ProSoundWeb EXPERT SERIES

CLARIFYING AUDIO POWER & THE AMPLIFIER/ LOUDSPEAKER RELATIONSHIP

Chapter 2 of 4 in the Amplifier Expert Series

WHAT'S A WATT? CLARIFYING AUDIO POWER & THE AMPLIFIER/LOUDSPEAKER RELATIONSHIP

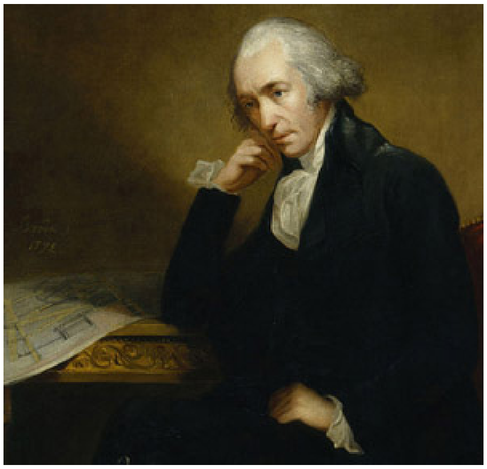
Answers start by focusing on the fundamental unit of measure in audio. *By John Murray*

Years ago, only car stereo makers would advertise "2,000 Watts Of Earthshaking Power!" But with the recent shift to switching power supply amplifier topology, we're now seeing this with many pro-oriented products.

What's behind the hype? And what about properly matching power amplifiers and loudspeakers? Answers start by focusing on the fundamental unit of measure in audio, the watt.

What is a watt? A strict definition according to Wikipedia: One watt is the rate at which work is done when an object's velocity is held constant at one meter per second against constant opposing force of one Newton. In electrical terms, one watt is the rate at which work is done when one ampere (A) of current flows through an electrical potential difference of one volt (V). It's symbol is W.

The watt is named after James Watt, the prolific Scottish inventor and mechanical engineer. He is noted for improving Thomas Newcomen's extremely inefficient atmospheric steam engine so much that Watt's version literally powered the industrial revolution.



James Watt, 1736-1819

In audio, the watt is the unit of power we use to rate amplifiers and loudspeakers. However, what some may not realize is that power, in watts, cannot be measured directly. It is a derived quantity that can only be calculated by the measurement of voltage or current in a circuit with a known resistance.

We do this calculation through the use of Ohm's Law. The most used version for audio is:

$$P\ (\text{watts}) = V^2/R$$

To complicate things further, loudspeakers do not present a purely resistive load to amplifiers. They present impedance to current flow (Z in place of R in Ohm's Law) that is a mixture of resistance, capacitance, and inductance, which varies with frequency.

This is observed as the impedance curve in a loudspeaker's specifications, and it also varies with the temperature of the voice coil as well. The higher the voice coil temperature, the higher the impedance will be. This phenomenon is also the cause of power compression.

Program Level & Headroom

During my time with Electro-Voice, Gary Ewald, a loudspeaker design engineer at the company, spent several months constructing a room where the power handling capacity of loudspeakers could be calculated accurately. This was not a trivial undertaking. It required thermal probes to connected to the voice coil area, among other particulars, in a very controlled environment.

As far as typical audio practitioners are concerned, we never really know how much power an amplifier is supplying to a loudspeaker when playing anything other than a sine wave signal. At best we can only guess.

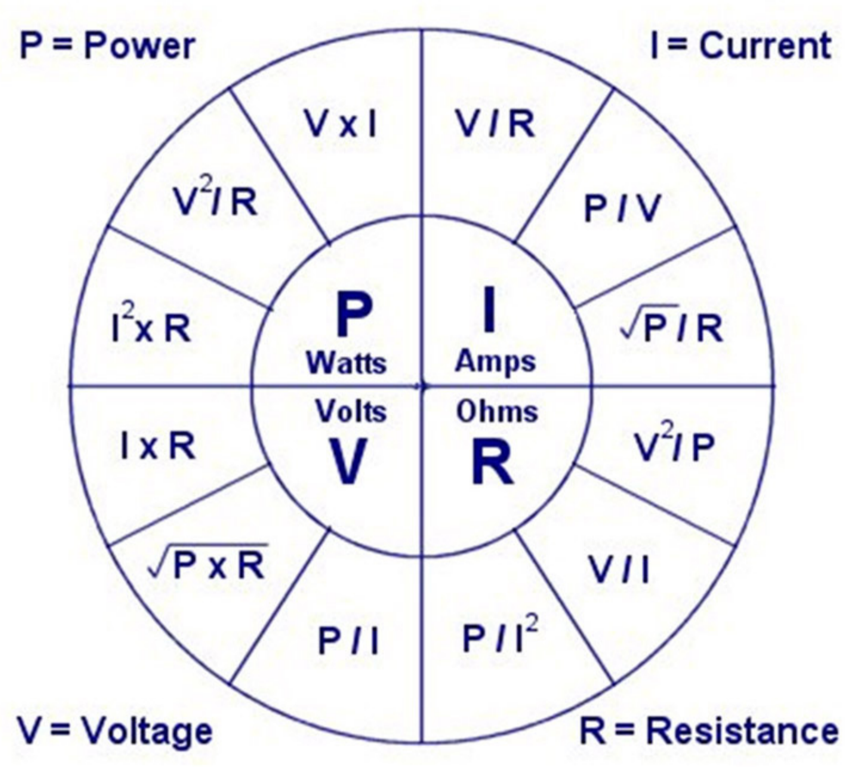
For example, imagine playing a music source directly into a 100-watt amplifier driving a loudspeaker, and the amplifier's input attenuator is set so the signal level is just below clipping. How many watts of power are being delivered to the loudspeaker? 100 watts? 50 watts? In fact, somewhere between only 1 and 4 watts are actually being delivered to the loudspeaker under these conditions.

If the program material was recorded with 20 dB of headroom, then the long-term average signal level is 20 dB below the highest peak of the music—100 watts minus the first 10 dB of headroom is 10 watts, and 10 watts minus the second 10 dB of headroom is 1 watt.

If the signal source was a properly mastered commercial CD, there is a good chance that the headroom for the recording is 14 dB. If 1 watt results from 20 dB of headroom, then 6 dB less headroom would be 4 times the delivered power, or 4 watts.

This is why the UL (Underwriters Laboratories) listing on the back of amplifiers is never at the rated power capacity of the amp. It's tested at 1/8th power, in this case, 12 watts, which is a program level with a significant level of clipping distortion where only the drunkest of partiers could stand to listen to it.

Think of the loudspeaker's sensitivity rating, for example, 95 dB SPL (1 watt/1 meter). The level at 1 meter in our 100-watt amplifier test case would be between 95 and 101 dB SPL. It doesn't seem that we get much out of that 100-watt amp does it?



The four quadrants of Ohm's Law.

Forget tube amps if you really want to listen to rock music at realistic levels. They just can't supply enough wattage for the headroom of high-level music. What you end up with at higher levels is even-harmonic clipping, which is the tube amplifier's warm tone that everyone talks about. It's nice, but not accurate.

When I'm asked what the wattage rating for the amplifiers in a sound system design should be, my answer is always, "How big is your budget?" Amplifiers are rated in watts and should be able to pass the peaks of the program material without clipping.

This means they ultimately should be sized to pass not only the long-term program-power capacity of the loudspeaker, say 500 watts, but also the peaks that the program headroom allows without clipping. At 20 dB, that would be a rather ridiculous 50,000 watts!

How We Got Here

The standard 20 dB of headroom was established way back in the early days of radio broadcasting when it was noted that uncompressed speech and music would never produce peaks more than 20 dB higher than the long-term average program levels. This is how we standardized on a +4 dBu nominal program level and a clipping level of +24 dBu for most audio electronics today.

But there is a problem in maintaining a 20 dB crest factor with the loud music played today. If the amplifier is below clipping, then the program level is often not loud enough for today's "enthusiastic" listening levels.

Standard CD mastering has 14 dB of headroom as a general rule of thumb. This enables program levels to be turned up 6 dB higher, while using only 6 dB of peak limiting, which is not generally noticed by a typical listener. In sound reinforcement systems, lowering the headroom to a 10 dB peak-to-average ratio is common to attain maximum program level without clipping, though the 10 dB of limiting is easily detectable by the listener.

This 10 dB of headroom also works out for loudspeaker transducers, as they generally can handle peaks 6 to 10 dB above their long-term average power-handling ratings.

Just remember that an AES average power rating is a 2-hour rating. When you employ 10 dB of limiting and can raise the program level 10 dB, that's 10 times the power to the drivers. If the loudspeaker catches fire just after 120 minutes of hard use with only 10 dB of headroom, it still passes the stated rating.

Touring sound companies often use the IEC 268-5 Power Handling Capacity standard as a limit to the average power delivered to their loudspeakers. The reason is that it's 100-hour rating. However, even with only 10 dB of headroom, a single 500-watt loudspeaker would require a 5,000-watt amplifier channel to use the loudspeaker to its fullest average power capacity. Now budget really becomes relevant, doesn't it!

IN SOUND REINFORCEMENT SYSTEMS, LOWERING THE HEADROOM TO A 10 DB PEAK-TO-AVERAGE RATIO IS COMMON TO ATTAIN MAXIMUM PROGRAM LEVEL WITHOUT CLIPPING, THOUGH THE 10 DB OF LIMITING IS EASILY DETECTABLE BY THE LISTENER.

Current class D amplifiers and other derived topologies with switching power supplies, etc., finally present units that are designed for program material rather than sine wave power. They're light, can produce high peaks, generate little heat, and are very efficient, but with more conservative long-term average power ratings are more in line with program requirements.

The newer topologies don't have high long-term average ratings like the old class A/B amplifiers did. Understand that those big numbers of watts we like to see in amplifier specifications are now short-term instantaneous-peak or burst ratings more akin to the car stereo ratings.

CURRENT CLASS D AMPLIFIERS AND OTHER DERIVED TOPOLOGIES WITH SWITCHING POWER SUPPLIES, ETC., FINALLY PRESENT UNITS THAT ARE DESIGNED FOR PROGRAM MATERIAL RATHER THAN SINE WAVE POWER.

The Bottleneck

Here's one last thing about watts. Remember Ohm's Law? With a standard AC electrical plug, all we can get out of a 15-amp wall receptacle at 120 volts RMS is 1,800 watts (P = V x I). Now multiply that by a roughly 75-to-80 percent class D amplifier efficiency, and only about 1,400 watts per circuit of sine wave can be delivered to a loudspeaker.

So anyone that plugs in their "Belchfire 8000" power amplifier to a standard wall socket, connects the amp to the loudspeakers, turns it up to clipping, and claims they're listening to 8,000 watts of ear-crushing power is suffering from "consumerdom suckeritus." (I've filed a trademark on this terminology.)

That is, unless it's like my sound room, which is wired with multiple 20- or 30-amp circuit breakers accompanied by those odd, high-power AC outlets and plugs. How many watts do the amplifiers in my system supply? As many as my budget allows.

John Murray is a 35-year industry veteran who has worked for several leading manufacturers and has also presented two published AES papers as well as chaired numerous SynAudCon workshops. He is currently the principal of Optimum System Solutions, a consulting firm based in Colorado.