Green Amps

By Mark**Frink**

Last February, when the Libyan civil war began, my wife and I began discussing how a sharp rise in the price of gasoline would make buying a Prius logical, as the money saved on fuel would cover the payments on the car loan. My wife is amused that I turn most life situations into math problems, but both my father's parents were math teachers, and pro audio is nothing without numbers. Since the average American drives 12,000 miles annually, switching from a 20 mpg Honda to a 45 mpg Prius saves 333 gallons of gas, which is $1,000 annually at $3 per gallon and $1,333 at $4 per gallon. Trading in her 2006 Element left us with $6,000 to finance. At $4 per gallon, the payback becomes 4 ½ years.

Today, energy costs are rising everywhere, and it looks like $100 per barrel crude oil is here to stay. The average U.S. commercial price of electricity is about 10 cents per kilowatt-hour, with California and the Northeast paying a few cents more and the Midwest, Northwest and Plains states paying a few cents less.

There are actually two technologies at work in what are generally referred to as "Green Amplifiers," amps that save enough energy over previous designs to pay for themselves over their lifetime. Modern professional power amplifiers increase efficiency and conserve energy through the mechanisms of switch-mode design, energy recovery of back EMF and power factor correction. Your father's old Class AB amplifiers had none of these advantages, operating at less than 50% efficiency and generating a lot of heat while producing just a few hundred watts of power.

With the cost of energy on the rise and many venues looking for ways to save money, amplifier efficiency is a new watchword. In the past, the sound vendor never saw a bill for the electricity they used, and the cost of energy at a concert wasn't part of settlement. Today, many larger and mid-sized venues are run by municipalities, from arenas to performing arts centers and community theaters, and, with newly-eroded property tax bases, many local governments have been forced to drastically trim budgets, closing libraries and laying off teachers, firemen and police officers. The next logical place to save is on the cost of energy. The largest consumers of energy in a sound system are its amp racks, so the best place to save is with efficient amplifiers.

For many sound engineers, the inner workings of a power amplifier are taken for granted. They perform like a "black box;" line-level signals go in and speaker-level signals come out. In order to examine what makes an efficient amplifier, we must understand how amplifiers work. There are two main parts: the power supply and the output section.

Class AB amplifiers commonly have peak efficiencies between 30 and 50% in audio systems. About a decade ago, a new amplifier design, called Class D, arrived on the scene and changed pro audio, supplying new kinds of amplifiers, with new companies springing up to manufacture them. Today's Class D switching amplifiers have efficiencies of 90-95%. Historically, "lightweight" amplifiers actually preceded Class D amplifiers, because the heaviest component in a traditional amp is its power supply.

Class AB

Class AB are conventional linear amplifiers, whether they use tubes, field effect transistors or bi-polar transistors. In technical terms, a Class B amp doesn't draw current until there's a signal, while Class A draws current continuously even if there isn't a signal. The combination of Class AB eliminates Class B's distortion with the help of Class A's idle current. For years most solid-state amps were a version of Class AB, going back to the Crown DC300, BGW750 and Phase Linear 700 models of the 1970s. The 4RU BGW750 weighs 57 pounds and produces 400W at 4 ohms.

In the historical quest for higher power levels, a variety of schemes were introduced to modify Class AB to produce power by dynamically changing the power supply's voltage rails to provide more power when needed for louder passages. Class G or H amps are class AB amps with adjustable power supply rails that adapt to audio program levels.

Class G amplifiers employ two or more power supply voltages and switch between them, increasing efficiency by reducing the wasted power at the output transistors at lower levels. Class H, the dominant design in older high-power designs, takes the concept of Class G a step further, creating an infinitely variable supply rail.

Famous examples include Crest's 8001, Crown's MA5000 and just about any higher power design from the 1990s. The 3RU Crest 8001 weighs 67 pounds and produces 1200W at 4 ohms, drawing 2.8A at idle and 10.5A at 1/8-power. While Class AB amps are up to 50% efficient, Class G or H designs with stepped rails can increase that to 75%.

The basic shortcoming of Class AB amps and even their turbo-charged class H variants stems from the nature of PNP/NPN bi-polar junction transistors (BJTs): when fully conducting, they're like a piece of wire, losing hardly any power; when fully off, they don't conduct at all, but in between, where they spend most of their duty cycle, the transistors waste power and get hot. That's why fans on amp racks have been a standard feature for years.

Power Supplies

Early power supplies employed heavy iron core transformers to convert AC voltages, which were rectified into DC voltages to power the amplifier's power transformers. These iron core transformers were quite heavy, primarily due to the weight of the core, and along with the capacitors and heat sink, were the primary feature on early amps, like the DC300.

Crown DC300, from behind

These were replaced in later models by toroidal transformers, which also used iron cores but were more efficient, because the primary and secondary wires were layered next to each other on a round iron ring. Toroids are smaller, save weight and are more efficient. They led to a smaller, two rack-space amp chassis, but the toroid was still the biggest component under the hood.

The 1990s brought the advent of switching-mode power supplies (SMPS), originally developed for smaller electronic applications and beefed up for power amp supplies, saving enormous space and weight by virtually eliminating the power amp's single largest component. Unlike iron-core transformer-based linear power supplies, the small air-core transistor of a switch-mode supply rapidly alternates between low-dissipation full-on and full-off states, minimizing wasted energy (and heat). Varying the ratio of on-to-off time regulates voltage — far more efficient, and substantially more complicated. Switch-mode supplies, married to Class H amplifiers became the "lightweight high-power" solution of the decade, and still are, for many, manufacturers.

Class D

Class D amps, often called "switching" amps, are quite different, incorporating not only a "switching" power supply, but also a "switching amplifier," saving considerable weight and electrical power due to their increased efficiency.

Class D amp employs a very high frequency switching signal, typically a 500,000 Hz square wave, modulated by an input audio signal which is then low-passed to smooth VHF ripple and produce a linear high power audio output. The advantage of Class D is its 95% efficiency, eliminating heat and substantially reducing the AC line power requirement.

Class D amplifiers have the advantage of being more efficient and with less power wasted as heat, so they need smaller heat sinks, resulting in lower cost and smaller amplifiers. Combined with previous iron-core transformers being replaced by switching power supplies, new Class D amplifiers are capable of thousands of watts in single rack-space chassis.

Ashly ne8250

Ashly Audio's ne8250 21-pound, 8-channel, 250W Class D installation amp draws less than 5A current at typical 1/8-power levels and 0.5A at idle. Compare this with the 40-pound, 2-channel DC300's 340W at 4 ohms, which used about the same AC power.

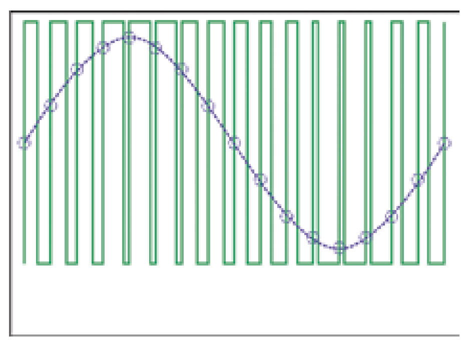
Yamaha TXn Series

Yamaha's three TXn series of two-channel DSP amplifiers are class D, with 8-ohm power points of 1000W, 1300W and 1700W, drawing 8A, 10A and 14A of current at typical 1/8-power levels, but only 1.6A at idle and 0.4A in standby mode.

QSC K series

Most manufacturers of self-powered loudspeakers employ class D power modules for the combined benefits of reduced weight, higher efficiency and lower heat by-products, all-important in portable systems.

Class D power amplifiers employ a different mechanism to create the high-voltage audio signal that will drive the loudspeaker, called Pulse Width Modulation (PWM). Instead of the biased complementary NPN-PNP push-pull output transistors used to swing the voltages that drive the loudspeaker up and down in Class ABH amps, the signal is created in a different fashion.



Class D Pulse Width Mode (PWM) modulation encodes the line-level audio signal into a stream of high-power pulses, with the varying pulse widths determined by the amplitude of the audio signal.

Class D amplifiers build the high-voltage waveform that drives the loudspeaker from hundreds of thousands of individual microsecond pulses. The pulses are created by turning high-speed MOSFET (Metal Oxide Semiconductor Field Effect Transistors) transistors on and off very quickly — every couple of microseconds. A line-level audio waveform is used to modulate or control the width of each pulse, with wider pulses constructing louder parts of the waveform that drives the loudspeaker, hence the common term for Class D amplifiers: Pulse Width Modulation. The width of the pulses is proportional to the input signal's instantaneous level, so the power delivered to the loudspeaker is the same as if the input signal had been amplified in the conventional way.

The waveform that these pulses combines to form has a very high frequency (VHF) component as a result of this pulse frequency, which is typically 10 to 20 times the highest audio frequency being amplified. This VHF ripple is filtered out using a low-pass LC network that smoothes out the ultrasonic ripple.

There are tradeoffs between Class AB/H and Class D amplifiers. Class D's lower heat by-products reduce the requirement for heat sinks and cooling fans. In high-power amplifiers, overall cost is competitive, because LC filter cost is offset by savings in cooling apparatus.

Class D PWM amplifiers achieve nearly ideal power conversion and reactive loudspeaker loads are easily driven because energy returned from the loudspeaker to the amplifier is efficiently "recycled" to be reused on the loudspeaker. Non-switching amplifiers are forced to dissipate all of the returned energy in the form of heat. This "recycling" of the loudspeaker's back-EMF is the final source of Class D amps' efficiency.

Crown I-Tech HD stack

Crown Audio's I-Tech Series (as well as their Macro-Tech i series) use Crown's patented class I (or BCA) technology, their proprietary refinement of Class D. Crown introduced its I-Tech amplifiers in 2004. The I stands for "Interleaved," a refinement of switch-mode Class D design, where a pair of switching output devices are arranged in parallel, with one dedicated to the positive current portion of the waveform, and the other to the negative current portion.

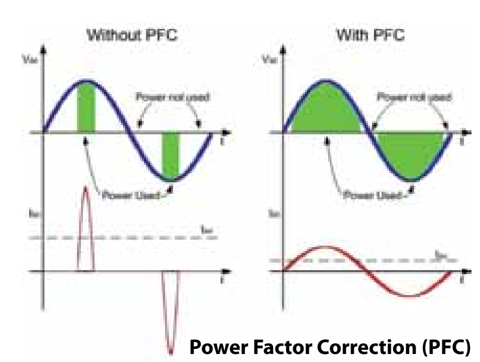
Lab.gruppen uses a form of Class D amplifier called Class TD or "Tracked Class D," which tracks the waveform to more accurately amplify it without the drawbacks of traditional Class D amplifiers.

Power Factor Correction

Power Factor is related to the current drawn from the AC line by a load.

Power Factor Technology utilizes a circuit that stores a reservoir of energy, acting like a "fuel tank" for a power amplifier's power supply, providing increased performance and stability.

Power Factor Correction (PFC) allows current to be drawn throughout the entire 60 Hz AC cycle of the line-frequency, providing maximum output power, while drawing significantly smaller peak currents from the AC line. Compared with an amplifier using a conventional power-supply, PFC requires less peak power to produce identical output power results—allowing a PFC amplifier to be serviced by a lower-rated breaker than a conventional amplifier of similar wattage.



Power Factor Correction (PFC)

When a power amplifier is reproducing audio content — especially live dynamic audio content with extreme transients — it may need a sudden large draw of current to reproduce the signal accurately. Most amplifiers will supply this, but when they do, their power supply attempts to stabilize itself with a large AC current draw. If current cannot be provided efficiently enough, the result is a phenomenon called current compression. Current compression can result in reduced fidelity, frequency response, and transients, leaving content sounding boomy, flat or dull.

Inside the power supply of most power amplifiers, the current is much higher than the instantaneous voltage, resulting in high peak current flow. This demand for high peak current requires higher power distribution capacity in the form of heavier wiring, larger breakers and bigger transformers. Power Factor Correction acts as a short-term energy reservoir for the amp's power supply, allowing it to draw current throughout the entire AC waveform in phase with the voltage, presenting a more purely resistive load to the AC line, reducing peak current draw by nearly half and minimizing AC waveform distortion even at maximum power. As a result, the power supply also operates on practically any AC line frequency and is highly tolerant of line voltage variations.

Powersoft M Series

DIGAM, short for DIGital Audio Amplifier, is Powersoft's patented Class D technology employing Power Factor Correction (PFC) behind their compact, powerful and efficient amplifiers. PFC also allows the amplifiers to operate at any international line voltage, from 95 volts to 265 volts, while maintaining a consistent power output and produces energy savings of about 40 percent. K series launched in 2004 and last year's new M series.

Power Factor Correction is also employed by Crown's I-Tech amplifiers and by Lab.gruppen's top-of-the-line PLM20000Q amplifier, allowing them to save energy while efficiently providing thousands of audio watts to loudspeaker systems.

Lab.gruppen PLM 20000Q (top) and PLM 14000

It's worth noting that for amplifiers without Power Factor Correction, output power can vary with the power supply (line) voltage. While many specs are based on 120V line AC, a non-PFC amp on 110V AC will provide about 4% less output power than its 120V specification. Amplifiers with onboard processing (and limiting) respond to voltages, not power levels, but outboard DSP can't easily adjust protection limiters to varying AC line voltages, another case for integrated amplifier DSP, as well as PFC.

In most venues, HVAC is also part of the energy footprint, and everyone with a house gig at an installed venue knows that the amplifier room requires a good air conditioning service to keep its amps running cool. The energy saved by Class D amps with PFC is energy that would normally be turned into a heat by-product and typically is 25% or more of the energy consumed by older amplifiers. Additionally, the HVAC energy that would be used to remove that heat from the amp room is also reduced, doubling the savings.

Jacksonville's Times-Union Center

A common installation and touring series of amplifiers in the U.S. is the Crown Macro-Tech, including the MA600, MA1200, MA2400 and MA5000. They provide 325W, 480W, 800W and 1300W into four-ohm loads. These amps power Jacksonville's Times-Union Performing Arts Center's 15-year-old sound systems in the Moran Theater and the Jacoby Symphony Hall, as well as being used across town at the Florida Theater. Jacksonville, like many US cities, is a "Crown town."

Short of actually metering electrical use, a lot of assumptions must be made about how amplifiers are used. For the record, I predict that in the next five years every major venue will have utility-supplied metering on company switches for tying in

Lab.gruppen E Series

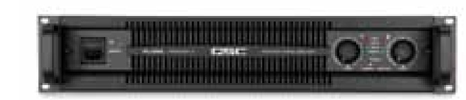
visiting production's electrical distribution systems for audio, video and lighting, and a bill for electrical services will be included in end-of-show settlements.

Most systems are turned on in the morning and left on until the last note of the show, typically a 12-hour day, with about 3 hours in moderate duty. The "duty cycle" of pink noise is 50%, rock 'n' roll 30% and background music 20%, so a fair assumption for most concert sound at a performing arts center is an average 25% duty cycle. At 25% duty cycle, the MA600 uses 3.5A, the MA1200 uses 4.7A, the MA2400 uses about 7A and the MA5000 uses 18A.

The Moran Theater — the oldest operating IQ system — has the following inventory:

Amps	A/amp	A/Total
(7) MA600	3.5	24.5
(3) MA1200	4.7	14.1
(6) MA2400	7	42
(1) MA5000	18	18
Sub-Total		*98.6A; 10,900W*

Using a national average of $0.10 per kilowatt-hour, it costs about $1.00 to run these amps for an hour. With about 200 shows per year in the Moran Theater, using the amps for 10 hours a day represents a



QSC PL380

cost of $2,000 per year.

What if we replace these amplifiers with more efficient ones? At 25% energy savings, a reduction in operating expense of $500 annually would be expected, and when that's combined with HVAC savings from not having to constantly remove those BTUs from the amp room, it combines to a savings of about $1,000 annually.

If we consider that the current amplifiers have been in use for 15 years, another fair assumption would be that the next set of amplifiers will see 15 years of use and changing to more efficient amplifiers would easily save $15,000, just about enough to pay for them, when considering the abundance of multi-channel amp models that can replace two-channel amps in a fraction of the rack-space. I suggest you look around your town for 15-year-old amps that you can replace for free.

If energy savings alone aren't enough, the additional features provided by today's sophisticated amplifier platforms for networkability, remote monitoring and control, complete system verification and to satisfy "life safety" requirements, make replacing old amplifiers a win-win for legacy installations. **FOH**

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