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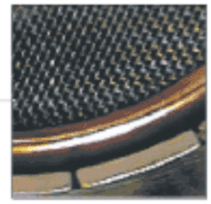

Solving the Power Puzzle

Questions (and Answers) about Power Amplifiers

The following text was requested by LIVE SOUND! International from QSC to explain and define the misunderstood electro-physics of power amplification technology.

Q.) What does a power amp do, anyway?

A.) In a nutshell, a power amp takes your audio signal and provides both voltage gain and current gain to drive loudspeakers. The voltage gain is necessary because line-level audio runs around a volt, peaking at maybe 8 to 12V, and speakers need more voltage than that to produce usable sound levels.

Voltage gain is determined by the amp's circuitry and the position of its attenuators or gain controls; it is typically expressed as a mathematical multiplier, such as "40x," or in decibels, such as "32dB" (which is equivalent to 40x, by the way).

In an amp with a gain of 40x, 0.25V in will produce 10V out, 1V in will produce 40V out, and so on, up until the output reaches the amp's clipping point. A considerate amp manufacturer will tell you either on the front or rear panels or somewhere in the user's manual what the amp's full gain actually is.

The current gain is necessary because compared to the amp's input, loudspeakers are very-low-impedance devices. You can think of impedance as the ratio of the voltage across a device to the amount of current it allows through. Therefore, the lower its impedance, the more current a device will allow to flow when you put a certain voltage across it.

An amp input might typically have an impedance of 10, 15, or 20kilohms, which means that for a line-level signal, the input will draw minuscule amounts of current. That's why crossovers, mixers, and other devices we use to drive amp inputs don't have to put out much power.

But speakers have to do lots of work, pushing and pulling air to create sound. They draw current because current, or electron flow, is useful. Electrons flowing through the speaker's voice coil make the magnetic fields that react with the speaker's magnet to push the cone or diaphragm in and out. Basically, current allows the speakers to do serious work. Thus, an amp has to have plenty of current capacity, although how much it puts out depends entirely on the output signal voltage and the load impedance.

With no load connected, meaning, a load impedance of infinity, the amp will produce voltage but no current. With an 8Ω, the amp will produce practically the same voltage and will put out current. With a 4Ω load, the amp will again produce the same voltage and put out twice as much current as at 8Ω, and so on (assuming you're always running below the clipping point).

That's what an amp does. How it does it will be explained in other answers. So read on.

Q.) If you take a 500W amp and turn it down 3dB, then it's a 250W amp, right?

A.) No, it's still a 500W amp. It just takes 3dB more input signal to reach that 500W full power level. For example, if the amp's input sensitivity (the voltage at which it reaches full rated power for a given load) is 1V, then turning the gain controls down 3dB means it will instead take a signal level of 1.4V to reach full power.

Q.) Should I always run my amps turned up to full gain?

A.) No, that's why your amps have gain controls in the first place — so you can adjust the gain. Some amps, particularly very high-powered models that were designed to match the input sensitivity of lower-powered models, have a lot of gain — sixty to eighty times or more. That could be a lot more gain than you actually need, too. That's because the amp also amplifies not only the signal, but also all of the hum and noise from upstream in the system.

Thus, with such an amp turned up full, you might find that the hum and noise is too high in the system, particularly if you've reduced the gain of the crossover, mixer, or other devices in the system to compensate for the amp's high gain. You could then improve the overall signal-to-noise ratio by turning down

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the amp gains and boosting the input signal accordingly, as long as you avoid clipping the upstream devices.

On the other hand, there are two reasons for keeping the amps turned up all the way:

1.) It's easily repeatable without making errors; and

2.) You just might happen to need all that gain. At any rate, it's always easier to deal with having more gain than you need than it is having not enough.

Q.) I'm considering an amp purchase, but its input sensitivity spec is over 2V. How will I ever drive the thing to full power?

A.) Fear not. Any line-level pro audio gear should be able to put out at least +18dBu (6.16V RMS) before clipping, and

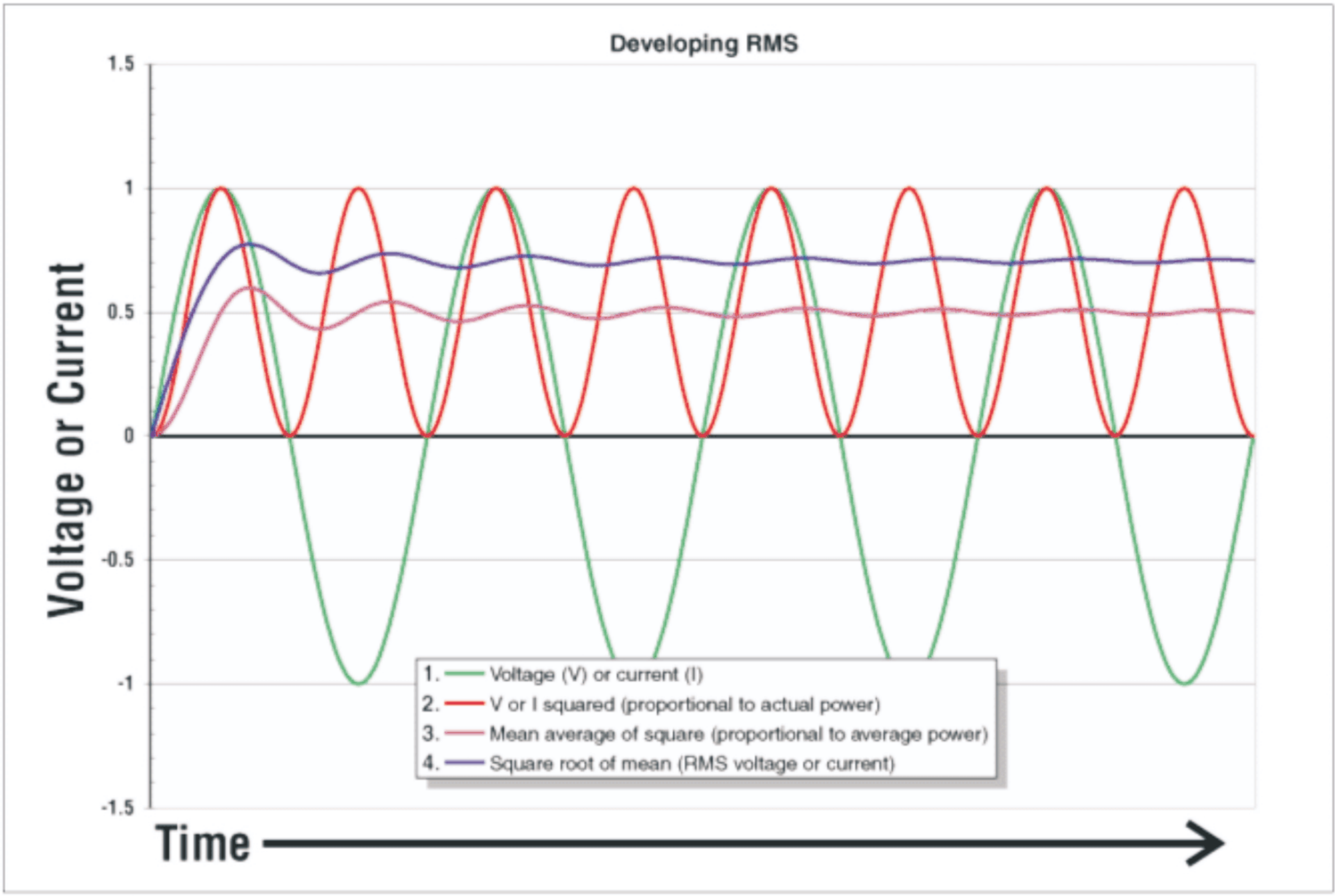

Figure #1: Developing RMS

many can put out signals as high as +24dBu (12.3V RMS). So hitting 2V or more on peaks is not a problem unless you have your gain structure severely out of whack.

Q.) Can I use constant-gain amps and constant-sensitivity amps together in the same system?

A.) Absolutely, as long as you calculate your gain and power needs correctly. But you need to do that anyway. Before we go further, let's clarify the terms here: "constant gain" means a group of amps have the same maximum gain despite their possibly different power points; the advantage of this is you can design your system around rules like "1V in = Xwatts at 8Ω, or 2Xwatts at 4Ω, or 4Xwatts at 2Ω" throughout.

"Constant sensitivity" refers to a group of amps that have the same or very similar input sensitivity, regardless of their power points. Knowing the sensitivity of an amp is useful for setting limiters and for avoiding clipping the amp, but knowing the gain will allow you to calculate a good initial setup on your system.

Q.) Amp power specs—are they RMS or peak?

A.) Please stand clear for the bombshell…there is actually no such thing as "RMS power." Yes, the term is used frequently and is usually understood to mean continuous or long term, but technically, it doesn't. So don't rely on RMS to mean continuous power, because in actuality you can measure RMS voltage or current of any portion of a waveform, long or short.

RMS is correctly used to express AC voltage or current in useful terms. It helps solve the problem of measuring and expressing AC. By comparison, DC is a snap. Measure the voltage of a 9V battery. 9V. Measure it again. Still, 9VDC doesn't change, other than some slight fluctuations or sags due to loading or other influences.

On the other hand, AC changes constantly and rapidly. Your electrical service cycles 50 or 60 times a second. Audio runs from 20 up to 20,000 cycles each second.

You could take a lot of instantaneous voltage measurements, like 20, -2, 92, 12, -29V. But they wouldn't at all be meaningful or accurate in describing the AC signal. You need to take AC measurements over a time period (either continuously or as many samples) and average them, and you also need to describe the measurements in terms that can be used to describe its power implications.

Thus there is RMS, which stands for root-mean-square. This is how it's derived. First, there is the AC signal. In this illustration, it is a simple sine wave (the *(Continued on page 76)*

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green curve) that starts from zero and peaks at +1 and –1. It could be voltage or current, but we'll just call it voltage for the sake of simplicity.

Power is proportional to the square of the voltage. For example, 1V across a load is twice the voltage of 0.5V, but it corresponds to four times the power. So that clues us into what we do first: square the voltage. V^2 is represented by the red line.

Notice that its frequency is doubled, that it's always positive, and its peaks are at +1 and 0. This curve is analogous to the instantaneous power in the circuit. And the actual magnitude of the power would depend on the current as well as the voltage.

Next, we need to average the power, which requires that we figure the mean. In an analog measuring circuit, this could be done with an integrator circuit. Some good quality AC RMS volt meters allow you to select the integration time. In DSP, it could be done as a simple mathematical algorithm.

The mean average power analog (analog only in the sense that it's analogous to the mean average power) is depicted by the violet line. Notice that after its initial fluctuations it starts to flatten out on the 0.5 line, which is the center of the V^2 waveform.

Now to get back into voltage terms again, we need to take the square root of the mean average power analog. That gives us RMS voltage, which is shown as a blue line. Note that it flattens out at 0.707.

When you multiply voltage times current, you get power. When you multiply RMS voltage times RMS current, you don't get RMS power — you get average power. Therefore, what is often referred to as "RMS power" should actually be called "continuous average power." And that's what any decent and believable amp spec should mean when it shows a figure. And, please, don't get me started about "peak" power specs for amplifiers.

The clipping point is defined as the level at which the total harmonic distortion of the sine wave reaches a specified figure, such as 0.05%, 0.1%, or 1%.

Q.) More on power specs: what do "FTC" and "EIA" mean?

A.) Those are currently the two most common ways of measuring amplifier power. One common method years ago was the IHF standard, which involved measuring an amp's maximum RMS voltage, just at the onset of clipping, across a load, such as 8, 4, or 2Ω.

The tricky part was that it was measured with a 1 kHz sine wave repeated pulsed on fully for 20 milliseconds, then 480 milliseconds at 20dB down (or 1% power, in other words). Consequently the spec measured headroom, and not continuous power, causing many wimpy amps to boast impressive numbers as power specs.

Thankfully, the IHF spec is almost completely gone now. A somewhat more rigorous method is the EIA standard, which requires measurement with a constant-amplitude single mid-band frequency. Most manufacturers choose 1 kHz. The amp drives the sine wave into a specified load resistance, such as 8, 4, or 2Ω, and the gain is turned up until the amp's clipping point is reached.

The clipping point is defined as the level at which the total harmonic distortion of the sine wave reaches a specified figure, such as 0.05%, 0.1%, or 1%.

This THD figure is only a reference — it describes a repeatable means of arriving at the clipping point. Don't confuse it with the amp's actual THD performance. At this clipping point, the RMS voltage is used to calculate the power delivered into the load resistance.

One shortcoming of the EIA spec, aside from its limited frequency spectrum, is that it allows a manufacturer to drive and put under load only one channel at a time. Not all manufacturers take advantage of this loophole, which can be used to conceal a weak power supply.

Far more rigorous is the FTC spec, which has been around since May 1974. Established as a consumer protection measure for home entertainment equipment by the Federal Trade Commission (FTC), an agency of the U.S. government, the FTC spec requires measurement using a sine wave over a specified range of frequencies, instead of the single mid-band frequency required by EIA or IHF.

Usually the frequency range used is 20Hz to 20kHz, although it can be different as long as it is specified. Also, all channels of the amplifier are driven and put under load at the same time, which would tend to expose any weak power supply.

But the most demanding aspect of an FTC spec has to be the preconditioning: sixty minutes at 1/3rd of full power, all channels driven into specified load resistances, with a 1kHz sine. Followed by five minutes at full power, all channels, specified loads, 1kHz. The amp cannot thermal, shut down, current limit, or otherwise quit during this time.

Now, to be honest, manufacturers don't go through this every time they measure power as part of a model's qualification for published specs. Most, though, have put the amp design through similar endurance testing as a part of the design process and are thus aware of whether the amp can pass or not.

But if it can't pass the preconditioning requirements, it can't have an FTC spec. That's why all but a very few amps have EIA specs, but not FTC specs, at 2Ω per channel, even though they may be commonly used at 2Ω.

Like the EIA spec, the maximum power point in the FTC spec is defined as where the THD reaches a specified level. Typical points chosen by manufacturers are 0.025%, 0.03%, 0.05%, 0.1%, and so on.

However, the THD spec chosen has to be valid from 250milliwatts, where any crossover distortion would be prominent, up to the rated power level. FTC is definitely a rigorous and demanding power measurement standard, and that may be a shortcoming because of the way it cannot describe 2Ω performance on most amps.

Q.) I've got a 2400W amp, but its manual says it draws only 12amperes at 120V. Who are they kidding?

A.) No one, and here's why. You need your amps' full power for peaks and large transients. Fortunately for your amps and the AC power system, these peaks and transients don't last long.

An amp with a good power reservoir can briefly put out more power than it draws from the AC. But averaging the power over time, even a period as short as several seconds, shows that the actual power put out is far below the peaks.

This is called crest factor, and depending on the kind of music or other program material, it can run as high as 20dB. That means although the peaks are hitting the clipping point at 2400W, the average power put out is only about 24W.

Compressed music has a lower crest factor, and light clipping will bring up the average power a bit. But even if, say, the bass player is using a compressor and hits a long, loud note, the attack of the note will still be several decibels higher than the sustain. If you've got enough power for the attack, the rest of the note will be a piece of cake.

Most safety agencies use pink noise at 1/8th of full power (corresponding to an effective crest factor of 9dB) as equivalent to the typical maximum music level that won't cause objectionable clipping.

Safety agencies aren't known for daring and permissive over- or understatement, so current draw ratings measured at 1/8th power are pretty safe to use for most normal operation.

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Way Back When…

Van photo courtesy of Tannoy Ltd,
Rosehall Industrial Estate, Coatbridge, Great Britain

Unless you live in the UK, you are probably unaware that "Tannoy" is commonly used as a generic reference to loudspeakers. This photo confirms the long-standing presence of the Tannoy brand and the origin of the "branding" which created this generic reference.