CINEXPO WHITEPAPER

Three-way Loudspeakers for the Digital Age

EAW
EASTERN ACOUSTIC WORKS

The Laws of Physics / *The Art of Listening*

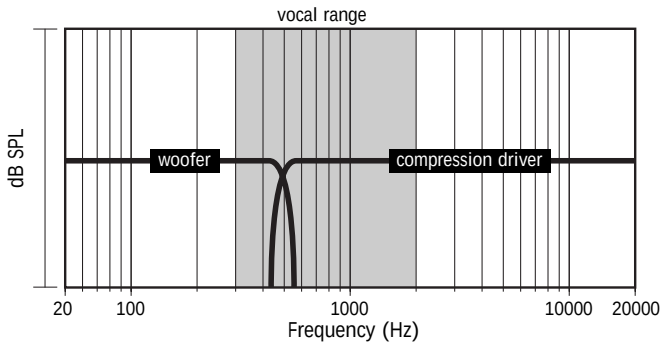
INTRODUCTION

The primary requirement of left/center/right main channel cinema loudspeakers is that they faithfully reproduce the entire audio spectrum from 20 Hz to 20 kHz. While crisp, natural reproduction of the vocal range (300 Hz - 2 kHz) has always been critical to good cinema sound, very high and very low frequencies (above 4 kHz and below 200 Hz) demand particular attention in the age of digital cinema audio. The advent of digital technology has brought sound effects to the very extremes of hearing, filling these ranges with sonic material which today defines the digital age cinema experience.

Traditional two-way cinema loudspeaker design (a large cone woofer and a horn-loaded high frequency compression driver) suffers from an unfortunate 500 Hz crossover placement that robs dialog of much of its warmth. By requiring the high frequency compression driver to cover frequencies as low as 500 Hz, two-way design introduces substantial, audible distortion in the vocal region, leaving voices sounding harsh and hollow.

Similarly, a 500 Hz crossover compromises a loudspeaker's reproduction of extreme high and low frequencies. Transducers (cone or compression drivers) have optimal ranges in which they are most "comfortable" and reproduce sound most easily. When a driver is asked to go beyond its "comfort zone," distortion and/or inadequate response result. While it is possible for a two-way design to employ drivers that cover extreme highs and lows adequately, it would require sacrificing response in other frequency ranges – notably the vocal range.

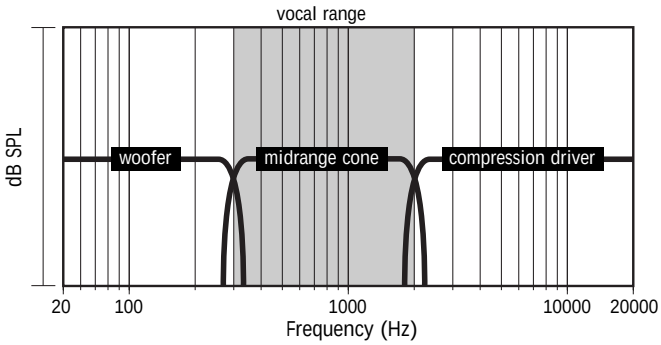
Traditional 2-way loudspeaker design



Finally, for a traditional two-way cinema loudspeaker to achieve adequate pattern control from 500 Hz to 20 kHz, the horn's throat must be of such a size that cancellations within the throat add yet more distortion, typically in the 700 Hz range.

This paper will endeavor to show that by dedicating a subsystem to the vocal region, three-way loudspeakers are better able to handle the new demands of digitally edited, mixed and encoded soundtracks. Compared to two-way designs, three-way loudspeakers improve vocal clarity and warmth, reduce distortion from both horn-throat cancellation and driver excursion, increase the loudspeaker's power handling capability, and improves performance across the audio spectrum including extreme highs and lows.

EAW 3-way loudspeaker design



DIVIDING THE AUDIO SPECTRUM

The audible spectrum spans just under 10 octaves ranging from 20 Hz to 20 kHz (20,000 Hz). Frequency is measured according to a logarithmic scale; for each octave ascended, frequency doubles. If middle "C" is 300 Hz, then the "C" above it would be 600 Hz and the "C" below, 150 Hz.

Since a single transducer can only effectively cover so much of this range, two-way and three-way loudspeaker systems divide the range into high/low- and high/mid/low- frequency sections, respectively.

Our research and experience have shown that a single transducer's comfort zone usually spans no more than three and a half octaves. Yet traditional 500 Hz crossover design requires the high frequency compression driver to cover well in excess of five octaves.

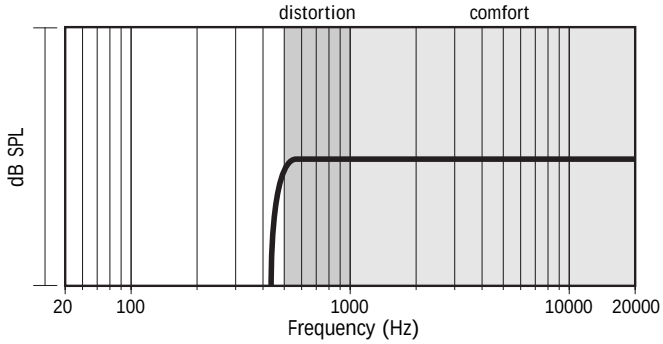
While compression drivers reproduce frequencies above 1 kHz quite well, much higher distortion result below that point due to excessive driver excursion. Critical vocal material in the compression driver's lowest octave (500 - 1000 Hz) falls outside the driver's comfort zone. The resulting distortion gives voices a harsh, unnatural edge sometimes rendering them unintelligible. One cannot overemphasize the importance this holds for cinema sound; without intelligible dialog, the cinematic experience is meaningless.

By dedicating a subsystem to the mid frequency range, three-way loudspeakers effectively eliminate these problems. EAW's three-way designs use large cone woofers, cone driven midrange subsystems and horn-loaded high frequency compression drivers. We place crossover points at specific frequencies selected to optimize the performance of each particular loudspeaker system. In general, the low/mid crossover is set around 350 Hz and the mid/high crossover around 2 kHz.

Simply adding another horn-loaded compression driver to cover the mid frequency range does not eliminate distortion from the vocal range; in fact, it aggravates the problem. If excessive driver excursion at 500 Hz causes a compression driver to introduce significant distortion, distortion at 300 Hz will be even greater. To eliminate distortion from the

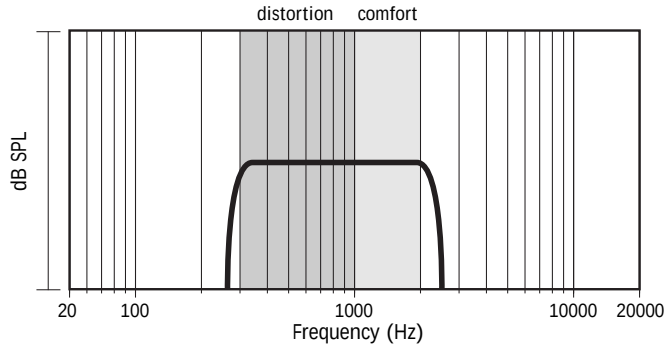
vocal region and give dialog exceptional warmth and clarity, EAW always employs cone drivers for its mid frequency subsystems.

2-way w/ compression driven high frequency



Since three-way design divides the audio spectrum between three subsystems, each only needs to cover a little over three octaves – a range over which each driver can be truly optimized. The high frequency compression driver now operates only in the true high frequency range, meaning better performance in the very high frequency range. Similarly, optimized woofers can better handle the low frequency sound effects that give films that "digital sound."

3-way w/ compression driven midrange



THREE-WAY IMPROVES OUTPUT

The maximum volume (peak output) that a loudspeaker system can generate is related to two factors: sensitivity (output generated by 1 Watt of power as measured at 1 meter) and power handling (the amount of power a loudspeaker can bear before failure).

Horn-loaded compression drivers enjoy excellent sensitivity characteristics but handle relatively low amounts of amplifier power, particularly when driven at very low frequencies (i.e. 500 Hz). By comparison, a horn-loaded, heavy-duty cone driver is somewhat less sensitive but handles substantially more power. The calculated peak output of the cone driven subsystem will be 6 - 10 dB higher than that of an equivalent compression driven subsystem. Higher peak output gives loudspeakers a greater dynamic range throughout the audio spectrum, which particularly improves reproduction of full range musical scores and sound effects. It also permits a greater degree of passive filtering to smooth the total system's frequency response without sacrificing peak output.

ACCURATE WIDEBAND DIRECTIVITY

The ability to put sound where it is needed and keep sound away from where it is not wanted distinguishes well-designed loudspeakers. When a loudspeaker with poor directivity characteristics sends some frequencies at wide angles and others at narrow angles, listeners at the edges of its coverage area will hear some frequencies and not others. Furthermore, uncontrolled soundwaves reflecting off walls and ceilings can create unacceptable reverberations that degrade the sound quality in the entire venue.

The directivity characteristics of a loudspeaker can vary widely depending on the frequency and the size of the sound producing device. The rule of thumb goes as follows: as the length of a sound wave decreases (with rising frequency) to approach the size of the driver cone or horn mouth, directivity narrows; as the sound wave becomes smaller than the size of the driver or horn mouth, directivity becomes too narrow for most applications including cinema. The lower the frequency, the more difficult it is to confine to a narrow angle; the higher the frequency, the more difficult it is to disperse at a wide angle.

Traditional two-way cinema loudspeaker design uses an exceptionally large high frequency horn to provide pattern control at 500 Hz (which it does admirably). But making very high frequency sound waves "fill the bell" of the horn requires an exceptionally long horn throat. So long, in fact, that cancellation effects within the horn throat cause significant, audible distortion in the 700 Hz region. Smaller format high frequency horns one encounters for smaller cinemas produce much less distortion, but lack the necessary pattern control at 500 Hz.

By asking each subsystem to cover a smaller range than two-way designs, three-way loudspeakers can control both mid and high frequencies without introducing distortion. EAW's larger three-way cinema designs – CB223 and MC4972 – employ smaller format high frequency horns with very short throats. Since they don't need to control sounds in the 500 Hz range, their size is quite manageable. These horns disperse the highest frequencies across a wide area without noticeable distortion. Our smallest three-way cinema system, CB150, loads a compression driver on our shallow, throatless Wave Guide Plate™ giving high frequencies an exceptionally smooth character.

EAW's proprietary manufacturing techniques allows us to produce the most mathematically accurate mid frequency horns in the industry. Automated saws and routers cut grooves in the enclosure that accept a flexible hardwood veneer shell which acts as a form for structural foam which we inject into the enclosure. The foam/veneer horn provides much greater rigidity than fiberglass horns, allowing it to control mid frequency sound waves with greater ease.

continued

CONCLUSION

The digital age of cinema audio demands more from loudspeakers than ever before and the systems designed for cinema use must keep pace. Sound effects at the extremes of the audible spectrum have come to define the digital age cinema experience and require updated loudspeakers to accurately reproduce them.

Three-way loudspeakers allow drivers to operate in more narrow, optimized ranges, eliminating the distortion that results from excessive driver excursion. These optimized drivers can then cover their intended frequency ranges more effectively, without sacrificing response at extreme frequencies. Since three-way design does not ask a single horn to control directivity from 500 Hz to 20 kHz, pattern control can be optimized without introducing distortion. EAW three-way loudspeakers employ only cone drivers for their mid frequency sections, providing better power handling and, when necessary, greater peak output than two-way or three-way systems using horn-loaded compression drivers for the midrange. EAW's cone driver, selected for their optimal mid frequency response, reproduce dialog with exceptional clarity and warmth.

By moving to accept three-way loudspeaker design as the new standard for digital age cinema sound, forward-thinking exhibitors can offer audiences the full advantages of digitally recorded, mixed and edited soundtracks which, until now, have only been enjoyed in production studios' private screening rooms.

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