LIR Linear Phase Crossovers
A White Paper from Linea Research

Paul Williams May 2013

LIR - A new ***Linear Phase*** crossover filter technology from Linea Research

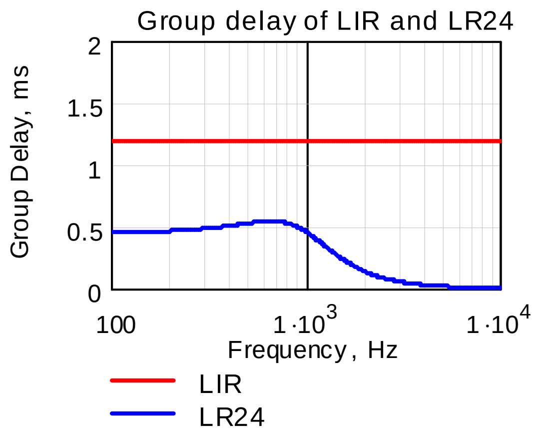
Linea Phase Crossovers

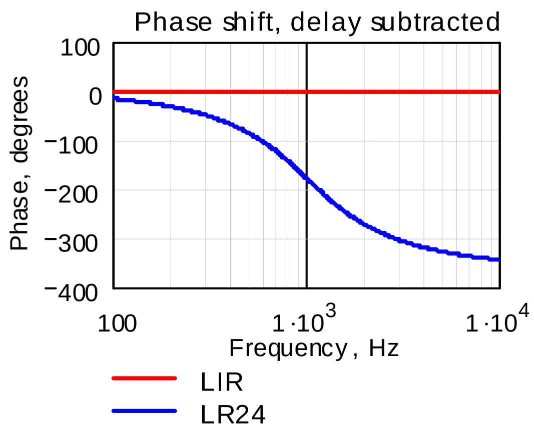
The advantages of using linear phase crossover filters are:

Improved sonics

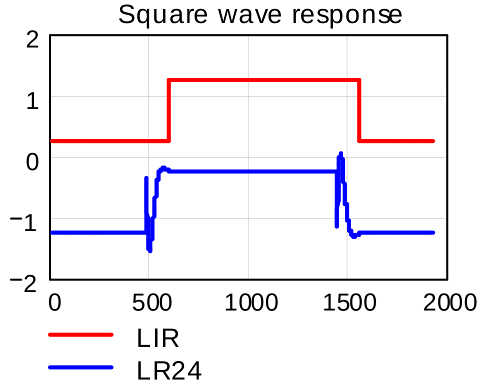
- Although there is no doubt that phase non-linearity can be audible, there remains debate about the threshold at which it becomes so. As we all continue to improve our system components, new weak links become exposed, and deficiencies hitherto thought to be of no consequence become of significance. It is our philosophy that every stage should be as good as we can reasonably make it. If the technology to attain true phase linearity exists, why risk anything less?
- There is evidence to suggest that today's quality high directivity loudspeaker systems which reduce reverberation further expose phase non-linearities which might otherwise be masked.
- In a linear phase system, all the frequencies arrive at the same time, so transient material is better defined. A square-wave input acoustically sums to a square-wave output. This has to be a good thing.

These plots demonstrate the ruler-flat phase and group-delay characteristics of LIR compared with 24dB/Octave Linkwitz-Riley:





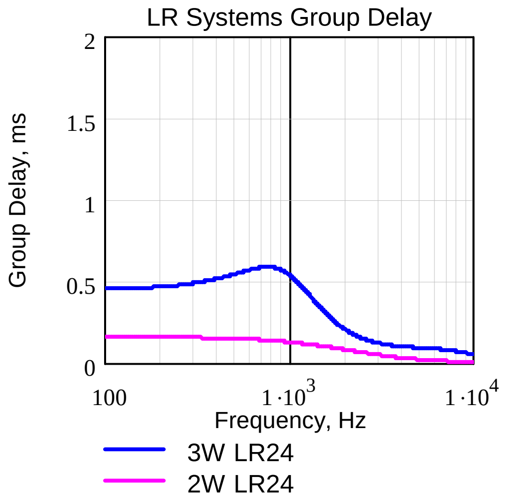
The plot to the right shows the square-wave response of the summed outputs of an LIR crossover as compared with 24dB/Octave Linkwitz-Riley.

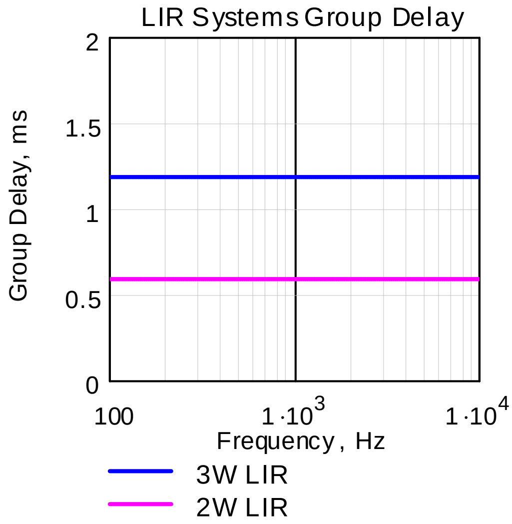


Easier to integrate system components

- Loudspeakers using conventional crossover filters will each have a phase curve 'signature' which will be unique depending on the crossover frequencies, the number of crossover bands, and the order of the filters used. Using dissimilar loudspeakers in an application where they can combine acoustically cannot produce a result which has a flat magnitude response or well behaved polar characteristics.
- Loudspeakers which use linear phase crossover filters will be in-phase with one-another at all frequencies, so it is much simpler to integrate them.

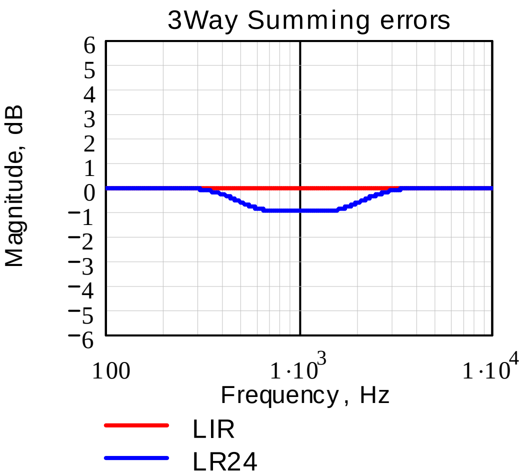
The following plots show the group delay of a system comprising a 2-way loudspeaker with 4th order crossover at 2kHz, and a 3-way loudspeaker with 4th order crossovers at 1kHz and 8kHz. In the first example using Linkwitz-Riley crossovers, no combination of delays will allow these two loudspeakers to acoustically combine in a useful way. Compare this with a similar system using Linear Phase crossovers. A simple delay will align them perfectly so that they both work in sympathy.





Conventional crossover systems only sum correctly in 2-way systems.

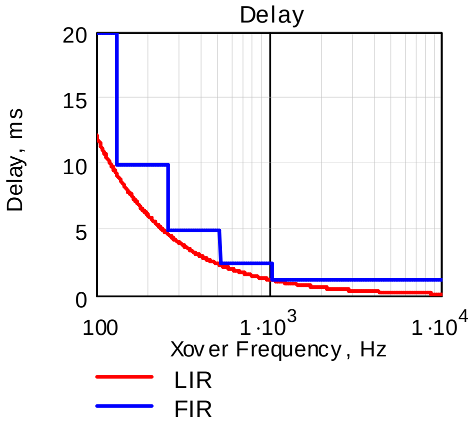
- Conventional systems employing 3 or more drivers (where there are one or more 'bandpass' outputs) do not normally sum correctly due to the phase shift errors caused by the opposing crossover filter. The low-pass filter causes phase errors on the high-pass response and vice-versa. This causes magnitude response and polar errors at both crossover points. The linear phase crossover does not suffer from this problem; the resulting acoustically summed output always has a flat magnitude response and good polar response regardless of the number of bands. The example plot here shows a 3-way system with crossover frequencies at 500Hz and 2kHz, for a Linkwitz-Riley 24dB/Octave crossover, and for a LIR crossover. The response error for LR may not look too significant, but this and the polar response become worse at narrower bandpass bandwidths.



Advantages over FIR based methods

LIR crossover filtering uses a technique developed by Linea Research which does not involve Finite Impulse Response (FIR) filtering. We call the technology “Linear Impulse Response” (LIR) filtering. This employs Digital Signal Processing techniques unique to Linea Research, involving some novel processing such as Impulse Response Mirroring (IRM).

There is nothing wrong with a well designed FIR filter at all, but we did not feel that this is always an appropriate technology for Linear Phase crossover filtering. Here's why:



- LIR crossover filtering exhibits lower latency delay for any given crossover frequency. The plot to the right shows the latency delay through a very low latency FIR design compared with the LIR crossover. You will see that the FIR design always has more latency; twice as much at some frequencies. Many FIR implementations will have latency delays much higher than that shown.
- LIR does not require you to select how much delay you can tolerate; the delay time is always kept to a minimum
- LIR crossover filters are controlled using a simple and entirely familiar user interface; You don't need to select delays, you don't need to select a special mode and you are not constrained by special cases
- LIR doesn't cause you to trade slope or phase linearity against delay. The result is always phase linear phase, always produces the selected slope, and always with the minimum delay.

Brick Wall?

Some FIR implementations of linear phase crossover filters allow very steep crossover slopes to be produced. These are sometimes referred to as “Brick Wall” filters.

We decided that 'brick wall' crossover slopes were inappropriate because:

- They produce audible high-Q ringing artefacts off axis
- Differences in driver dispersion patterns become accentuated

We also note that whilst 48dB/octave crossover filters have been widely available for many years, they are very rarely used, suggesting either that they are not necessary, or they impair the perceived quality of the sound.

We decided therefore not to make a brick-wall response available.

These subjects are discussed in more depth in our white paper “Crossover Filters”. See http://www.linea-research.co.uk/documents.html