Dynamic Adaptive Amplifier Technology™

(DAA™)

iSP Technologies
Intelligent Signal Processing
ISP Technologies patented Dynamic Adaptive Amplifier Technology™

**Audio power** is the electrical power off the AC line transferred from an audio amplifier to a loudspeaker, measured in watts. The power delivered to the loudspeaker, based on its efficiency, determines the actual audio power. Some portion of the electrical power in ends up being converted to heat. Recent years have seen a proliferation in what is called specmanship at a minimum and outright fabrication of misleading specifications at worst. The bottom line is power amplifier ratings are virtually meaningless today since there is no standard measurement system in use. This leads to confusion and serious misunderstanding in the audio community. ISP Technologies has for years rated the D-CAT power amplifiers in true RMS output power and as a result have shown modest performance specifications when compared with competitive amplifiers or self powered speakers. Some manufactures have gone so far as to claim they are offering 20,000 watt RMS power amplifiers with power consumption off the line on the order of 30 amps. I would like to see the patent on this amazing technology since there would be countless power companies beating a path to their door to license this technology. This white paper has been written to help shed some light on different types of power amplifier technologies and realistic and actual power amplifier power performance ratings and to also explain the advantages of the new ISP Technologies DAA™ Dynamic Adaptive Amplifier™ Technology now in use by ISP Technologies. An audio power amplifier is theoretically designed to deliver an exact replica of an audio input signal with more voltage and current at the output. An ideal amplifier would do this with zero harmonic distortion, zero inter-modulation distortion, limitless slew rate and transient response, virtually infinite output drive current, with zero output resistance and a ruler flat frequency response from 20Hz to 20KHz. How close the amplifier gets to ideal is what separates the good, bad and the ugly. There are many classes of amplifier topology with Class A, A/B, C, D, G, H to name a few. Many newer amplifiers are using Class D or digital amplifier designs mainly to increase efficiency.

**Power Conversion**

To give an understanding of why so many power amplifiers specifications are a total fabrication, let’s start by examining the power conversion of an audio amplifier. Simply put, you cannot produce more RMS output power in watts than the amount of watts consumed at the AC power input side of the audio amplifier, PERIOD. Most amplifiers will consume nearly twice the AC power off the line compared to what they can produce on their output. We will dive deeper into this later in the paper with an explanation of why the new generation of ISP Technologies Dynamic Adaptive Amplifiers, offer power conversion better than any other amplifier available, backed by both science, patents and patents pending.

**Actual RMS Audio Power**

The term RMS power, while technically an invalid term since there are RMS volts and RMS current but technically no actual RMS watts, is theoretically the power output of the audio amplifier with a continuous sine wave (RMS voltage) driving a specified load resistance up to the point just before clipping occurs. If the applied waveform is a pure sine wave, the relationships between amplitudes of the peak-to-peak, peak and RMS voltages are fixed and known. This is not true for a non-periodic or actual music waveform which is not periodic or continuous. For a pure sine wave, the relationship is:
Volts Peak to Peak = 2 x Peak
Volts Peak to Peak = \( V_{\text{RMS}} \times 2\sqrt{2} \) or (2.8284)
Volts Peak to Peak = \( V_{\text{AVERAGE}} \times \pi \) or (3.14159)

Power (P) into a resistive load (R) is defined with a constant current as \( P = I^2 R \). However, if the current is a time-varying function, \( I(t) \), this formula must be extended to reflect the fact that the current (and thus the instantaneous power) is varying over time. The power into a purely resistive load averaged over time is \( P_{\text{Avg}} = V_{\text{RMS}} \times I_{\text{RMS}} \). I know many manufacturers will argue that we don’t listen to pure sine waves so why measure with a pure sine wave. The reality is we really are interested in the true RMS output as a meaningful measurement of the brute force power the amplifier can deliver and this would be a truly meaningful way to compare one power amplifier’s performance to another if all manufactures were to measure the output power into a specified purely resistive load with a pure sine wave input signal.

Most who do provide an RMS specification will measure this mid-band with a 1KHz sine wave since a 30Hz sine wave will require far more sustained current over time than a 1KHz sine wave and so a 1KHz measurement still will not reflect what a subwoofer power amplifier will produce with for example dubstep type music with prominent sub bass frequencies. This is one reason some amplifiers simply sound better when powering subwoofers since they have more continuous RMS based output capability which you cannot discern from the current rating method of most power amplifiers.

Most power amplifiers today are specifying the output power in Peak output power. This is typically measured with a very short term burst signal at mid-band into a given load. For example a short term burst or transient that can hit 100 volts at the point of clipping into a 4 ohm load would produce 25 amps of peak current delivering a peak power of 2500 watts. If this amplifier could sustain this peak signal level before clipping with a continuous pure sine wave signal this would be equal to 100 volts \( \times .707 = 70.7 \) volts RMS into a 4 ohm load = 17.675 amps RMS = 1250 watts. As you can see this is \( \frac{1}{2} \) the peak power. The problem is most power supplies simply cannot sustain the same voltage with a continuous signal and will sag therefore delivering considerably lower output voltage swing. The signal will swing from 0 volts to positive and negative peaks based on the internal power supply rails.
Most power supplies cannot sustain continuous high current output levels without some amount of power supply sag. There are a number of factors that determine how much continuous current can be sourced before a large percentage of SAG occurs.

The new generation of ISP Technologies DAA amplifiers incorporate regulated switch mode power supplies, which means we have virtually zero SAG of the internal power supply rails. Back to RMS ratings, most manufactures don’t want to publish RMS based power since most power supplies will sag between 15% and 25% under heavy load. This means an amplifier that may deliver 2500 watts Peak for a very short term burst of a couple of milliseconds may deliver less than 800 watts with a continuous sine wave RMS. The manufacturer would much rather publish this meaningless spec of 2500 watts which gives no real indication of the continuous average output power. Bottom line is that if an amplifiers performance is measured with RMS based power of say 1000 watts you are guaranteed that amplifier will truly deliver well over 1000 watts plus of music based power.

**MUSIC / PROGRAM or BURST POWER**

Some companies will specify their power ratings as MUSIC Power, PROGRAM Power or BURST Power but the problem is there is no common standardized measurement for this type of power rating. This will vary from manufacturer to manufacturer so you cannot compare this rating between power amplifiers. Some will specify a typical music burst for X number of milliseconds and claim that is much more representative of reproduction of music while others will not explain how the measurements are made and just give you power in WATTS.

**HIGH CURRENT TRANSIENT POWER**

While we don’t listen to sine waves, it is worth noting that we want an amplifier to be capable of delivering sustained High Current plus what we term “Transient Power”. While any amplifier will drive a low frequency subwoofer, not all amplifiers will sound the same. If you do listening tests with several different power amplifiers you will find that a well designed power amplifier section coupled with a well designed power supply that can deliver sustained high current, will make a subwoofer sound deeper, tighter and punchier. The ability to deliver enough sustained current for 20Hz or 30Hz signals means better continuous sustained power but we also want excellent transient power. Transient Power is the instantaneous current available to drive the load with a sudden large transient. All of the ISP Technologies amplifiers are designed with high current class B, bootstrapped output current pump sections capable of delivering up to 4 times the required current to drive the load. This ensures the ability to deliver large transient current when required while avoiding large bias currents in the output stage of the amplifier. This technology improves the dynamic punch of the amplifier.
This advantage of higher output current for both sustained low frequency information and high current transient impact is the basis of one of the ISP Technologies patents.

ISP Technologies Patent number 6,831,514 “Method of increasing output current capability of negative feedback amplifiers with output current limiting and freedom from thermal runaway” discloses in detail the advantages of this improved power amplifier technology. The simplified schematic below shows how bootstrapped output devices are connected to supply large amounts of current dynamically on demand to improve the output current drive. Multiple high current drive output devices are incorporated to become active only when the demand for high current is required. This removes the devices from the amplifier bias loop to improve the thermal stability of the amplifier while providing extremely high current drive on demand. This provides better current drive to the load, better transient response, and better dynamic impact.
ADAPTIVE RAIL TECHNOLOGY

Adaptive Rail amplifiers have been around for years. Class G and Class H amplifiers offer better efficiency than Class A/B or Class B designs. This is due to the fact that when an output transistor is delivering power to the load, the average voltage across the transistor will be far greater than what is required to drive the actual load. For example, the figure below shows a plot of a music signal in a Class A/B power amplifier with power supply rails of plus / minus 100 volts. You can see the music signal is typically far below the 100 volt peak output swing. When the output signal is at 50 volts with an output load of 4 ohms, the amplifier will be delivering 12.5 amp instantaneous current to the load. With a 100 volt power supply rail and a 50 volt output signal swing, there will be a large amount of heat generated by the fact that the output devices will be delivering 12.5 amps of current to the load at a 50 volt output swing with an additional 50 volts across the output transistor. When the output signal swing is very close to the power supply rail there is far less heat generated since there is no longer a large amount of voltage drop across the output transistors.

Class G amplifiers will set multiple rail voltages in order to reduce this excessive voltage drop across the output transistors as shown in the figure below. This figure shows a class G amplifier with two positive rails, +Vs and +Vss and two negative rails –Vs and –Vss.
In operation when the output signal swing gets close to $+V_s$ or $-V_s$ the amplifier will switch to the higher rail voltage $+V_{ss}$, $-V_{ss}$. While Class G provides improved efficiency of the amplifier it has a major drawback in creating glitches in the output signal when the rails would switch.

Class H power amplifiers provide tracking rails that will track the actual output signal swing by only a few volts above and below the output swing. Below is a plot of the new ISP Technologies Dynamic Adaptive Amplifier output swing, shown in red, the positive power supply shown in green, and the negative power supply in blue. When the output signal swing gets within a couple of volts of the power supply rail, the rail voltage will track the output signal swing. This provides efficiency very close to that of Class D but without the associated problems inherent in Class D topology.

![Graph showing output swing comparison](image)

**A brief note on Class D amplifiers:** If Class D were the best amplifier solution, there would no longer be any other Class of amplifier in use. That is not the case. There are still major problems with Class D amplifiers. One of the main issues is that Class D is a very efficient radio transmitter. Class-D amplifier outputs propagate as radio waves, potentially causing interference with radio receivers and other equipment. The problem is in the run of cables connected to the output. A Class D amplifier requires a filter on the output to remove the high frequency switching components. The filter that is supposed to remove the high-frequency components and leave only the audio signal is quite shallow in its slope, typically 6dB or 12dB per octave so there's quite a lot of RF energy still on the output signal. The level of this signal is also related to the amount of current the amplifier is driving into the load. Class D amplifiers used in car audio will severely impact the radio reception. The ISP Technologies DAA power amplifier technology, when applied to car audio, provides performance that rivals that of Class D
without any of the RF problems. In professional audio it is beneficial to reduce any potential RF interference with other RF system in use such as wireless transmitters and receivers. A second major problem with Class D amplifiers is that the output filter response will change with different inductive loads connected. The output response will change based on the actual inductive and capacitive parameters of the connected loudspeaker.

The typical Class H power amplifier will use a low voltage positive and negative rail and will lift the power supply rails as needed to track the output signal swing. The internal power supply needs to source current at both a low voltage power supply rail, and at the maximum output swing of the amplifier. The typical approach is to provide a fixed low voltage power supply and fixed high voltage power supply. As the signal swing approaches the low voltage rail, Power MOSFET transistors are used to pull the low voltage rails up and down to track the output voltage swing. This means with a Class H power amplifier capable of a 100 volt peak output voltage swing into a 4 ohm load, the peak current delivered to the load would be 25 amps. This will require a power supply for both the positive and negative supply rails that can deliver 100 volts x 25 amps or 2500 VA (volt amps). Volts times amps is the same as watts, so if we assume an amplifier had 100 percent efficiency, it would require 2500 watts of power off the AC line in order to deliver 100 volts output swing into a 4 ohm load. This is where the new DAA amplifiers break the rules. The new ISP Technologies DAA amplifier technology is covered under a first patent number 9,402,128 “Adaptive Rail Power Amplifier Technology” with other patents pending. A simplified block diagram is shown below.

**Simplified Dynamic Adaptive Amplifier block diagram**
The ISP Technologies DAA amplifier uses stored energy to lift the rail voltages not direct power off the line. With fixed low voltage rails ranging from +/- 15 to +/- 33 volts, and a peak current of 25 amps in both positive and negative swing, we now only need 825 VA of power off the AC line not the 2500 VA in the above example. By storing the low voltage high current energy for use when peak signal swings are required we can reduce the power consumption off the AC line by about one third to one half of the typical amplifier through the use of stored energy. As mentioned before, no amplifier or power supply is 100 percent efficient so some power is wasted in heat. This means we don’t get 1000 watts RMS out with 1000 VA in but we have a considerably better power conversion factor with this method than any other amplifier topology, and can get closer to the theoretical 1 / 1 power conversion. What this means for the user is that a sound system with ISP Technologies DAA power amplifiers can deliver more SPL per watt of power consumed off the line than any other system available. The advantages of ISP Technologies Dynamic Adaptive Amplifier Technology are based on patent number 9,402,128, issued July 2016 shown below. ISP Technologies DAA amplifiers provide excellent audio performance with typical mid-band THD (total harmonic distortion) of .003%, dynamic high current output drive which translates into superior transient response, improved efficiency, reliability, and the best power conversion of any audio power amplifier.