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WHITE PAPER

Design Considerations for High-Output Portable Amplifiers

Overview of Application Requirements

Since the late 1960s, touring sound has led the professional audio industry in the development and application of new technologies. This, coupled with the high profile of major tours and their sound system providers, makes touring an important proving ground for advances in sound reinforcement technology.

The Show Must Go On, Efficiency is a Must, but It's All About the Sound

Ruggedness and reliability, coolness under fire, watts per kilo, initial costs and long-term operating costs; all of this matters to the tour operator, but audio performance comes first with the artist, whether on stage or behind the console. As ticket prices continue to rise, the expectations of audiences rise along with them. It takes more and more of an "experience" to pry the ticket-buyer out of their home theater or away from the internet. Income from concert tickets and merchandise is becoming increasingly important to artists and the music industry.

Total fidelity requires headroom, flat frequency response, good full-range damping, controlled and non-destructive clipping when pushed, and freedom from any kind of premature breakup. In addition, signal alignment due to digital processing, including any delays in the amplifiers, must now be taken into account.

To summarize, concert amplifiers must be light but extremely rugged, precise but powerful, high quality but cost-effective, and more recently, must work equally well in digital and analog systems.

Further Considerations

Rental companies demand flexibility. Inventory only earns money when it's on the road. The more a given piece of equipment can do, the less time it spends in the warehouse. So an amp that can drive subwoofers in bridged mono, 12 inch or 15 inch woofers in stereo, bi-amplified floor wedges and even high-frequency drivers, is a better investment than a one-trick pony.

Compatibility is also a key factor. Many sound systems use one type of amplifier for all four frequency bands. This may require adjustable input sensitivity to optimize the amp for its designated role. Other systems use different power levels for different frequency bands. When updating a system, owner/operators of this type of sound system may prefer to replace one frequency band at a time, requiring any new amps to play well with the rest of the system.

Signal delay, adaptability to digital processors, remote monitoring and control, full protection against hazards and accidents, freedom from radio emissions, rack depth, adequate mechanical strength, sufficient cooling – these and many other factors must be thoroughly tested before any piece of equipment is ready to take to the road.

Installed systems too are increasingly expected to provide concert sound performance. In fact, the primary difference between many installed systems and concert systems is that the amp racks of the former lack casters.

Next-Generation Power Amplification for Portable Live Sound: Requirements

Challenges facing the designer of new power amplifiers include:

- Reducing size and weight.
- Increasing output power; low-frequency amplifiers should deliver 1000 -1500 watts per 8 ohm driver to take full advantage of the latest cone driver capabilities. This requires a rating of at least 4000 watts per channel into 2 ohm loads.
- Avoiding signal latency so that phase alignment can be as precise and repeatable as possible; this is also a requirement for backward compatibility with most existing amplifiers.
- Providing reasonable adjustments and indicators that let operators fit the amps into various system architectures, often on short notice, without specialized equipment.

PFC vs. Fixed-Voltage Power Supplies

One feature not mentioned above is Power Factor Correction. In a typical active PFC circuit, an additional boost converter is inserted in front of a standard switch mode supply to pre-regulate its input while optimizing power draw from the AC line. If sufficiently well-designed, this may also permit the power supply to work on a wide range of AC voltages. Unfortunately, this approach requires additional semiconductor switches and control electronics and the additional circuitry also reduces overall efficiency of the power supply. However, it's increasingly rare to transport the P.A. all over the world. Usually there are acceptable rigs located wherever large concerts are being promoted. Moreover, touring amps are not connected directly to the wall socket, but to an AC distribution system which may have the ability to supply the correct voltage to the power amp racks. The bottom line is that PFC can theoretically reduce peak AC current requirements, but we can do this with greater reliability and lower cost by simply improving overall efficiency.

Upper Class, Lower Class: Which Operating Class?

Clearly, amplifier efficiency is very important in concert sound applications. However, audio performance is also critical. Most modern amplifiers use switch mode power supplies for weight reduction while still using various types of linear output sections for high audio quality. Recently, switch mode technology (various forms of Class D) has been applied to high power amplifiers, most successfully for low-frequency applications. Lower power midrange and high-frequency amplifiers can still use Class H linear outputs to optimize audio performance with acceptable efficiency.

So Let's Go to Class!

The earliest high power professional amplifiers used linear Class B operation. The concept is simple and the performance can be excellent. Positive and negative power transistors are connected to positive and negative DC rails. When idling, both transistors are basically "off", so idle temperature is low. A relatively simple "phase splitter" causes the positive transistor to reduce resistance when we want to move the speaker cone forward, and the negative transistor reduces resistance to move the cone backward. Only one transistor is working at any one time, so they never oppose each other, thus reducing unwanted losses. However, losses within each transistor are quite high when delivering typical, partial output powers, since the devices are operating as variable resistors. **(Figure 1)** On music, losses can greatly exceed the average power delivered to the speaker. Efficiency is very low, and therefore it is difficult to scale this approach up to very high power levels.

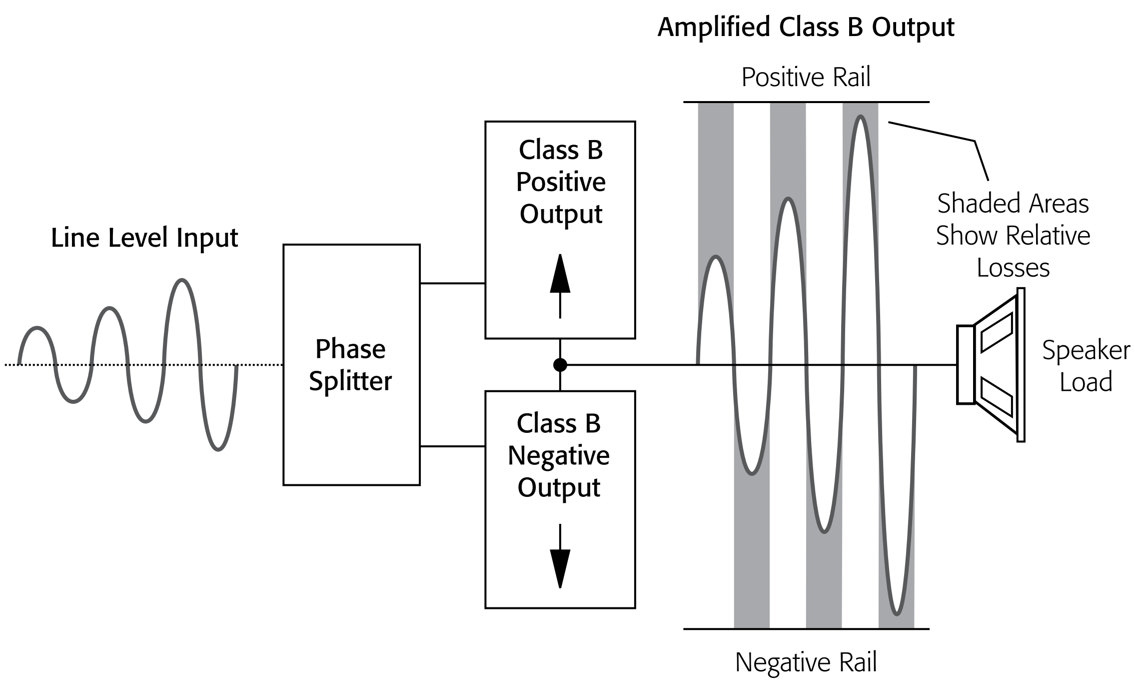


Figure 1 - Class B Amplifier with Losses

We can reduce these losses significantly, especially at average music levels, by using a "Class H" system. This technique adds one or more additional sets of power supply rails at intermediate voltages. **(Figure 2)** Special steering circuits connect the output transistors to the nearest available rail, thus greatly reducing the average voltage drop across the output stage, which greatly reduces its resistive loss. It takes considerable experience to do this without sacrificing audio performance, but QSC has successfully used this technique to double or triple the power capacity of a given platform. However, heat sink size and voltage limitations of available linear devices still limit the maximum safe power to about 2000 watts per channel in a 2RU chassis.

The fundamental problem with all linear designs is that thermal losses are inherent to the technique, regardless of how much one is willing to spend on the circuitry. To make further progress, we must consider a fundamentally different way of controlling the power we deliver to the load. Designers have long understood that the only way to eliminate power losses is to eliminate the resistance; an ideal semiconductor should operate either fully "on" (as close to zero resistance as possible) or fully "off" (which avoids all current flow and losses). We must drive the device as a "switch" instead of a resistor and vary the power by controlling the percentage of time it spends in the "on" state. This is the essence of switch mode operation, and it is theoretically capable of nearly lossless operation. This mode of operation was recognized early in the history of amplifiers, and was assigned the letter "D" – hence the commonly used term, Class D amplification.

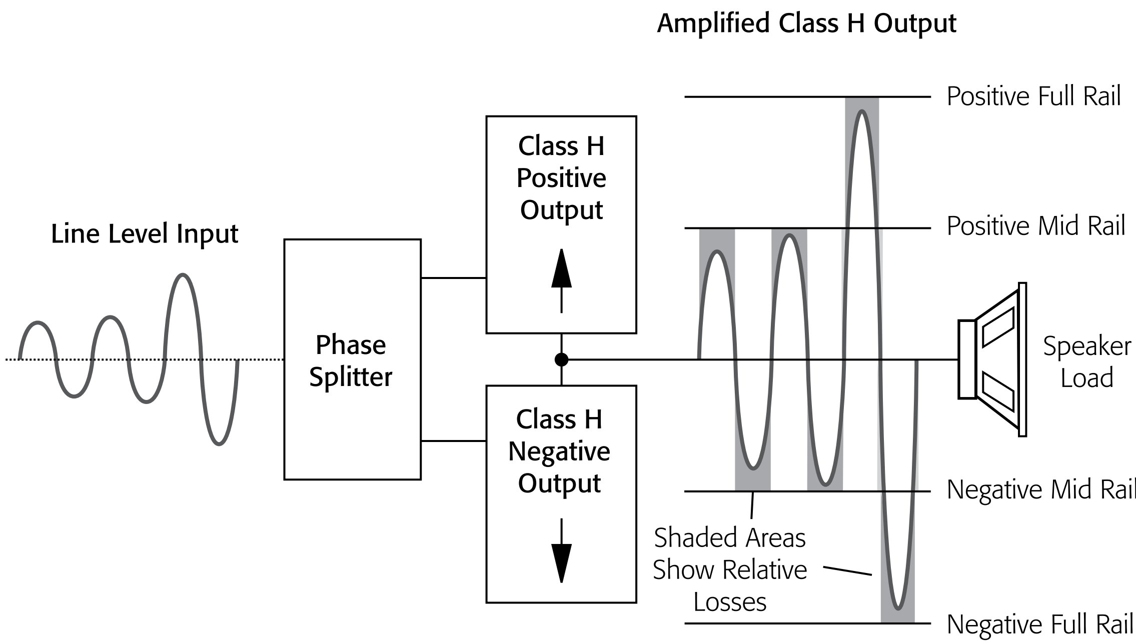


Figure 2 - Class H Amplifier with Losses

Basic Elements of a Class D Amplifier

The basic principle of Class D is to operate the "switches" at a frequency much higher than the audio range so that the resulting pulses can be filtered and smoothed out leaving only the desired audio signal. This takes three major processing blocks plus important error correction and protection systems which are explained in basic terms below. **(Figure 3)**

The **modulator** sets the switching frequency and receives the continuously varying analog input signal. The signal's amplitude is mapped into a continuously varying on/off ratio, thus delivering pulses whose relative width represents the signal level. This is termed Pulse Width Modulation, or PWM.

The **switching stage** uses the best available high-speed switching devices connected to positive and negative rails. These switches are driven, in turn, by the output of the modulator, thus amplifying the PWM pulses to a much higher voltage. As with linear amps, the maximum output power is still limited by the power supply voltage and the safe switching current, but ideally, the switches can operate with very little waste heat. Therefore, it is possible to control a large amount of power with relatively small losses.

The **output filter** must blend the pulses together to reconstruct the desired audio output. It is basically a high-power low-pass filter whose cutoff frequency is set just above the audio range, but low enough to block the switching frequency. This requires large passive components whose quality and performance set limits on what the Class D amplifier can achieve. Among other problems, the filter's roll off damping is dependent on the load impedance, which is highly variable at 20 kHz. Therefore, Class D amplifiers have struggled with load dependent high-frequency response.

Although each of these subsystems can be fairly linear in themselves, there are many opportunities for distortions to creep in and modern audio practice calls for a total error budget that is only a small fraction of 1%, ideally well below 0.1%. Therefore, error correction is the critical "glue" that makes all these systems work precisely and harmoniously.

And finally, of course, the amplifier must not fail due to normal hazards, so protection systems must keep voltages and currents within safe limits regardless of load and signal conditions.

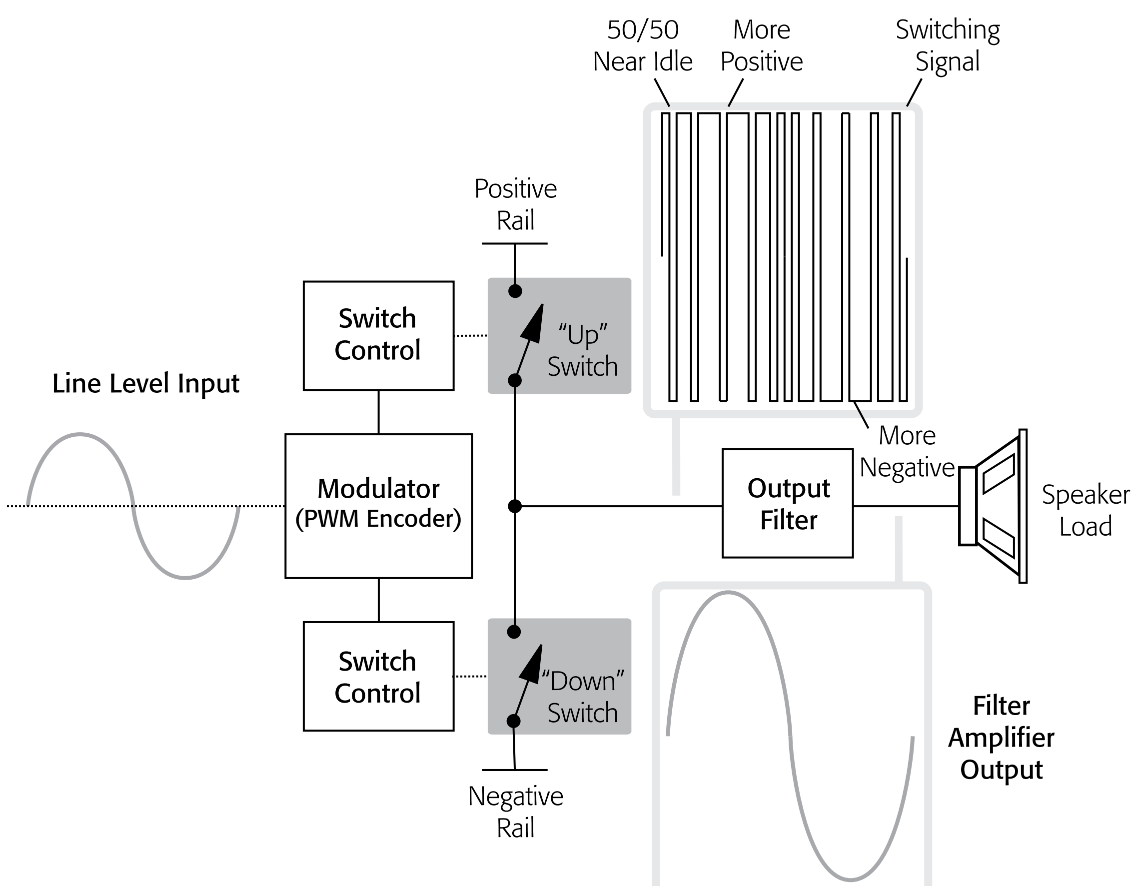


Figure 3 - Class D Amplifier with Modulation

A Deeper Dive into the Technicalities

The author has been interested in Class D technique for his entire career, and has worked patiently since 1992 to develop elegant, robust and refined Class D technology. We had to reject many approaches due to inadequate performance or insufficient reliability. The PM1000/1400 power module used in our MD Powered Series loudspeakers was the first product to fully meet our standards. Now it is followed by the Class D PL380, with more than twice the power and thermal capacity of our previous 2 RU Class H benchmark. For the edification of the eager reader, we present some of the thinking behind our design decisions.

Power Supply

The PowerLight™ supply that has served so well for over a decade is still the most efficient and reliable system that we know of, so we simply scaled it up to serve as the reliable foundation for our new Class D amplifier.

Class D Output Topology

Many Class D systems, including our own PM1000 platform, use "H-bridge" output structures. These have certain advantages, but since they already operate in "bridged mode" they cannot support external bridge-mono operation of a 2-channel amplifier. In addition, the semiconductor industry has been actively developing high current, high voltage switching devices for multi-kilowatt motor drives and other AC-powered applications. The PL380 therefore uses two of these "big boys" per channel **(Figure 4)** in a half-bridge topology, switching between positive and negative rails at almost 190V each. This reduces circuit complexity to the simplest possible level, allowing us to spend more to optimize each of the elements. The 500V rating also ensures against breakdown even in the face of abnormal line transients.

The PL380 uses the most basic, elegant "Class AD" switching mode. In this mode, the "up" and "down" switches operate in precise synchronization so the load current is always being controlled by one switch or the other. This requires highly refined gate driver systems (discussed below) to avoid the possibility of switches overlapping and shorting the two supplies ("shoot through" currents). Other amplifiers allow more "dead time" between the switches for safety's sake, at the cost of more distortion. Another major competitor uses a Class BD scheme, under a proprietary designation, that supposedly eliminates shoot through problems by operating only the positive or negative switch at any given time. This merely replaces short-term current peaks with longer-term inductive currents and introduces significant problems combining the positive and negative output currents.

Figure 4 - PowerLight 3 Output Device (left) Compared with Typical Output Devices

Gate Drivers

In order to obtain full efficiency and low distortion, the switching devices must be turned on and off in precise synchronization within tens of nanoseconds – about the time it takes light to travel across an average classroom. This is beyond the ability of the best highly integrated gate driver ICs, so each gate drive uses the fastest available optocoupler to translate the logic signal from the input section to the high voltage switching stage, followed by an ultra fast low voltage gate driver IC with 9 A peak output, with each gate powered by its own floating, regulated DC supply to ensure completely consistent performance.

Current Limiting

The highest possible current should be available to drive the load, without exceeding device ratings. However, safe current capacity diminishes at high operating temperatures. Therefore, we use a dynamic current measurement system that actually measures the power in each FET during its on-period with respect to its temperature, and if necessary feeds a signal back to the modulator to keep the output from exceeding safe levels regardless of temperature. When loudspeakers and amplifiers are at normal temperatures, full currents exceeding 75 A are available. If the amp and speakers are being driven hard at 2 ohms, the amplifier will heat up and its peak current limit must be reduced somewhat, but the associated voice coil heating will increase the speaker's impedance so that actual peak voltage swing remains the same. However, if a speaker or wire should short out at full power, the amp is still fully protected.

Modulator

The PWM encoder has a major impact on the quality of the audio and there are many different schools of design. Certain products, generally intended for use within speakers, use a type of encoder with internal error correction that reduces distortion, but forces the switching frequency to vary as the signal increases. This makes it more difficult to fully filter the switching frequency as needed to drive long lines and produce low THD readings. Most rack-mount amplifiers use a "clocked" modulator that runs at a fixed frequency, but without error correction. These designs depend entirely on overall feedback to reduce distortion, which is difficult at high frequencies due to the phase shift of the output filter. QSC uses a hybrid scheme with a crystal controlled clock for precise frequency control, plus internal error correction that reduces THD by 20 dB before the overall feedback is applied.

Crystal Clock

Both Class D channels and the main power supply are frequency locked to submultiples of the same crystal-controlled clock, preventing any beat frequencies from contaminating the audio stream.

Silent Muting

Amplifier muting must occur at precise times to allow the switching currents to engage and disengage without appreciable transients. Logic circuitry receives muting commands from various subsystems and synchronizes them with the clock frequency for predictable silent muting.

Error Correction

Although the basic process of PWM encoding is fairly linear, Class D amplifiers are subject to errors from minor timing variations, device resistance and especially power supply voltage changes. All of these errors cause the high-power switching waveform to deviate from the ideal pulse train coming out of the modulator. QSC uses an internal error correction system that measures the actual switched voltage and feeds it back to the modulator to correct deviations. This ensures that a clean signal is presented to the output filter.

This error correction allows us to switch at a lower frequency than most other clocked systems, substantially improving efficiency and power handling.

Output Filter

The classic 2-pole output filter uses a substantial inductor to smooth the switching pulses, filtered by a capacitor to ground to shunt the switching frequencies aside. Our inductor uses a proprietary winding technique to pack more copper on a smaller core, reducing size and weight. This filter is tuned to roll off just above 20 kHz. It provides about 40 dB attenuation of the 250 kHz switching frequency. This is improved to 55 dB by inserting a 250 kHz trap in the output network, which would only work, of course, in a stable clocked system.

Global Feedback and High-frequency Stabilization

Since the internal error correction reduces THD by 20 dB, the overall global feedback can be tailored primarily to correct the output filter's behavior. Without feedback, the output filter response at 20 kHz would vary by 20 dB or more depending on load impedance. Due to the carefully tuned feedback network utilized in the PL380, this variance is reduced to about 1.5 dB from no-load to 2 ohms and THD is reduced to as little as 0.01%, comparable to most good linear amps. At 10 kHz, the total frequency-vs-load variance is less than 0.4 dB and below 5 kHz, impedance has no effect on frequency response. A major competitor suffers from several times the variation at 20 kHz, accompanied by significant peaking at 2-3 kHz moving in the opposite direction, thus producing a distinctly audible sonic signature into certain loads.

Maintaining No-Load Stability

Virtually all highly tuned feedback networks have their lowest margin of stability into no-load, where the filter peaking is strongest. Aside from the need for the amplifier to operate safely with no speaker connected, cone drivers have very high impedances at 20 kHz. Even though they may not be driven at these frequencies, the amp must remain stable to avoid misbehavior associated with clipping. Therefore, it is common to connect an R-C zobel network to the output in order to maintain a reasonable load impedance at 20 kHz and above. These networks absorb power at high frequencies, which frequently requires the designer to severely limit permissible high-frequency outputs, sometimes starting below 10 kHz. QSC uses special heat-sink mounted resistors that can handle 200 watts per channel, so full power can be swept beyond 15 kHz, with almost 1000 watts available at 20 kHz. Any required limiting occurs automatically and the net result supports substantially more high-frequency power than any known competitor.

Protection Systems

In order to prevent unwanted muting of the amplifier, the first line of defense for any "out-of-bounds" condition is to engage up to 35 dB of analog limiting. This can occur in response to clipping (if engaged) and also limits in the event of overheating, high-frequency overload, long-term overcurrents and long-term AC consumption in excess of 30A at 120V (more than double a major competitor's limits). Most of these limits will never be encountered in normal operation, but if triggered, will result in a half-bright display of the red Clip LED. If for any reason, 35 dB of limiting cannot control the condition, the amplifier will then (and only then) resort to full muting. During muting, all Class D switching on that channel ceases, thus eliminating all significant sources of loss.

Balanced Input Voltage Limits

As part of our mission to produce "the ultimate analog amplifier", the PowerLight 3 series has specially tailored active inputs designed to receive signals exceeding +21 dB even on the most sensitive input setting. Special measures are taken to prevent any internal overloading downstream of the input stage in order to preclude opamp "kacking" even at the highest inputs. All models include a 3-position input switch settable for 1.2 V input sensitivity (gain varies by model), or 32 dB or 26 dB input gain (sensitivity varies by model). These and other features are fully detailed in the PowerLight 3 spec sheet.

DataPort Control and Monitoring Signals

As with other QSC products featuring DataPorts, internal circuitry measures amplifier output voltage, current, clipping and temperature for each channel, plus the status of the Bridge Mono and Sensitivity switch, plus Standby enable and internal rail voltage. The DataPort supports the usual plug-in DSP accessories, and QSControl™ 3.0 will include have the new models in its recognition list. One significant difference in the PowerLight 3 Series is that the DataPort input signal no longer enters the amp by its own internal signal path, but is now paralleled directly with the regular inputs. This enables any signals received through the DataPort to be cross-patched to other amplifiers.

Construction Technology

Switch mode circuitry typically replaces heavy chassis-mounted components with multiple lightweight components. Furthermore, control of high-frequency interference is a must. For these reasons, QSC builds each switch mode platform on a single, large, carefully designed, multi-layer PCB. This provides complete repeatability, reduces assembly costs, supports automated assembly and eliminates potentially troublesome internal connectors and contacts. QSC's elaborate product testing includes multiple vibration, temperature cycling and drop tests to identify and correct any weaknesses in the structure. Other high power amplifiers use up to 15 individual PCB assemblies with multiple interconnects and points of failure.

Q & A

Does the "D" in Class D stand for Digital?

A Class D output stage is a *switchmode stage*. That is, the output devices are either fully on or fully off at any given moment. This bears a superficial resemblance to the *binary* encoding used in logic circuitry. However, that does not mean that Class D is digital. True digital technology requires encoding analog signal levels as high resolution numbers, or digits, that computers can manipulate and store without further loss of accuracy. The PWM comparator that samples the analog input signal transforms the continuously varying amplitude of the analog input into continuously varying "timing pulses". In effect, the analog input amplitude has been mapped to an analog pulse width. The high power output stage amplifies the PWM pulse train, which is then filtered to blend the pulses together and restore a continuous analog signal closely resembling the input. **(Figure 3)**

This is an analog process – just a very different one from the more conventional *linear mode* in which output transistors vary their resistance in order to control the power being sent to the speakers. No matter how the amplifier operates, the end result is the same: an analog input results in a highly controlled, greatly magnified analog output voltage that is sent to the speakers with sufficient current to overcome all resistance in the way.

Why Does the PL380 Feel Warm at Idle?

Class D circuitry has a different loss curve than conventional linear designs. Linear designs can be adjusted for minimum idle loss, but losses increase rapidly at any significant power. **(Figure 5)** Therefore, linear designs idle cool but require a lot of fan boosting at high power levels. Class D designs constantly process a certain amount of power, and therefore run somewhat warm at idle. However, you will notice considerably less increase in temperature and fan speed, even at very high power levels.

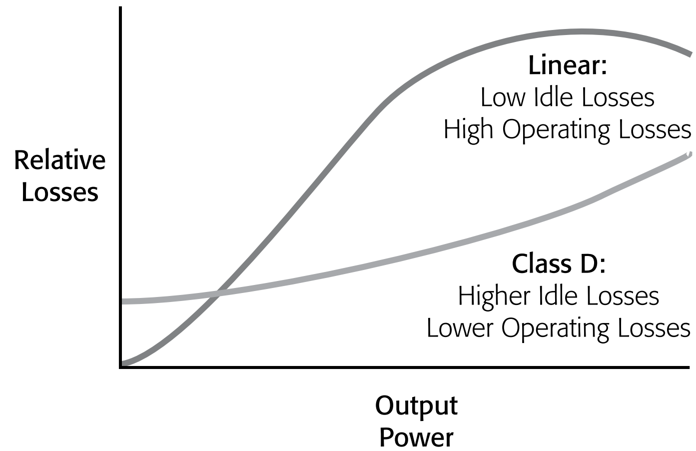


Figure 5 - Linear vs. Switchmode Loss Curves

Measurement and Real World Performance Issues with Class D Designs

Why Don't Class D Amps Show Ultra-low Distortion Specs at Full Rated Power?

It is possible to make good Class D amps with quite low distortion over most of their operating range, but for a variety of reasons, distortion rises somewhat over the last few dB of the power range. For instance, it is quite common for Class D amps to exhibit some extra switching noise, or dithering, just below clipping, which registers as an increased THD reading. This makes it impossible to cite the usual wideband power rating with incredibly low THD right below clipping: so far, there are no Class D amps with "0.0x" THD at full rated power. This is not a serious flaw musically, since as our VP of R&D Mark Engebretson points out, the very atmosphere is frequently starting to distort at these power levels, let alone any realistic loudspeaker.

Because Class D "THD at full rated power" figures don't look good on the spec sheet, most other companies disclose very little THD data. QSC believes its customers have a right to know, so we cite "typical distortion" from -20 dB to -3 dB, as noted below, plus power at the point of actual clipping.

8 ohm THD runs about 0.01-0.03% up to about 5 kHz, rising to 0.2% at 20 kHz and full output.

4 ohm THD runs about 0.03 - 0.06% up to about 5 kHz, rising to 0.2% at 20 kHz and full output.

2 ohm THD is about 0.05 - 0.1%, rising to 0.2% at high frequencies and full output.

Although some other products achieve slightly better low-frequency THD, few if any match the full-range distortion performance of the PL380 and all distortion products are smooth low-order harmonics.

Does Class D Have a Different Sound?

As noted, this method of processing power can introduce types of errors that don't exist in direct-coupled linear designs (power supply modulation, variable high-frequency damping, but mostly low-order distortion products). Therefore, early Class D amps tended to have more coloration, although generally of a musically acceptable "tube-like" quality.

The PL380 has been made as neutral and "linear-like" as possible. Any remaining differences are similar to the differences heard among various linear amplifier designs. The main listening impression is one of tremendous power and definition.

Does Class D Require Different Bench Test Setups Than Linear Amplifiers?

Class D amplifiers require a different approach to output performance evaluation relative to conventional linear amps. QSC uses extra filter traps to eliminate switching frequencies, but switching residue is still about -55 dB, requiring additional filtering to measure THD and noise floor in the -100 dB to -80 dB range (0.01%). Active filters built into existing measuring tools such as the Audio Precision are moderately effective, but best results require a passive pre-filter available from the test equipment manufacturer. It should, however, still be possible to confirm THD performance and frequency response at normal power levels.

Output Power Rating vs. Real World Thermal Capacity

The midband power output of the PL380 at clipping exceeds 1500 watts (8 ohms), 2500 watts (4 ohms) and 4000 watts (2 ohms), with both channels driven. Somewhat higher powers are available single channel and peak headroom can exceed 185 Vpk.

We believe the PL380 has the highest overall efficiency from AC plug to speaker terminal of any amplifier available. Full power efficiency can range as high as 85%, roughly half the losses of other switch mode amplifiers in this power range. Like all switch mode amps, losses and therefore heat generated are even lower at normal program levels. As a result, the PL380 can deliver up to twice the long-term, thermally limited, average power as "other" high power Class D amps – over 1000 watts per channel continuous at 4-8 ohms per channel, and over 600 watts continuous at 2 ohms. Furthermore, unlike linear amps, Class D amps do not lose efficiency when driving reactive loads. Since 2 ohm (nominal) loads can actually be 4 ohms or higher at many frequencies, the amp can deliver up to 1000 watts of "apparent" average power into most such loads.

To put these thermally limited average powers into perspective:

25% - 33% of rated power represents a heavily clipped, or highly compressed, program without any pauses or breaks. The PL380 will easily and indefinitely support such levels into any 4 - 8 ohm load, and into many 2 ohm loads.

12% of rated power is the standard safety agency testing level, and represents the loudest that most program material can play without audible clipping. This level should readily be possible even into worst-case 2 ohm loads.

The New PowerLight 3 Series: A Foundation for Modernizing the Concert Sound System

The PowerLight 3 Power Amplification System includes three models:

PL380 - Class D, 4000 watts per channel in Stereo mode driving 2 ohm loads.

PL340 - Class H, 2000 watts per channel in Stereo mode driving 2 ohm loads.

PL325 - Class H, 1250 watts per channel in Stereo mode driving 2 ohm loads.

QSC's Class H technology has the lowest THD, flattest frequency response and best full-range damping factor available, so it makes an excellent choice for powers up to 2000 watts per channel, at very reasonable costs and weight. These amplifiers will be the choice of users who don't require the massive power of the PL380 or who prefer the sonic character of a linear amplifier, especially at high frequencies.

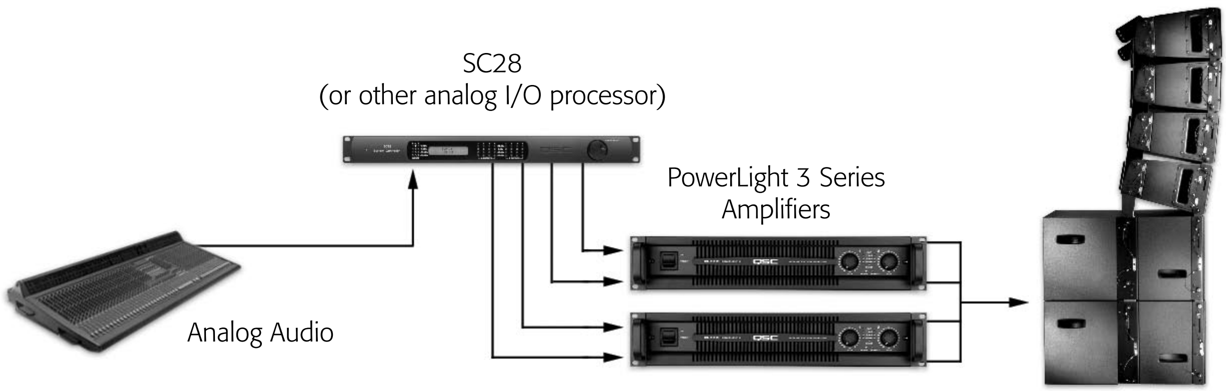
The PL380 specifications exceed many linear amplifiers, and its higher efficiency is the best way to provide the power required by modern LF and subwoofer sections of a typical 3-way plus sub PA with minimum weight, power consumption and heat generation. Its real-world audio performance is well within the range of other reputable professional amplifiers, and it is fully usable in all frequency ranges.

System Integration

Common features shared by all three amplifiers are designed to make it easy to use either the entire PowerLight 3 Series, or any single model, as part of a concert sound system. These common elements include:

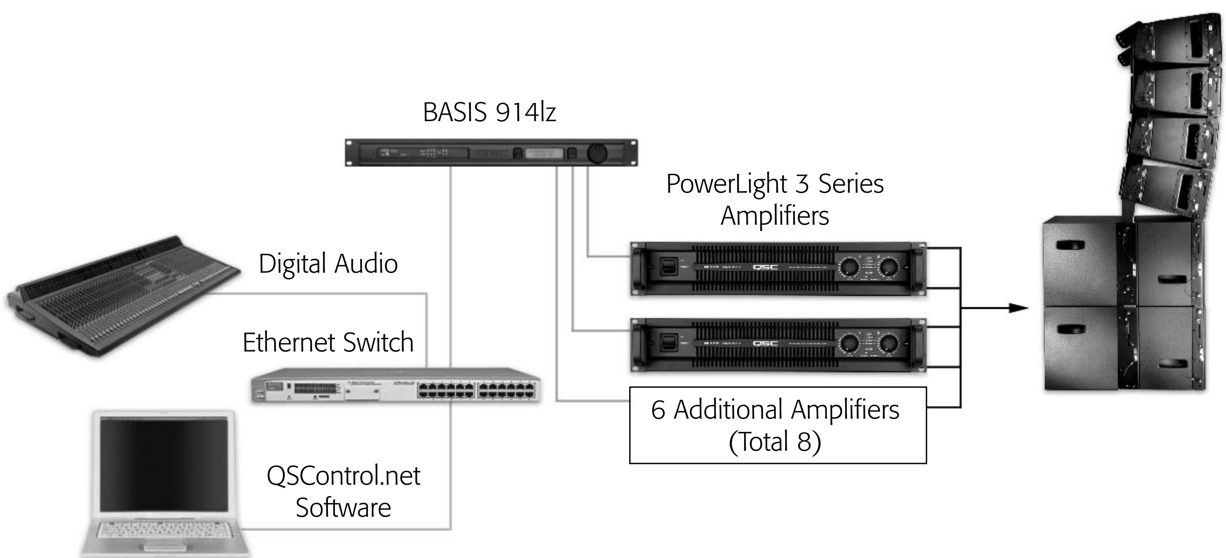
- Upgraded / Updated PowerLight power supply with larger capacitors and more robust semiconductors, for greater peak power, energy storage and hold-up time.
- Looping male-female XLR analog inputs; Euroblock analog inputs; DataPort audio paralleled with analog inputs for additional flexibility.
- 1.2V, +26 dB, +32 dB Input Sensitivity / Gain switching.
- Switchable Clip Limiter on each channel converts hard clipping to softer peak clamping; does not affect normal program levels.
- Compatible with optional DSP4 processing module for basic loudspeaker management applications.
- QSC DataPort connectivity for remote monitoring via QSControl.net: amplifier management can be accomplished with the appropriate BASIS™ products. BASIS units can also provide CobraNet® digital audio distribution, digital signal processing with drag-and-drop configuration and remote amplifier management.
- UL & CE safety approvals.
- EMI rating: given today's increasingly crowded RF spectrum, we do everything possible to eliminate RF noise buildup from the amp racks. The PL325 and 340 meet the strict "Class B" consumer standard. Like other large Class D amps, it has been difficult to meet this standard on the PL380. Early products have been shipped meeting the less stringent Class A rating, permissible for professional equipment unlikely to be used in the home.
- Stereo, Bridged or Parallel input routing.
- Switchable 33 Hz / 50 Hz High Pass Filtering on each channel
- Both Neutrik Speakon® and "touch-proof" binding post outputs. The Channel One Speakon® carries both channels for simple connection to bi-amplified speakers such as monitor wedges.
- Two Rack Spaces, 16.5 inch depth, 22 – 24 lbs weight.
- Zero Signal Latency: allows easy integration with older equipment, and eliminates the amp racks as a potential problem when time-aligning a complex multi-way sound system.

Flexible System Architecture



Analog System Compatibility

With ample power and excellent cost, weight and rack space per watt, the PowerLight 3 Series is your best choice. Zero-latency throughput in the amplifier racks using QSC's SC28 System Controller or your favorite DSP unit means your meticulous system alignment won't be compromised.



Total Audio Networking Functionality

PowerLight 3 amplifiers are compatible with BASIS processors and the QSControl.net network forming a comprehensive system incorporating extensive DSP, digital audio transport plus amplifier monitoring, management and control.