Danger, Low Power: The Drawbacks of Using Power Amplifiers that are Too Small – A JBL Professional Technical Note

We often get asked what size power amplifier we recommend for a particular passive (i.e., non-powered) loudspeaker model. In general, the recommendation is that you should pick an amplifier that can deliver power equal to twice the speaker's continuous average power rating. This means that a speaker with a nominal impedance of 8 ohms and a continuous average power rating of 300 watts, for example, would require an amplifier that can produce 600 watts into an 8 ohm load.

Why is it that we recommend a power amp that's twice as big as the speaker? The short answer is that a quality professional loudspeaker can handle transient peaks in excess of its rated power, if the amplifier can deliver those peaks without distortion. Using an amp with some extra headroom helps assure that only clean, undistorted power get to the loudspeaker.

For a more complete answer, JBL published the original version of this Tech Note a few decades ago. The principle is as valid today as when it was first introduced. However, it has been re-written and updated to remove references to ancillary equipment that is no longer in common use today, reference items that are more common than they used to be, add more details about which power rating to use as your loudspeaker power baseline, and mention exceptions and new concerns that should be taken into consideration.

1. Too Little Amplifier Power Can Produce "Too Much"

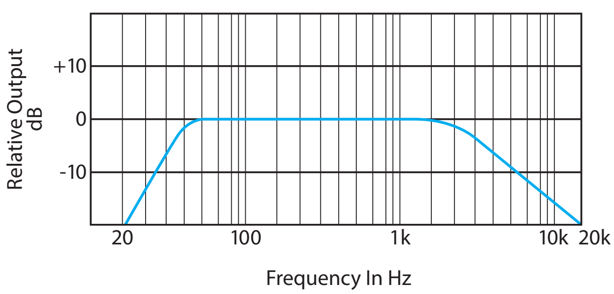
We occasionally hear of loudspeaker owners who damage the high frequency components of their loudspeaker systems using amplifiers that are rated at less – rather than more – power output than recommended. Understandably, they may wonder how it is that such an amplifier can actually burn out components when the loudspeaker system is rated to handle larger amounts of power. The loudspeaker's specifications are true, provided the amplifier is not overdriven. But that's a very important caveat – not overdriving the amplifier. Driving an amplifier too hard in order to get higher sound level from it (whether perceived or real) can damage some components -- especially the high frequency components.

To understand this more clearly, it is necessary to understand the nature of music as it relates to amplifier power and distortion.

2. The Nature of Music

Not all musical notes are created equal. There is much more power in the lower registers of music than in the midrange and high-frequency regions. If we examine the accompanying graph, we can see that the energy content of high frequencies (6 kHz and above) is typically 10 to 20 dB less than bass and midrange frequencies. Therefore, even if we allow for 10 dB peaks in the high frequency program material – which is common – the high frequency driver of a system will be called upon to handle only about one-tenth the power that the low and mid frequency components must sustain.

This natural distribution of musical energy means, for example, that a loudspeaker system capable of handling 100 watts should have a high frequency unit capable of handling 10 watts (which is -10 dB) in the frequency region where the natural distribution of content is 10 dB lower. Thus, if the high frequency unit is designed to handle 20 watts of power in that range, we are building a 100% safety factor. The result is that the capabilities of the components of a loudspeaker system parallel the natural energy distribution of music.



Energy distribution of typical rock and electronic music. Orchestral music tends to follow the same general contour, although with slightly reduced low-bass content.

3. The Nature of Amplifier Power

The power output specification of an amplifier is not absolute. Under certain operating conditions – such as when the volume control is set too high or when the input signal is too great or for shorter periods of time – the amplifier can exceed its published output. The power output of an amplifier is rated with reference to a given level of total harmonic distortion (THD). If required to produce more power, the amplifier will try to do so, but at considerably greater distortion levels. Between the fact that the amplifier is trying to produce more output power and the fact that people perceive distortion as being higher output, it may be natural for some users to do this at times – it sounds louder.

For example (using round numbers), an amplifier rated at 100 watts at no more than 0.5% THD could be overdriven to produce 200 Watts of output power to the loudspeakers. Under these same adverse conditions, an amplifier rated at 200 Watts could deliver 400 Watts to the loudspeakers; a 300 Watt amplifier could deliver 600 Watts, and a 600 Watt amplifier could be overdriven to deliver 1200 Watts.

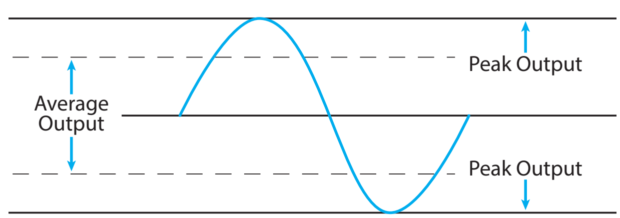
It's important to be aware that much of this extra power from overdriving the amplifier in the treble region, as we shall soon see.

4. Distortion Generally Affects High Frequency Drivers

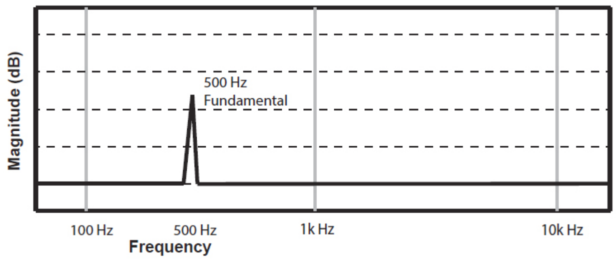
The additional power generated by overdriving the amplifier is rich in harmonics (distortion). In a passive (non-powered) full-range speaker, these harmonics get routed by the crossover network to the high frequency driver. Harmonics are higher frequency multiples of the original signal. Therefore, the high frequency component of a loudspeaker system must bear the brunt of the distortion – even though the original signal may be at a lower frequency.

5. Here's What the Signal Looks Like

When a sine wave test signal (a signal consisting of a fundamental frequency without overtones or harmonics) is looked at, its top and bottom extremes will exhibit normally rounded contours. Average output power is one-half the peak output power.



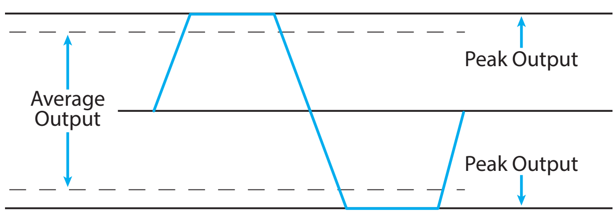
Typical Sine Wave. Average output of a sine wave is one-half of the peak output.



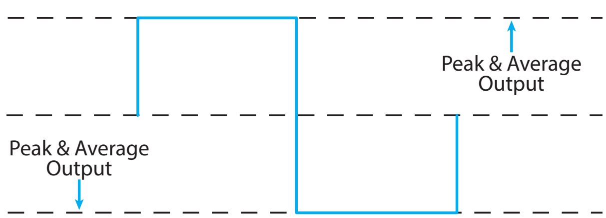
Frequency Response of 500 Hz Sine Wave shows content only at 500 Hz. This will not damage the speaker unless it is too much power for the Low Frequency (or mid-range) driver.

But when an amplifier is overdriven, the contours of the wave are “clipped” off, producing a near square wave, having flat areas at the top and bottom limits.

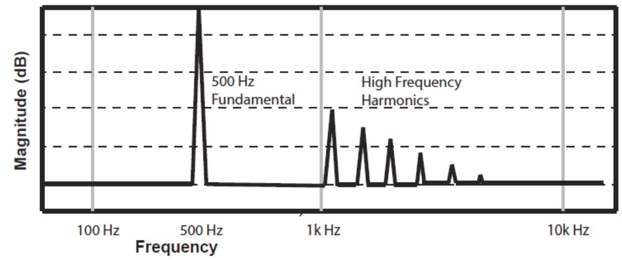
The average power approaches the peak power. When this occurs, up to twice the amplifier’s rated output can be delivered, and much of that extra power is from harmonic distortion, which get routed by the loudspeaker’s crossover network to the high frequency driver(s), which may not be capable of handling the abnormally high level of power.



In a clipped Sine Wave the average output approaches the peak output.



In a full Square Wave the average output equals the peak output.



The Frequency Response of a highly clipped 500 Hz Sine Wave shows that the 500 Hz fundamental content is higher, plus there is additional high frequency harmonic content, which can easily exceed the power rating of the high frequency driver.

Switching to using a higher powered amplifier instead, the required power levels can be generated without clipping, allowing the loudspeaker system to receive clean program material containing a normal distribution of energy levels. Under these conditions, damage to the high frequency driver is unlikely. Plus, it’s going to sound a lot better.

6. What Can the User Do?

1) **Matching the Amplifier to the Speaker(s)** Purchase an amplifier that will provide more power than you will need and then never run the amplifier into clipping. Remember, a loudspeaker can require up to ten times the average power level for those instantaneous bursts of sonic power known as transients, so having an amplifier that’s capable of cleanly driving short-term peaks – without distortion - is important. If the amplifier has enough reserve power, transients will be clear and crisp. If not, the transients will be muddy or dull. When an amplifier runs out of undistorted power, it is forced to exceed its design capabilities, producing dangerous power levels rich in high frequency distortion. **<u>As a general rule-of-thumb, when possible, the ideal situation is to use an amplifier that’s rated at double the loudspeaker’s 2-hour average pink noise power rating.</u>** That will allow you to get all the sound level from the loudspeaker that it’s capable of producing.

a. **Why double?** The recommendation of "double the power rating of the speaker" has to do with the fact that loudspeakers and amplifiers are tested, measured, and rated differently. Loudspeakers are tested with a signal - pink noise with 6 dB peaks (ie 6 dB "crest factor") - where the peaks are 4 times (+6 dB above) the average power of the signal. By contrast, amplifiers are tested with a signal - sine wave - where the peaks are only two times (+3 dB) the average power of the signal. So in order to cleanly drive the peaks that the speakers are tested to be able to deliver, the amplifier has to have double (+ 3 dB) the power rating of the speaker. The amplifier's +3 dB from being double the power rating is added to the +3 dB peak above its power rating, so that matches the + 6 dB (above its rated average pink noise power capability) that the loudspeaker is capable of producing. The amplifier is then able to cleanly drive the peaks that the loudspeaker is capable of reproducing. No clipping of the amplifier is necessary in order to get the peaks through cleanly to the loudspeaker.

b. **Which Power Rating to Use?** Most loudspeaker specification sheets show multiple power ratings. The standard loudspeaker measurement is typically based on a pink-noise signal with a 6 dB crest factor (peak to average ratio), and figures are listed for the Average Continuous Pink Noise Power, Program Power, and Peak Power; with ratings for a 100-hour or 2-hour duration; rated per IEC, EIA or AES spectrum and standards. Which one should be used?

   For the purposes of this paper, use the **Average Continuous Pink Noise Power** figure (which is based on the RMS voltage of the drive signal). Use the **2-Hour-Duration figure**, if that's stated on the spec sheet (if the 2-hour figure is not listed, see below). And it's best to use the **IEC** rating for a full-range speaker or the AES or IEC rating (whichever is provided) for a multi-amplified (bi-amp or tri-amp) speaker system.

   For duration, if the spec sheet only lists a power figure for a 100-hour duration, you can usually come up with a conservative estimate of the 2-hour power figure by adding 25% to the 100-hour figure.

   So, for example, a speaker with a 240 Watt 100-hour Average Continuous Pink Noise Power rating can be estimated to have a 300-Watt 2-hour Average Continuous Pink Noise rating, so it would require a 600W amplifier.

c. **Exception 1: Critical Listening** – For critical listening situations such as in a studio environment, four times the speaker's rating may be advisable to maintain peak transient capability.

d. **Exception 2: If You Don't Need All That SPL** – The guideline of double power for the amplifier is based on the presumption that you WANT to get as much output from the speaker as it's capable of delivering. But if you don't want or need that much sound level (Max SPL), you can indeed use a smaller amplifier. But again, you need to make sure you're not going to be clipping the power amplifier (which, again, creates the square-wave distortion). If you only need the system to get 3 dB lower than its maximum capability, you can cut that amplifier size in half (matching rather than exceeding the average pink-noise power rating of the speaker). If you don't need the system to get any louder than 6 dB below its maximum capability, you can cut that in half again, to one quarter of the recommended size. And so on. Each time you cut the power amplifier size in half, you lower the Max SPL capability of the system by another 3 dB. Again, just make sure you're not using an amplifier that's too small for the sound level you need, because cranking a power amplifier into clipping to get more output results in distortion, which can overpower the HF driver(s) even when the amplifier is small. It's best to err toward the amp being too large rather than too little.

2) **Using a Protective Limiter** – Many amplifiers have DSP or limiter capabilities built-in. Use it, but be aware of some caveats.

   a. **Difficult to Set DSP-Device Limiter** – If the limiter is located inside a DSP device that is before the amplifier in the signal chain, it's difficult to properly calibrate the limiter simply because the amplifier provides an additional - and often variable (via the amplifier's volume control) -- gain stage that's between the limiter and the loudspeaker. Even a small adjustment of the amp's volume control can throw off the calibration.

      Because of that, it's best when you can use a limiter that's inside the amplifier itself. Amplifier-based limiters "know" how much power is coming from the amp at any point in time. In this case, the limiter usually gets set based on either dB below full amplifier output capability or on voltage of the output signal (which can be set to the Max. Voltage specification on the loudspeaker's spec sheet).

   b. **Understanding the Shortcomings of Protective Limiters** – Unfortunately, even when limiters are set perfectly, we cannot rely on any limiter to be fool-proof. Here are a few examples:

      • If there is a limiter on a full-range (passively crossed over) speaker, and there is a high frequency feedback squeal (or even a long high frequency note from a guitar), the total power into the speaker may not be high enough to kick in the limiter, but all the power will be going to high frequency driver, which is not capable of handling that amount of power all by itself. Or, if something is being clipped earlier in the signal flow, those square waves from the clipping are mostly made up of high frequency harmonics, which again go right to the high frequency driver and can blow it, even though the total power to the speaker may not be above the limiter threshold. In fact, this can happen if there is something like a synthesizer that is purposely sending square waves as its sound.

      • If a limiter is primarily based on the limiting of peaks rather than the reduction of RMS/average power, the more it engages, the peak-to-average ratio gets smaller. That means that while the peaks get limited, the average power going to the speaker gets higher and higher. That can result in overpowering the speaker.

      • Some limiters have a fairly small range of signal reduction. For example, some will only reduce the volume by 10 dB or 15 dB max, and then after that they can't reduce the volume any more. For those limiters, you can simply overwhelm them.

      • Some limiters result in square waves after the range of the signal reduction has been met. And poorly-designed limiters can result in square waves during the limiting.

      • The bottom line is that limiters usually help to protect a speaker against damage from momentary overdriving, but they cannot be totally relied upon to keep the speaker out of trouble, and using a limiter does not mean that the speaker is protected from the kind of damage that can come from overdriving too small of a power amplifier.

3) **70V and 100V Distributed Systems** – While the transformer within a distributed speaker limits the voltage that gets through to the drivers, any clipping of the 70V or 100V amp – or any other strong high frequency signal -- still gets through the transformer and gets to the drivers. That sounds bad and can similarly stress the drivers.

4) **Using a Powered Speaker** – With a well-designed powered speaker, the amplifier is already designed to work properly with the drivers. For powered speakers that contain separate power amplifiers for each frequency band (or each driver), they often also contain a multi-band limiter, which helps to protect each of the drivers.

7. Summary

We are not saying that any clipping of a power amplifier will blow your loudspeaker. But for passive (non-powered) speakers, if a small amplifier must be heavily overdriven to obtain the desired volume levels in the listening space, thus generating high power and distortion levels, the user would be better advised to purchase a larger amplifier capable of producing the required power with negligible distortion. In any case, the ideal situation is that an amplifier should be selected with an output power rating that is greater than the maximum power that will be used – the general recommendation is that the amplifier should be capable of delivering double the power rating of the loudspeaker. This margin of reserve power will ensure that the amplifier will not attempt to deliver more power than its design allows. The net result will be distortion-free sound reproduction and longer loudspeaker life.