A number of magnitude specifications exist for Bessel filter crossover pairs³. These magnitude specifications result in various attributes such as flattest magnitude summation and phase matched pairs.

The Dolby Lake Processor implements Bessel filters as phase matched pairs. The phase matched pair implementation results in reasonable magnitude summation (not perfectly flat) and an optimal polar response.

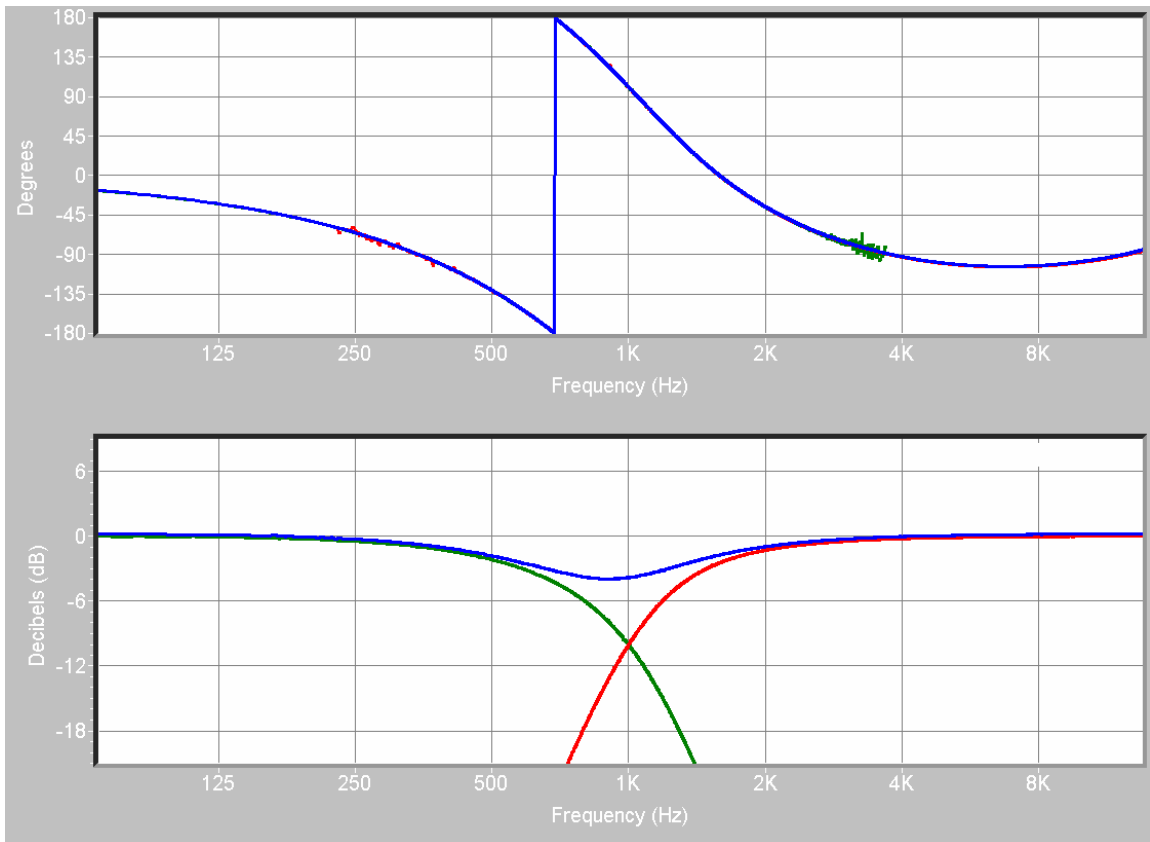


Figure 7 36 dB Bessel Low and High Channels Summed

4. References

- ¹ S. H. Linkwitz, "Active Crossover Networks for Noncoincident Drivers," *Journal of the Audio Engineering Society* 24 (1976); 2–8.
- ² C. S. Lindquist, *Active Network Design*, (Long Beach, Calif.: Steward and Sons, 1977).
- ³ R. Miller, "A Bessel Filter Crossover and Its Relation to Other Types," 105th AES Convention Preprint 4776 (1998).

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