



**Musical Amplification:
Power Without Corruption**

March 1, 2010

Power Ratings Explained

In our first installment, “The Purpose of Power,” I mentioned the various ways that amps are rated for power output and stressed that musicians should exercise caution when evaluating and comparing these ratings. In these few pages, I would like to expand on that subject, explaining how power output is measured (and advertised) and why this is important to you as a player.

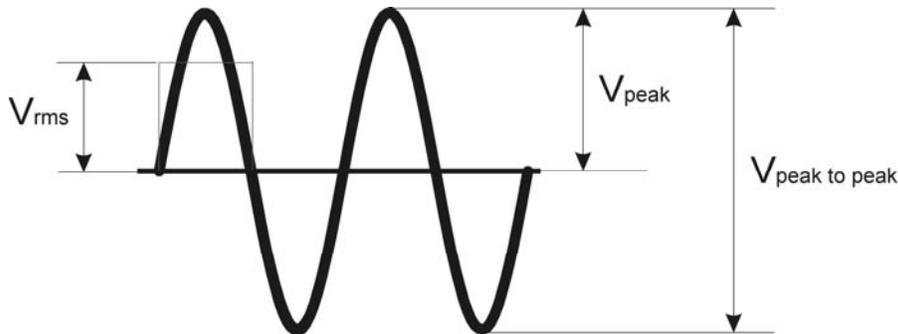
At the risk of giving things away upfront, the key messages are: that power can be measured in a number of ways...that some manufacturers often don't explain the basis for their ratings, leading to confusion for you, the buyer...and that, even the most straight-up power ratings tend to ignore *transient power*—the measurement we believe is very important to any musician when assessing an amplifier purchase.

How Amps Are Measured

In the home audio market, power amps are measured and rated in many different ways. Power output, frequency response, distortion level and other performance characteristics are widely used. In most cases, test procedures are standardized and the results are easy to compare between the various amps that are on the market. In the musical instrument amplifier market, however, amps may be measured in great detail but the results are almost never reported to the public and there is no test standardization so that results are frequently impossible to compare.

It may surprise you to know that musical instrument amps actually have a much more difficult job to perform than home audio amps. By the time the recorded instrument signals get to the home audio listener, they have been compressed and processed in various ways that limit their dynamic range. In short, transients and peak levels have been “smoothed” to remove the possibility that they will overdrive the amp or speakers. In a live music amplification application, amps and speakers are often overdriven and stressed to their limits. Yet, even in that challenging environment, high fidelity signal reproduction is still required.

But in both home and pro sound amplifiers, power output is measured using *sine waves*. The figure below shows a voltage signal that is a sine wave. As you can see, there are three ways to measure the amplitude of the sine wave: 1) measure the voltage difference between the peaks of the waveform ($V_{\text{peak to peak}}$),

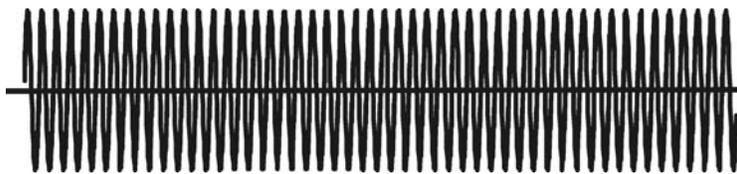


2) measure the voltage difference between the zero level and the peak (V_{peak}), or, 3) measure the height of a square wave that

has the equivalent area under the curve as the sine wave (the root mean square value of the voltage or V_{rms}). For those who are mathematically minded, relationships exist between these three values:

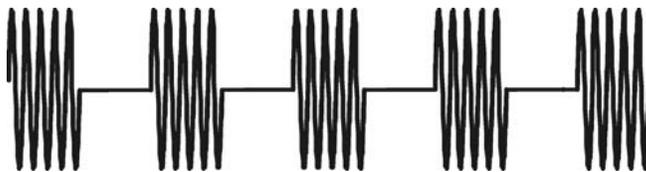
$$V_{\text{peak to peak}} = 2 \times V_{\text{peak}} \text{ and } V_{\text{rms}} = 0.707 \times V_{\text{peak}}$$

Another important concept relative to power measurements has to do with something called *the duty cycle*. A continuous sine wave signal has alternating peaks and valleys as shown. In other words, the signal is on “continuously.”



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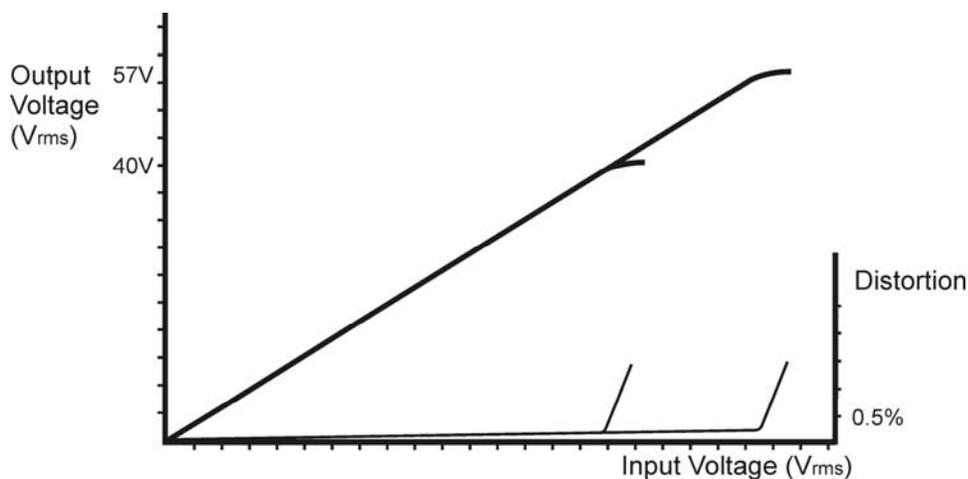
A 50% duty cycle signal has bursts of sine waves followed by no signal so that the signal is on only 50% of the time. An example is shown in which five cycles of sine wave are followed by 5 cycles of no signal in a repeating pattern. There are 10% duty cycle signals as well as



10% duty cycle signals as well as

90% duty cycle signals.

Essentially, a power amp takes an input signal, like a sine wave, and increases its amplitude (“amplifies” it) and delivers it to a load like a loudspeaker. Ideally, the output signal looks just like the input signal, i.e., it has low distortion. If you were to plot the output voltage of an amp as a function of the input voltage, it would look something like this:



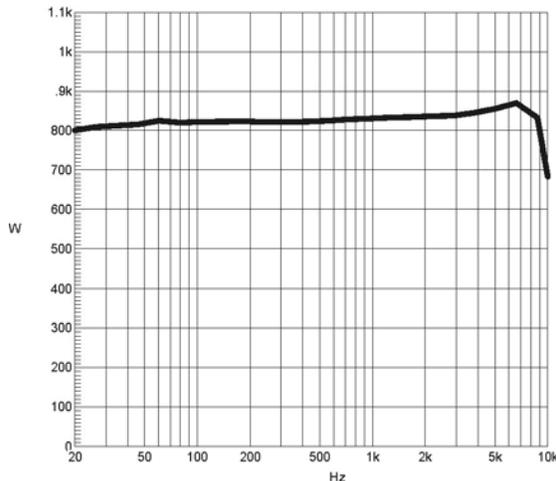
In this case, rms voltage of one frequency (1 kHz) is being plotted for two different amplifiers. Note how there is a straight line relationship between the input voltage and the output voltage up

to a certain point in the case of each amp. At that certain point, the output voltage deviates from the straight line and begins to flatten out. That is the point where the amp can no longer amplify the input signal; it has reached its limit. Two amps are shown to illustrate the fact that, by design, one amp can have more maximum voltage output than another. Also shown in the plot is the distortion for each amp. Notice how the distortion starts to rise rapidly at the same point where the output voltage starts to flatten out. This is another way to tell that a given amp has run out of gas. So it's important to specify the distortion level for a given measured power level.

The voltage output of an amp is measured using a resistor as a load. Typically an 8 ohm or 4 ohm resistor is used, a fixed value that does not vary with frequency. A loudspeaker is not a resistor. The resistance (or more properly, impedance) of a speaker varies with frequency and that makes amp measurements more difficult to make. Hence, the fixed value resistor is used.

Rms voltage is shown in the plot. Because we know this and the resistance of the load on the amplifier, we can calculate power output. Here's how: power equals voltage times current...and current equals voltage divided by resistance... so power equals voltage squared divided by resistance. Simple, right? Well, in the case of the two amps shown in the plot, the load resistance is 4 ohms so one of the amps has a power output of $40^2/4$ or 400 Watts and the other has a power output of $57^2/4$ or 812 Watts. Since the voltage is measured as an rms voltage, the power is stated as rms Watts. You can see how it is important to specify load resistance or impedance in order to define power output.

It's worth noting that power can be measured for one frequency or for a band of frequencies. Since music signals contain more than one frequency, measurement over a band of frequencies better describes how a given amp would handle music signals. This type of measurement is called a *power bandwidth curve*. An example is shown below.



Power Bandwidth Curve

In this case, you see the power output in rms Watts plotted against frequency. The power bandwidth curve is essentially the frequency response of the amp at full power output and a given distortion level (in this case 1%). This particular amp has an rms power output above 800W from 20 Hz to 9 kHz.

In the previous examples, rms values were used. Peak values could also be used. For the 800W rms example, the peak power would be 1600W. As you can see, it is important to specify what type of measurement is being made when making comparisons between amps. If one was specified as rms and another was peak (without either being identified), the comparison would not be valid.

So what's the best way to specify the power output of an amp? The most conservative way is the rms rating, but this doesn't always meet the needs of the marketing department of the company selling the amp because other ratings look a whole lot better to naive consumers who don't know the difference. The lesson: it is important that you know the basis for the power rating. Unfortunately, some manufacturers don't make this available.

An rms rating tells you more about the average performance of an amp (a good thing) and forms a solid basis for comparing amps (there is less chance of fudging the numbers), but it doesn't tell you everything you need to know. Since music is not a constant amplitude, continuous signal, it is good to know something about the *transient* performance of an amp.

Amplifying Music Signals

Music signals consist of a number of sine waves of various frequencies and amplitudes added together. They differ from fixed amplitude, continuous sine waves in that they are not continuous and the amplitude can vary widely in a given period of time. The duty cycle of music signals can vary from small to nearly continuous with an average around 40%. And as I previously pointed out, amplitude can vary by as much as ten times or even more. So, how can you rate an amp that is dealing with those types of signals?

One way is to use *non-continuous sine waves* (for example, a sine wave with a 40% duty cycle). The resulting rating can then be called *music power* instead of

rms power. In fact, this rating is higher than the rms rating because the amp is not being driven as hard so it can put out a little more power. In the case of the 800W amp shown earlier, the music power rating would be 1000W. Rms voltage is used to calculate this power rating, but since the signal is not continuous, the rating is stated as “1000W music power (rms, 40% duty cycle, 1 kHz, <1% distortion)”. For completeness, a frequency or band of frequencies and a distortion level should be specified. Note also that you can’t compare music power ratings between amps unless you know the specific testing conditions. Different conditions mean different ratings.

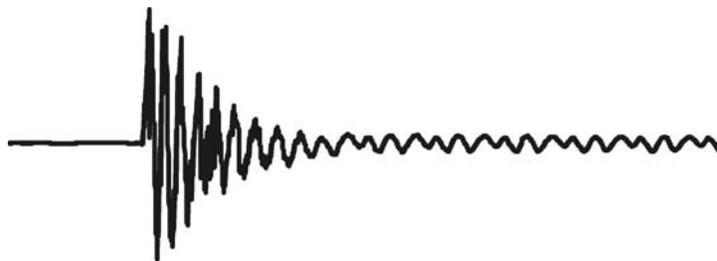
A related specification is called *dynamic headroom*. This is the ratio of the continuous rms power rating to one measured with a low duty cycle. It tells you how much the amp’s power output drops when the signal becomes continuous and it gives you an idea of how well the amp handles transient signals. Again, a frequency or band of frequencies and a distortion level should be specified. For the 800W example, dynamic headroom is 2 dB at 1 kHz and 1% distortion.

Transient Power

As was pointed out in our first paper, the purpose of power in musical instrument amps is to reproduce transients (a big part of music signals) without “clipping”.

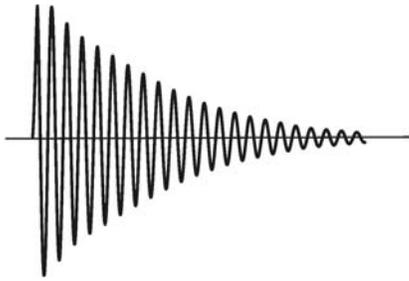


This is several-second segment of a piano trio. As you can see, there is an average component to the waveform and there are many transient signals with amplitudes that are considerably higher than the average, in some cases up to ten times.



Here is another example of a transient waveform. This is signal of a slapped bass string. In this case, you see a large transient signal that decays to a steady signal.

So, how would you measure an amp's ability to deal with signals like these? We like to use *peak transient power*. This measures the peak, rather than rms, output because it is a peak signal that needs to be reproduced. A decaying sine wave signal can approximate the above slapped bass signal and be used to measure the peak transient power. This is what the signal looks like. You can see how it approximates the slapped bass signal.



When played through an amp, this signal sounds like a "thump."

The test signal frequency and distortion level should also be specified. It turns out that the transient power test is best run with lower frequency signals because it is at lower frequencies that transient power is most needed. The above test signal is a 100 Hz signal.

For the 800W example, the peak transient power is 1800W into 4 ohms, 100 Hz, <1% distortion.

So a complete spec for the example amp would be:

>800W rms continuous from 20Hz to 9kHz, 4 ohms, <1% distortion
>2 dB dynamic headroom at 1 kHz, 10% duty cycle, <1% distortion
>1800W peak transient power into 4 ohms, 100 Hz, <1% distortion

This is a fairly complete description of the amp that should allow you, as a player, to evaluate how this amp would perform in comparison to other amps. Of course, you should still listen to each amp because even if two amps have the same specs, they will sound different. Why? Because there are many more variables involved in the sound of an amp than just power and distortion. In fact, there are too many to measure. Your ears should always be the ultimate guide.

I haven't said much about *distortion*. In reality, is as important as the power level but harder to measure since there are many types (*harmonic distortion, intermodulation distortion, transient intermodulation distortion, etc.*) and how much distortion is too much is very subjective. The distortion referred to in the above examples is harmonic distortion. Typically, harmonic distortion levels below 1% are inaudible. Most players can't hear the effect of 3% harmonic distortion and often, musical instrument amps are specified at as much as 10% harmonic distortion. As a rule of thumb, as long as an amp is specified at 3% or less harmonic distortion, the result will not be audible.

Summary

At Acoustic Image, we are dedicated to providing the best solutions for musical instrument amplification. While rms power performance is critical we believe that transient performance is just as important. In fact, our designs have always been--and will always be--optimized for transient as well as continuous performance.

Going forward, we intend to specify the performance of our amps using the concepts I've just explained so that you, the customer, will have the best and most reliable information at hand for evaluating our products.

When you work as hard as we do to build superior, hi-fidelity musical instrument amplifiers, you have everything to gain by better informing buyers. And that's what we are committed to doing.

If you have questions, shoot me an email.

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