



TECHNICAL WHITE PAPER

THE BENEFIT OF USING SPEAKER TUNINGS FOR COMMERCIAL LOUDSPEAKERS



EXECUTIVE SUMMARY

The use of speaker tunings is commonplace in high-performance environments that require line arrays and multi-transducer speakers. However, even in commercial applications with full-range speakers, it's important to have proper speaker tunings to manage the voltage and frequencies going to the transducers in order to maximize quality and efficiency while preventing damage. In this white paper, learn some of the technical considerations behind why this damage can occur and discover how speaker tunings address these issues.

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A PRIMER: AMPS AND SPEAKERS WORKING BETTER TOGETHER

Any audio engineer will tell you that you never buy an amplifier or speaker in isolation. You select the amplifier based upon the speakers you're driving, and you select the speakers depending on your sound application. The space you're trying to fill with sound and the application you're addressing will ultimately determine the sound pressure level (SPL) you need to get out of the system. SPL, measured in decibels, denotes how loud the sound is within the space. Depending on your SPL requirement, you select your speaker(s) and that determines how powerful and how many amplifiers you will need.

In other words, your amplifiers and speakers work together, and this is important, because your speaker selection not only determines the size of your amplifier, but also affects how you set up your amplifier as well. The speaker is the point at which audio is converted from electrical energy into acoustic energy (ie, sound waves), with each speaker having specific physical attributes that determine the nature of the sound you are hearing. Ensuring the audio sent to the speaker is optimized to its physical attributes is vital in both producing high quality sound and protecting the lifespan of the equipment. This is why speaker manufacturers like JBL Professional provide speaker tunings to help sound engineers optimize the audio reproduced by the speakers.

Speaker tunings aren't a new concept, but often, people will associate them with two- or three-way speakers or with array speakers, because these types of speakers require crossovers and delays to make the system work correctly. It has not been as common in the past to get factory-recommended tunings for simpler, full-range loudspeakers, but there are some real benefits to using tunings with these speakers.

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BAND-PASS FILTERS: WHEN NOT ALL FREQUENCIES ARE CREATED EQUAL

In order for speakers to generate soundwaves, they need to physically move the air. Lower frequency soundwaves have longer wavelengths and creating them requires more air movement and physically larger speakers. Because of this, speaker transducers designed to produce lower frequency signals require more power (measured in watts). Higher frequency soundwaves have shorter wavelengths, which means less air movement. Comparatively, high frequency devices such as tweeters and compression drivers are smaller in physical size and generally require less power.

This is important because each speaker transducer is designed to generate a specific range of frequencies and by design, handles the amount of power required to generate those frequencies. If you send the transducer more power than it can handle, it will overheat and fail. Additionally, if you send frequencies to a transducer that it isn't designed to produce, in a best case scenario you're wasting power and adding distortion, and in a worst case scenario you are in danger of damaging the transducer. Technical data on speaker systems can be found on the spec, data, or cut sheet. It will include the power rating and frequency range that the speaker will be able to handle to assist in choosing the amplifier needed.



In two- and three-way speaker system designs, a crossover network is used to direct some frequencies to one channel of the amplifier and other frequencies to another channel. A frequency point is set on the crossover network where the amplifier channel handling higher frequencies delivers those signals to the compression driver or tweeter, and the amplifier channel handling the low frequencies delivers those signals to the woofer or subwoofer. That way, you're only sending frequencies that each speaker component is designed to handle and you aren't wasting energy and possibly damaging the speaker components.

In full-range speakers that get driven from a single, full-range amplifier channel, an internal crossover network is used to passively direct frequency signals within the enclosure. These passively crossed speaker systems also benefit from specific tunings because they also have limitations regarding which frequencies can be reproduced and how much power they can handle. For example, sending a speaker frequencies that are below its cabinet tuning can cause distortion or damage, even if you aren't sending a substantial amount of power.

Adding a high-pass filter, tuned to a specific speaker, will prevent this distortion or damage, which is important because many users love to crank the bass in order to get strong low frequency output. For example, DJs often equalize the system in a way that boosts the bass to get the energy they want to empower creative mixing. Similarly, in school gymnasiums, cheerleaders and drill teams often want to dance to music with heavy bass. Even someone shouting into a microphone can overdrive a speaker system. Unfortunately, there are many situations that have the potential to cause distortion or to damage loudspeakers, because users don't know how much bass is safe to output. While some speakers will sound stressed when overdriven, others may sound fine—right up until the point when they blow.

To protect the speaker system from low frequency damage, it is important to add a high-pass filter to roll off damaging low frequencies before they can reach the speaker. This is important for all applications and both active and passive speaker systems. There are several ways that outputting too much bass can damage the speaker, but here are two of them:

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The first issue to be concerned about is potential damage through over-excursion of the low frequency driver (i.e. woofer). If you have ever seen a cone speaker move or vibrate in and out, that movement is called “excursion.” If a speaker is sent a lower frequency than it is designed to generate, the speaker will try to reproduce that frequency and in doing so may try to move beyond its physical capability, which can damage it. This can happen even at power levels below the speaker’s power rating, if the frequency is low enough.

In ported cabinets, also known as bass reflex or vented systems, there is additional potential for damage. Many speaker systems use port tubes that are tuned to a frequency at or just above the lowest fundamental frequency that the woofer is capable of reproducing. This is done so that the system can produce the maximum amount of bass it is capable of reproducing safely. Whatever power the speaker is rated to handle, the speaker can handle at its full rated power, but only down to that frequency.

The danger comes in when the program material goes below that frequency. At those especially low frequencies, it is possible to damage the woofer with considerably less power than the woofer is rated to handle. By using a protective high-pass filter set to the correct frequency, you will protect against accidentally damaging the woofer with bass frequencies that are below the port tuning.

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CONSTANT VOLTAGE SPEAKER TUNINGS: BETTER SOUND WITH FILTERS

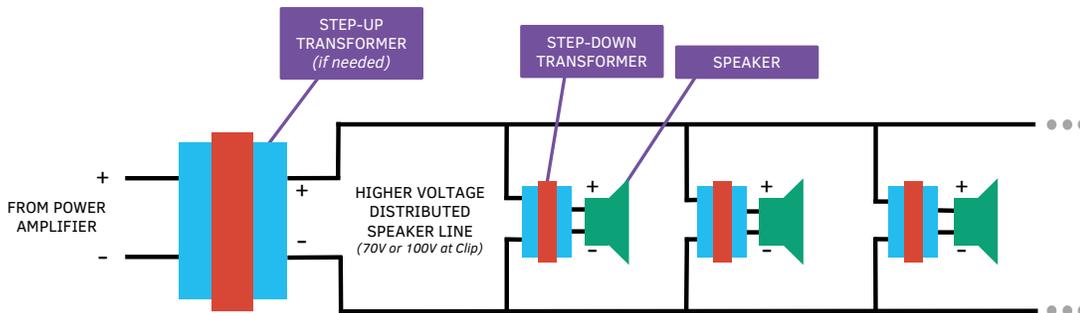
So far, we’ve been talking generally about low-impedance (4 ohm or 8 ohm) speakers. However, there are particular considerations when it comes to constant voltage speaker systems – also known as distributed audio, 70 Volt (in the US) or 100 Volt (outside of the US) systems.

Constant voltage audio systems – which are designed to distribute audio to large numbers of speakers along long cable runs tied to a single amplifier channel – employ a method that electric power companies have long used to distribute power over long distances. When electric companies run power through miles of cable, they minimize resistive power loss (electricity that dissipates as it crosses over a wire) by running it at high voltage and low current. To do this, they use a step-up transformer at the power station and a step-down transformer at each customer’s location. This reduces power loss due to the resistive heating of power cables.

The use of the constant voltage concept in the design of distributed sound systems allows the ability to cover large spaces that require large numbers of speakers without the added expense of using multiple amplifiers. Over the years, manufacturers have been able to improve the design of these systems both from the amplifier side and the loudspeaker side of the system to maximize quality as much as possible, such that most of the audio quality issues in modern constant voltage systems are now related to not using the appropriate filters.

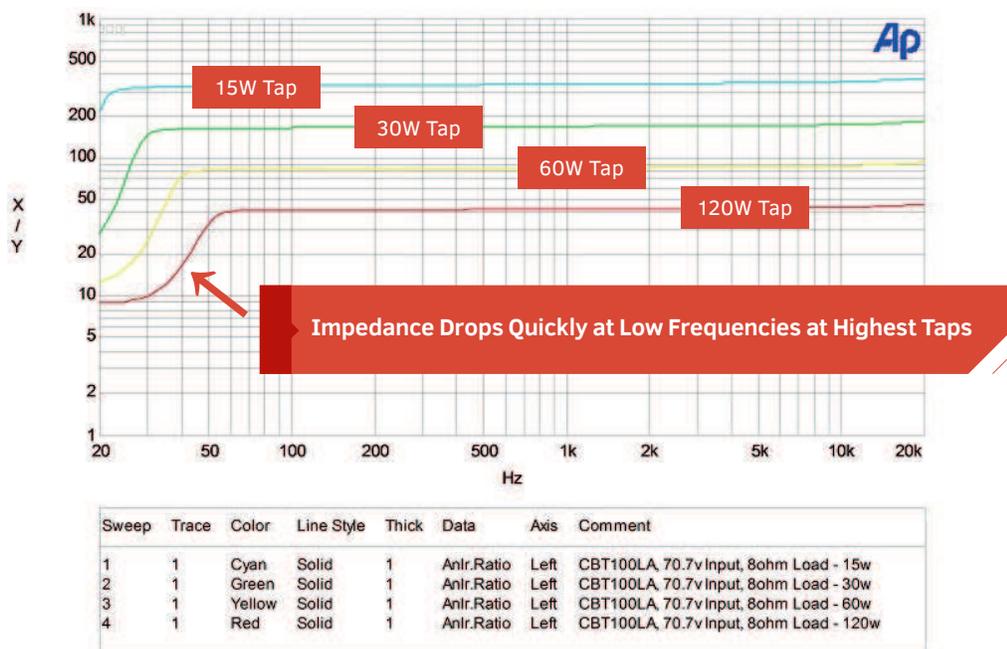
High-Pass Filters for Constant Voltage Systems

Let's take a look at an example of a 70V (or 100V) constant voltage system to better understand how they work:



Traditionally, a transformer was used at the power amplifier output to step up the voltage to approximately 70 volts (100V for outside the US) at full power. More modern amplifier designs that have the capability to drive 70V or 100V lines, such as the Crown DriveCore Install (DCi) Series and CDi DriveCore Series, offer direct 70V and 100V output and do not need an external transformer. Most speakers designed to be used in these systems have multi-tap transformers, allowing each speaker to draw different levels of power from the line depending upon the volume needs for that specific speaker's location.

The transformer mounted inside the speaker assembly is the point in the signal path where the audio signal is taken off the line and converted back to the speaker's proper voltage level. The amount of power drawn from the distributed line depends on the impedance of the transformer tap. However, since impedance is frequency dependent, this process is not consistent at every frequency. Consider this impedance chart:

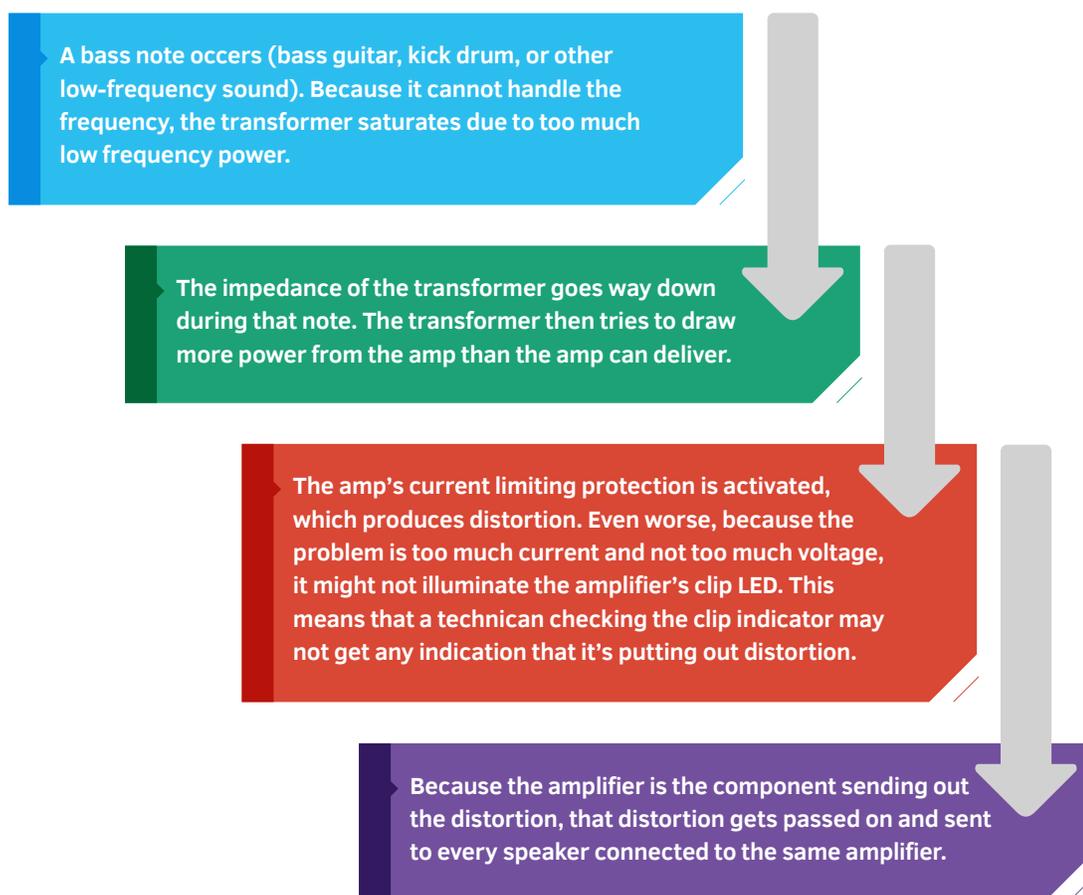


↑ **Transformer Impedance** ↑ (example from JBL CBT100LA)

This chart shows the impedance curves on a JBL Professional CBT100LA speaker system. It has curves for each of the four transformer taps and shows the impedances by frequency. Each of the taps has its own impedance, and that's what determines how much power that speaker draws from the distributed line. The impedance of each tap stays at nearly the same value for most of the frequency range, but you can see that the impedance drops precipitously when it begins to enter the low frequency range. This is called transformer saturation (or bass saturation) and it is particularly noticeable on the red curve, which shows the impedance of the highest-power tap. This example shows that if the speaker is set at the highest tap and you send this speaker lower frequencies (below 50 Hz in this example), the impedance of the transformer drops. That allows too much power to be drawn from the distributed line. At JBL we use high quality transformers that behave quite well, as the graph above shows. However, inexpensive transformers, usually found on inexpensive speakers as well as in small speaker-level in-wall volume controls, can saturate at much higher frequencies and exhibit much steeper drops in impedance, which means a quick path to bass saturation distortion.

It may be surprising to learn that the distortion effect is not always restricted to just that one loudspeaker. If you send low frequencies to a transformer at a frequency where the transformer saturates, you set off a chain reaction that can actually send distortion to the other speakers that are connected to that same 70V (or 100V) line.

Here is the unfortunate sequence of events that occurs when the system fails:



How can you stop this chain of events? The answer is to simply use a properly set high-pass filter. This filter should be set well above the point where there is a danger of bass saturation. The Crown DriveCore Install (DCi) Series and CDi DriveCore Series are all equipped with Digital Signal Processor (DSP) engines that can be set with the proper high-pass filter (and limiting voltages) to protect both low and high voltage systems. If you are using an amplifier that does not have an onboard DSP, you can use an outboard DSP or analog high-pass filter.

In short, without a properly set high-pass filter, distortion can propagate and degrade the sound quality of the entire system. Even if the transformer that's saturating is very small – like a transformer-based in-wall volume control – it can still create significant distortion throughout the entire system every time a bass note is produced. And this is also the case for bass notes that are so low in frequency that the speaker doesn't reproduce them, which might give the impression that they aren't getting to the speaker, but they too can cause this chain reaction.

Luckily, the solution is simple. A protective high-pass filter set to the right frequency keeps low frequencies from getting to the transformers or to the speakers.

LIMITERS IN AMPLIFIERS: CONTROLLING VOLTAGE, NOT JUST VOLUME

In addition to a high-pass filter, the use of limiters to protect speaker systems from being over-driven with too much power is an important and effective way to protect the speaker system from damage. A limiter is a type of compressor that sets a hard voltage threshold to prevent the amplifier from producing damaging voltage. This process limits the amount of power that can get to the speakers in order to prevent overdriving or damage. As we said before, transducers are only designed to handle a certain amount of voltage.

While limiters in a soundboard or other DSP are typically only concerned with volume, in this context limiters actually control voltage. That's why it's important that you include your limiter in the amplifier. You may ask, "Couldn't you set this up in a DSP earlier in the signal chain?" The truth is that you certainly could, but it's usually not as effective. There are a number of places in the signal chain where a limiter could be useful. However, the best place for the kind of limiter we're discussing is inside the amplifier, such as the limiters provided by the DSP in some Crown amplifiers such as the CDi DriveCore. Since these amplifiers can provide high-pass filters as well and the tunings are "built-in" to the DSP programming by model number, it makes setup much simpler.

These Crown amplifier models employ LevelMAX technology that utilizes a number of factors to intelligently limit the voltage output of the amplifier itself.

If you're using a DSP upstream of the amplifier in the signal chain, you can certainly set up speaker tunings there. However, once the signal reaches the amplifier, there is usually at least one additional variable gain setting within the amplifier itself, in the form of an input gain or sensitivity adjustment. Because the amplifier is after the DSP in the signal chain, the DSP has no way of knowing how much gain is happening in the amp after it, which is a potentially dangerous situation for the speaker system.

To try to set the limiter in this case (with the limiter in a separate upstream DSP device), you would need to compute the voltage gain of the amplifier and correlate that with the capabilities of the speakers. If your limiter setting is not perfect, you could either be limiting too early (and missing out on some efficiency and headroom available on the amplifier) or be limiting too late and you could damage the speaker. Even if you are able to achieve the right balance when setting the system up during the initial install, if someone changes the volume control on the amp even just a little bit, that limiter setting is suddenly no longer set correctly.

Another important point to remember is that one of the goals of good overall system design is to provide the maximum amount of headroom from the amplifier as possible. If the limiter is not set correctly, you might not maximize the headroom available to you in the amplifier. This is why you want to be sure you are sending the speaker the maximum voltage it can handle and no more. With the right kind of limiter inside the amp, using the right settings, you can ensure you're providing both the greatest headroom and the greatest protection possible for your speakers.

HARMAN LevelMAX limiters have been designed to limit accurately to the specified voltage thresholds. The addition of a thermal limiter allows thresholds for the faster-acting RMS and peak limiters to be set higher, providing more output and maintaining dynamic range before the onset of limiting, while protecting the long term integrity of the transducers. This produces higher SPL output from existing loudspeakers while also offering better protection with minimal sonic degradation.

CONCLUSION

This is ultimately why HARMAN offers Crown Amplifiers with built-in speaker tunings for a variety of JBL speakers, including commercial speakers. Because HARMAN manufactures amplifiers and speakers, we can ensure the industry-leading technology within our Crown amplifiers delivers audio optimized to the power and frequency needs of our industry-leading JBL loudspeakers. This simplifies the initial setup and configuration of the system, and also ensures the system sounds its best for years to come.



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