QSC CINEMA

WHITE PAPER

Cinema Intrinsic Correction

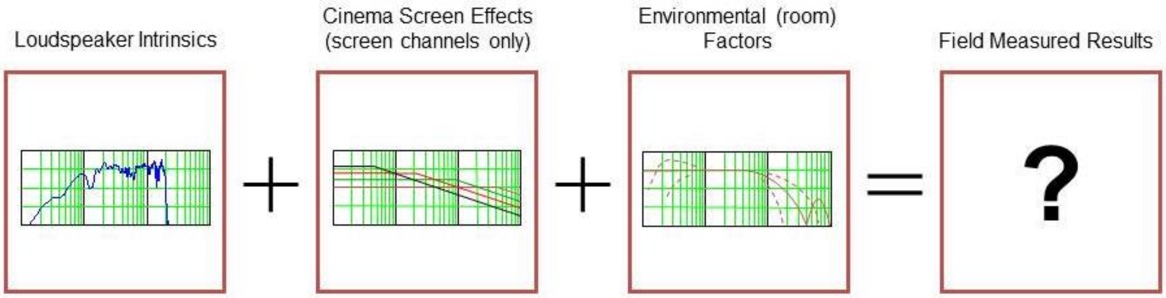
Once a cinema sound system is installed in a room, it has been common practice to conduct a final process known as “tuning” to optimize the system’s performance in a given acoustical space. Program material and filtered “pink” noise is played through each individual loudspeaker. The typical process includes setting up one or more measurement microphones in various seating locations to collect audio samples, averaging the inputs from the various microphones (also known as “spatial averaging”), and then viewing a graphical representation of the response on a real-time analyzer (RTA). The shape of the curve appearing on the display of the RTA is intended to represent the total power response of the loudspeaker; it’s generally believed that the “flatter” the line, the better.

To achieve the flattest line possible, system engineers have traditionally used electronic graphic equalizers, which simply increase or decrease the electrical drive signal going into the amplifier at various one-third octave frequency bands. Gain (increase) or attenuation (decrease) adjustments are made which roughly correspond to the various peaks and dips seen in the RTA display. If necessary, adjustments are made to approximate the so-called “X-curve” high frequency roll-off standard.

While the process sounds simple, it’s complicated by the fact that there are at least three factors which contribute to the response seen on an RTA. If the response shows unusual peaks and dips instead of the desired curve, it’s nearly impossible to separate which of these factors may be causing the problem, or the degree to which each or all three of them may be contributing to it.

Some might assume that causal factors don’t matter – that we only need to correct the observed deficiency with equalization filters without regard to what caused the deficiency – but that simply isn’t the case. In fact, the process itself is fraught with errors, and unsatisfactory results are often made worse by the very measures intended to correct them.

Three Factors Affecting Measurement Results



1. Loudspeaker Intrinsics – These refer to inherent characteristics of the loudspeaker and its components. These intrinsics are the result of natural physics; with current transducer technology, they are unavoidable, regardless of quality or cost. These intrinsics result in frequency response anomalies which cannot be corrected in the field, since their effects cannot be isolated from the other causal factors in the room.

2. Cinema screen (screen channel loudspeakers only) – It seems intuitive that placing any barrier in front of a loudspeaker will affect the sound measured and heard on the other side of the barrier. A standard perforated screen certainly qualifies as a barrier since most screens are only about 4% to 7% porous. It is known that perforated screens cause significant high frequency roll-off, and they also affect the dispersion characteristics as measured—and heard—on the "listener" side of the screen.

3. Environmental factors – These refer to the absorption of high frequency energy at the molecular level (air absorption), and what sound professionals call "room effects" – conditions caused by the acoustical and physical characteristics of the room. Because no two cinema rooms are alike, the effect environmental factors can vary widely from room to room. Room dimensions, furnishings, environmental noise, and room surfaces are just a few of the things that contribute to the overall acoustical environment.

At QSC™, research is constantly underway to explore all of these factors to gain a comprehensive understanding of how each of them impacts the overall listening experience heard at each seating location in the audience.

In this paper, we'll explain how QSC addresses the first of these factors – loudspeaker intrinsics.

The First Link in the Chain

QSC has developed a new and reliably consistent, easy-to-use method for correcting loudspeaker performance. We call this process "Cinema Intrinsic Correction™" because it corrects the intrinsic behaviors of cinema loudspeakers, removing any anomalies from the equation of factors that affect measured response and, ultimately, the quality of sound.

Over the last several decades, it's been common among audio manufacturers to provide equalization pre-sets tailored to a specific loudspeaker model. These "pre-conditioning filters" are recommended signal processing settings, typically implemented in DSP (digital signal processing) before the power amplifier.

But Cinema Intrinsic Correction is much more than the application of preconditioning filters. It is an exacting process of loudspeaker characterization, qualification, and correction.

Objectives of Cinema Intrinsic Correction

Cinema Intrinsic Correction simplifies the process of achieving good sound in the actual cinema because it addresses many potential issues before the sound system is ever installed. Its main objectives are:

- Accurate acoustic replication of the composite electrical input within the spatially-averaged nominal coverage of the loudspeakers.
- Correct for inherent performance deviations of transducers and sub-systems.
- Provide easy to use, performance reliable system set-up tools that deliver consistent and predictable quality results.
- Enable reasonable and appropriate user adjustments and features that will not imperil critical system alignment functions.

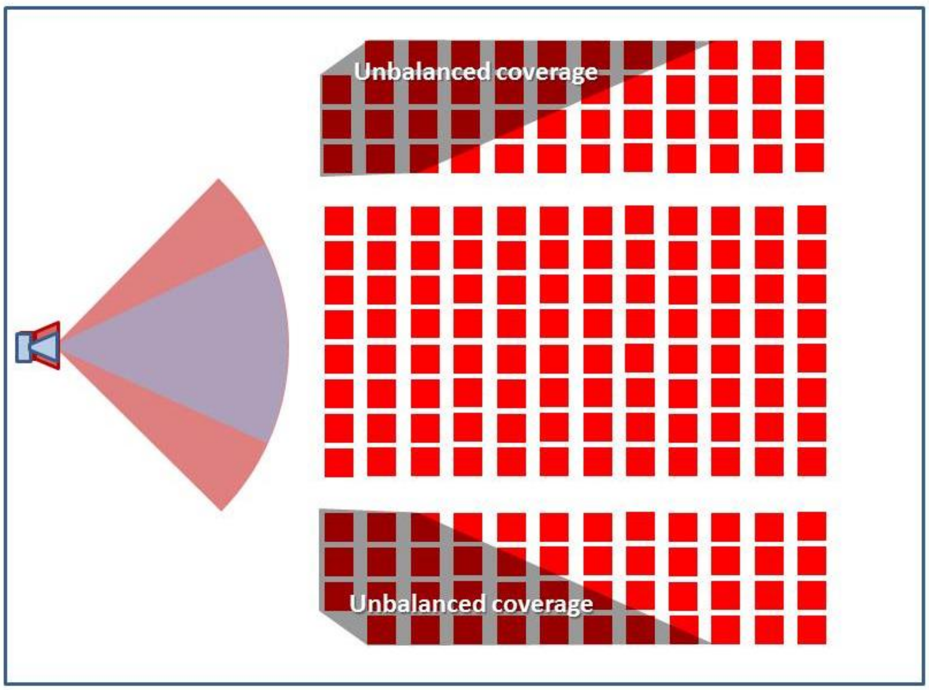
Prerequisites for Success

At the device level, the successful implementation of Cinema Intrinsic Correct depends on three characteristics, which are addressed at the design and manufacturing stage of product development.

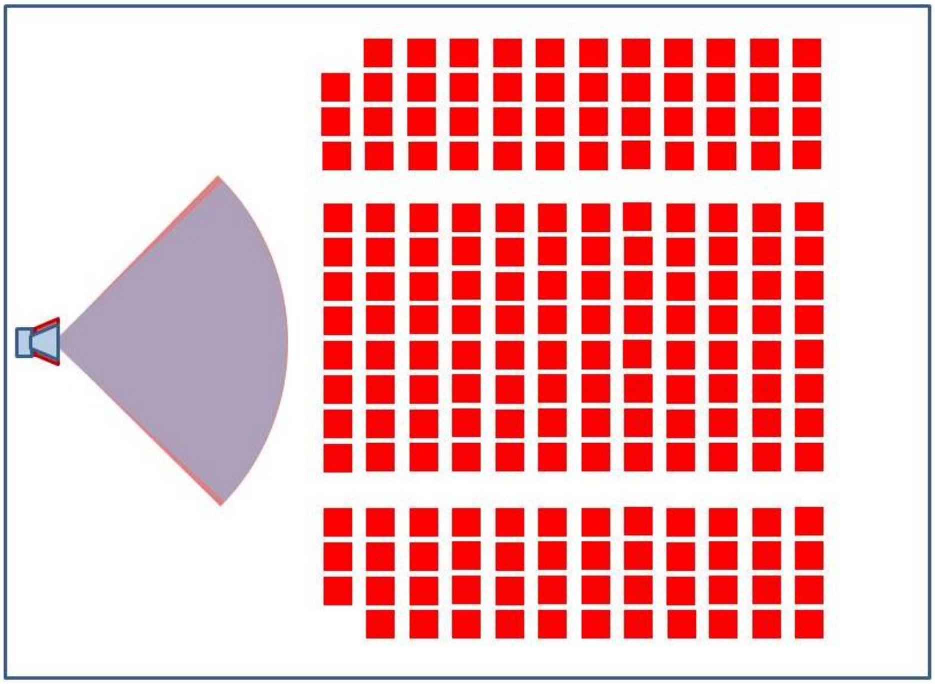
First, each subsystem (LF, MF, HF, etc,) must be properly designed to **exhibit minimal power compression**; that is, the output must remain "linear" (or constant) with respect to the input throughout its specified frequency range. Achieving this requires careful attention to every aspect of the loudspeaker design, including choice of materials, construction, and matching of each individual part and subsystem.

Next, it's critical that the loudspeaker provide sound coverage that is **spatially consistent throughout its specific coverage pattern**.

At QSC, we use a design methodology called "Directivity Matched Transition" (DMT), which matches the directivity of low and high frequency components in the crossover frequency region, resulting in smooth frequency response throughout the coverage pattern of the loudspeaker. One characteristic of a loudspeaker designed with DMT is an axisymmetrical cover pattern, which radiates its power equally in all directions. Our research has shown that conventional asymmetrical HF horn patterns (such as 90 x 50) make it impossible to achieve smooth coverage at the crossover frequency, since directivity control is not possible for the LF component. DMT involves choosing the right crossover frequencies, driver configurations, mechanical alignment, and horns to create a speaker that is well behaved in coverage and time of arrival.



A mismatch of the LF and HF horizontal coverage patterns at crossover can result in unbalanced coverage for up to 25% of the audience.



QSC Directivity Matched Transition results in coverage that lets the entire audience hear balanced sound.

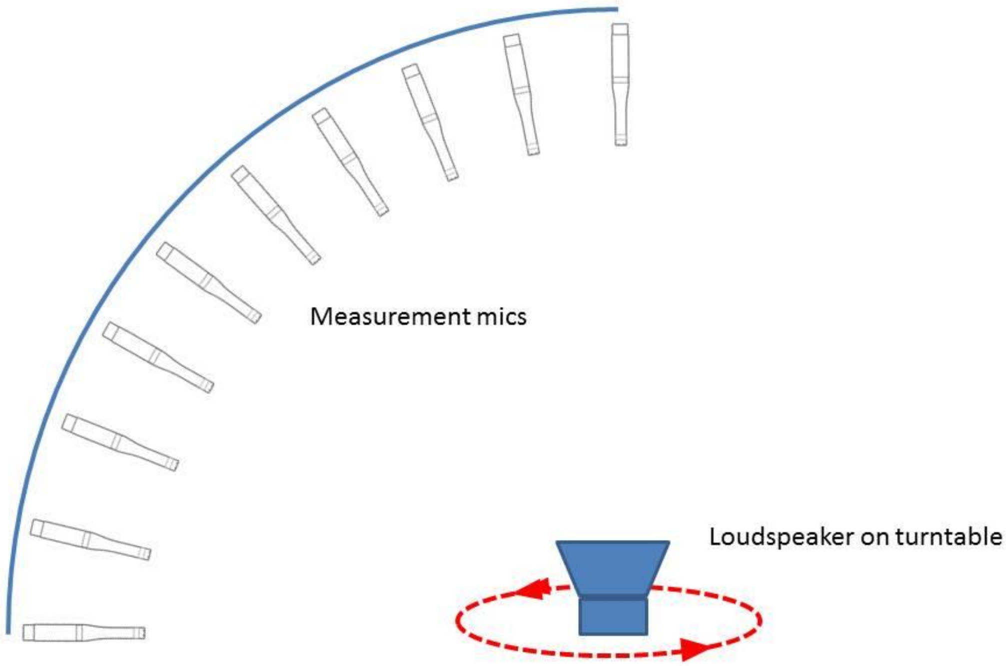
Finally, manufacturing production tolerances must provide for **a high degree of unit-to-unit consistency**. Cinema Intrinsic Correction assumes that the loudspeaker installed in an actual cinema will perform nearly identically to the one tested and measured in the laboratory. When such tight production tolerances are achieved, the predetermined signal processing settings can be reasonably assumed to produce the same results as those achieved in the lab.

Steps to Achieve Cinema Intrinsic Correction

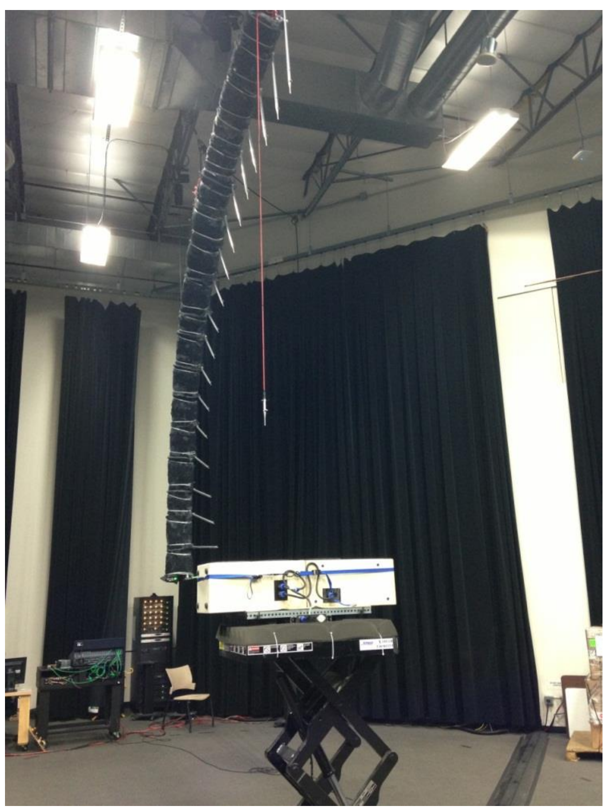
Correcting loudspeaker intrinsics is a laboratory process involving a sophisticated process of spatial averaging to characterize the loudspeaker response, followed by the appropriate application of preconditioning filters. There are four major steps in the process.

1. Start with a good loudspeaker design. Cinema Intrinsic Correction begins at the product design stage, following the guidelines previously discussed in the "Prerequisites for Success" section of this whitepaper.

2. Characterize the loudspeaker. The hemispherical radiation pattern of a sample loudspeaker model is measured in the lab using a specially-designed rig. This process allows us to see exactly what the loudspeaker is doing at each point in its coverage. In order to properly characterize a loudspeaker in the laboratory, extensive measurement is necessary, typically involving 60 to 75 free-field measurements, which are then reduced to a spatial average.

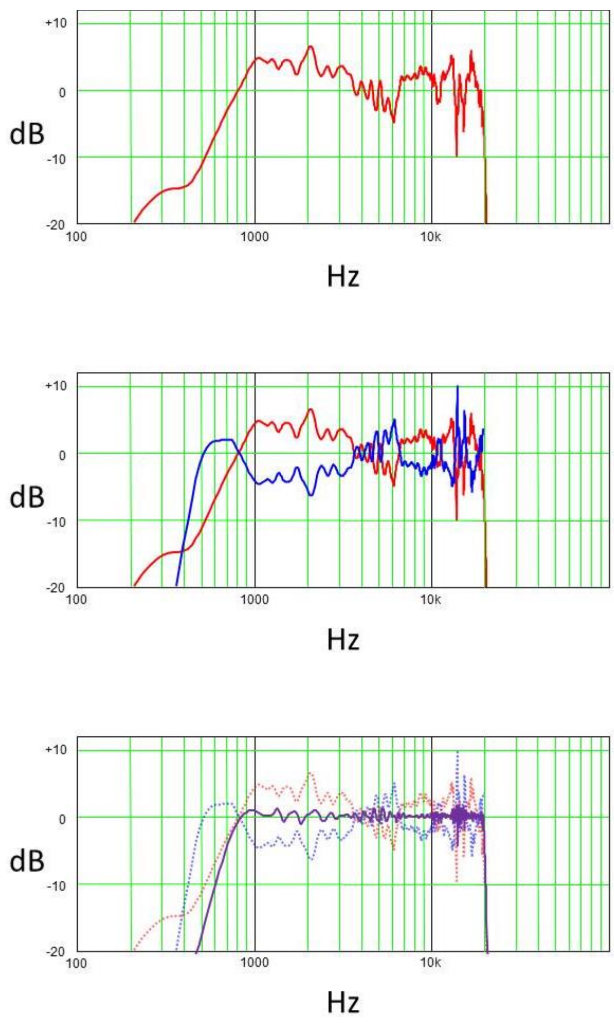


A large number of specially-calibrated measurement microphones are mounted on a 90 degree arc. A loudspeaker is rotated on a turntable; at each degree of rotation, a series of measurements are made, resulting in a full 180 degree hemispheric series of measurements which capture the sound of the loudspeaker in every direction of its sound radiation.



The actual test rig in the QSC sound laboratory.

3. Average the responses using the QSC averaging process. We then take the average response of all microphone measurements, and generate an inverse FIR filter. Once the spatially averaged response of the loudspeaker is determined, the filter is applied to adjust this response to a "flat" bandpass target. A complex digital Finite Impulse Response (FIR) filter is used in order to achieve highly-detailed correction with minimum latency (time delay due to processing time). This correction is essentially an upside-down "mirror image" of the original, unaltered loudspeaker response. When the two are combined, a more flat power response is possible.



A curve is generated representing the unaltered response of the loudspeaker (top, red line). Then, an inverse of that response is created using FIR filters (middle, blue line). When the two are combined, the result is a much flatter response (purple line, bottom).

4. Use only broad-band equalization to adjust the LF and HF response. Equalization is the process of boosting or cutting the electrical signal applied to the amplifier and loudspeaker at specific frequencies or bands of frequencies. The proper application of equalization filters depends on careful adjustment combined with an accurate method to monitor the results of these adjustments. Unfortunately, the traditional method of monitoring results (viewing the spatially-averaged response from 1 to 4 microphones on an RTA) doesn't always produce visual resolution that's high enough to see exactly what is happening when 1/3-octave equalizers are applied. In laboratory analysis, we have found that 1/3-octave equalization, while effective when judiciously and minimally applied, can often prove to worsen the overall response of the loudspeaker. While the RTA display may show a fairly flat response, human hearing can detect dips and peaks which are invisible on the screen, especially in the critical 300 Hz to 2 kHz "speech" band, which is critical for dialog intelligibility.

Cinema Intrinsic Correction results in the proper level of equalization and other processing necessary to achieve good response from a given QSC loudspeaker. Field adjustments should only be necessary (if at all) to address screen HF loss or low frequency (below 300 Hz) room effects. Even in these circumstances, the use of broad-band equalization filters with minimal boost or cut (no more than 3 dB) should be used. Parametric equalizers are preferable since they allow you to adjust the "Q" or filter width, allowing a broader equalization curve than is possible with a fixed-width 1/3-octave graphic equalizer.

Cinema Intrinsic Correction in the Real World

Once Cinema Intrinsic Correction settings are determined for a specific loudspeaker, they are made available to cinema technicians and can be uploaded to a QSC DSP-based signal processor with IIR (Infinite Impulse Response) and FIR (Finite Impulse Response) filters. For modern cinema applications, we recommend Q-SYS™, our most powerful, integrated scalable networked audio platform.

The QSC Q-SYS Core 110c

Cinema Intrinsic Correction is used to correct inherent device characteristics by themselves and in isolation. Once loudspeaker intrinsics are corrected, we can then address other factors that affect good sound in the cinema.

While a body of knowledge is continually being developed, we do know that if the performance of a screen channel loudspeaker behind a screen is optimized and relatively flat up to its high frequency limit, then the primary effect of the screen is a roll-off of high frequencies, conveniently approximating the X-curve.

That leaves environmental correction for the user, if it’s necessary. With the exception of very low frequencies, a Cinema Intrinsically Corrected loudspeaker with flat spatially averaged response and well-behaved power response will usually require no equalization to fall within +/- 3 dB of the X-curve. Depending on room volume and proportions, one might need to trim the low frequencies a bit, and if there is a very long propagation distance, make correction for high frequency absorption. The Q-SYS Core processors provide the foundation for implementing Cinema Intrinsic Correction and any other signal processing that may be required to compensate for screen or environmental effects. QSC Cinema Intrinsic Correction implemented via Q-SYS effectively removes one variable from the equation of factors that affect good cinema sound, by providing the cinema technician with what was once thought impossible: a lab-tested “standard” for every field application.