QSC's FAST Platform

By
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(United States)

QSC Audio Products in Costa Mesa, CA, is a global professional sound company with a reputation for making solid, reliable gear. QSC rarely leads the market, but it always seems to fill customer needs in a cost-effective and efficient way. QSC is successful because it does things just a bit better than the first players out there. This has resulted in consistent growth and market acceptance over the years, with QSC remaining a solid competitor even against companies with significantly more resources. A survey of review sites shows extremely high customer satisfaction, with almost no negative comments and many glowing endorsements.

Photo 1: Housed in a 2U rack-mount configuration, CXD and PLD Series amplifiers feature new QSC proprietary Class-D power devices, which enable multichannel, high-performance power. Flexible Amplifier Summing Technology (FAST) provides better power allocation by actively distributing the total amplifier power across one, two, three, or all four outputs enabling amplifier channels to be combined for maximum current or voltage output.

QSC's amplification product platform is based on an approach invented by founder Pat Quilter, who has been associated with reliable and well-accepted analog amplifiers for many decades. When designing his Class-D amplifier line, Quilter used conventional circuitry and added a few twists to it.

In Quilter's circuits, an amplified version of the input signal is compared to a constant frequency triangle wave. The triangle wave is generated by a simple RC integration of the clock, which has a typical frequency of about 400 kHz. The comparator's output then drives the gates, which control the output MOSFETs's switching. This is all conventional but done with a particularly simple triangle wave generator.

Normally, the amplifier's distortion performance depends on the accuracy of the sawtooth—its frequency and linearity. Quilter's amps can use the simple triangle circuit and still realize low distortion because of two feedback loops, a traditional global loop from the output to the first stage's inverting input, and a second loop that applies a current proportional to the switched (i.e., pre-output-filter) output voltage to the summing point of the clock voltage and the amplified analog input voltage at the comparator input. By choosing the right ratio of the three source resistances (and hence currents, with clock signal current being larger than current from the local feedback resistor), the PWM output is linearized, locking the switching frequency in synchrony with the clock. Quilter claims that this circuit trick reduces distortion of the unfiltered PWM signal by an order of magnitude, linearizing everything up to the output filter. His patent shows half- and full-bridge implementations.

A Class-D amplifier's output is also modulated by the power supply rail for the output stage. Quilter's patent addresses that issue as well, using a novel combination of an output-controlled regulator and rectification via an envelope detector. The combination of a tightly regulated low-noise supply and the multiple feedback loops is supposed to reduce overall amplifier distortion levels to figures comparable to analog amplifiers, but with greater simplicity and efficiency than other Class-D approaches. None of this is revolutionary, it's evolutionary.

Power Trios

A perfect illustration of QSC's "don't worry about being first, just worry about delivering a solid take on a well-accepted technology" approach is a new pair of four-channel amplifier product lines, each line comprising three models with different power ratings (400, 625, and 1,150 W/channel into 8 Ω). The CXD line is intended for permanent installations (e.g., churches, conference centers, auditoriums, and public addresses). The PLD series amplifiers are essentially the same as their CXD counterparts, minus the 70- and 100-V output lines, and with standard XLR input and NL4 output connectors. The target markets for the PLD series are touring shows, DJs, and other portable applications. Both product lines have the same 2U form factor and use half-bridge outputs (see **Photo 1**).

The PLD and CXD amplifiers are QSC's first products to incorporate its proprietary Flexible Amplifier Summing Technology (FAST), a method that uses a multichannel amplifier as user-selectable sets of bridged, paralleled, or solo channels (see **Photo 2**). For example, a four-channel amplifier could be configured as four independent channels or as a two-channel amplifier with one side comprising two of the four channels in parallel (doubling the current capability) and the other side comprising the remaining two channels in bridge (doubling the voltage capability). It could also be used as a single amplifier with all channels in parallel, and or other permutations.

The concept of bridging and paralleling isn't new, and there have certainly been analog and other Class-D power amplifiers with the same capability. QSC claims that its new FAST amplifiers take a different approach and can achieve the same results with simpler circuitry and greater efficiency (e.g., in parallel mode). They don't need ballasting resistors. Although QSC is as yet unwilling to discuss how this is done, you can garner a few clues from its public statements.

First, the output stages are configured as a half-bridge. Second, parallel channels use the same comparator signal to control the output stage MOSFET gate drive circuitry. This can serve to balance dead time with shoot through, both of which become bigger issues with multiple-output devices. QSC doesn't specify whether paralleling occurs before or after the output filter. Third, instead of having separate feedback loops for each paralleled channel, there's a single feedback loop for all of the paralleled channels (see sidebar). In addition, you can infer the high-power supply rails are the same for each of the paralleled channels and that the regulator feedback is also fed from just a single channel.

One of the FAST amplifier's construction features is an output device that appears to be matched power MOSFETs on a common thermal carrier (see **Photo 3**). There's additional unspecified circuitry on the same carrier. The QSC engineers were rather coy about revealing what's inside the package, but it's entirely possible that it comprises the matched MOSFET pair and output control circuitry, much in the manner of Crown's DriveCore devices.

A look inside the box shows QSC followed the pattern of its earlier amplifiers and mounted the circuit board component side down (see **Photo 4**). This is said to reduce the dust accumulation on thermally sensitive parts, but does require some care in

a)
b)

Photo 2: The CXD lineup includes three models. The rear panel features four balanced Euroblock input connectors and four Euroblock touch-proof loudspeaker connectors enabling integrators to terminate wiring before connecting to the amplifier (a). The PLD series, designed specifically for portable sound applications, also consists of three models from 400 to 1,150 W/channel at 8 Ω (continuous) with four balanced XLR input connectors with loop-thru and six Speakon NL4 loudspeaker connectors for easy setup (b).

Photo 3: QSC's proprietary output MOSFET packaging contains two MOSFETS (presumably matched at the die phase) and steering circuitry.

Photo 4: This isn't a top view of the interior; it's a bottom view! Note the inverted construction, which QSC uses to avoid dust collecting on the circuitry and heatsinks.

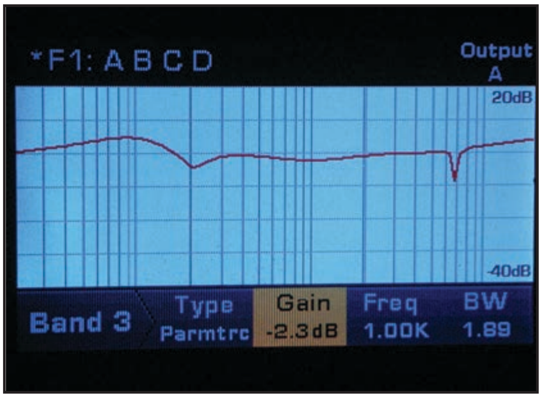

Photo 5: The user interface for PLD/CXD DSP functions has several options, parametric equalization is shown here.

thermal management, since the hot air flow through the heatsinks is restricted by the PCB (see **Photo 4**).

Divided We Stand

Professional sound equipment operators usually have a rack full of components to drive the loudspeakers. In addition to power amplifiers for each driver or stack, there are electronic crossovers, equalization, and limiters. Since these requirements are near-universal, the current generation of top-end professional amplifiers usually builds in these other features. The amplifier then functions as a flexible control center with full DSP capability and can be customized for the specific loudspeakers or drivers to which it's connected.

There are several ways in which the DSP control may be implemented:

Front panel control and display—The user or installer can set up the amplifier configuration through a user interface integrated into the amplifier.

Network—The amplifier is set up as a device on a network and controlled via a computer on the network, and eventually through smartphone apps for true remote flexibility.

Integrated system—The amplifier system can include a network-linked computer internally to enable overall system control.

The QSC PLD and CXD amplifiers use the first type of implementation. The advantage of the current QSC approach is compactness and simplicity—the amplifier system's operation does not require an external computer network and can be highly automated via amplifier firmware. The user has a shallow learning curve and doesn't need to have expertise in networking. For example, instead of needing to decide "single-channel," "bridge-mono," or "parallel" configurations, PLD simply asks for loudspeaker impedance and power handling, then decides the right configuration internally to optimize power delivery.

The disadvantage of this approach is the lack of flexibility and limitations on system control, since the operator/installer must use the front panel interface or be tethered by USB. Future versions are likely to incorporate a more sophisticated network capability using a standard Ethernet connection, which is certainly the trend in modern professional amplifiers.

Included in the on-board DSP for the FAST amplifiers is source selection and mixing,

About the Author

Stuart Yaniger has been designing and building audio equipment for nearly half a century, and currently works as a technical director for a large industrial company. His professional research interests have spanned theoretical physics, electronics, chemistry, spectroscopy, aerospace, biology, and sensory science. One day, he will figure out what he would like to be when he grows up.

Bridging and Paralleling

The Ideal World

When it comes to theoretical amplifiers and theoretical loads, an amplifier is generally idealized as a voltage source. "Voltage source" means that the output voltage is linearly related to the input voltage, and the source impedance of the amplifier is zero. The latter implies that 100% of the voltage generated by the amplifier is delivered to the load. There are a few oddball amplifiers that act as transconductance amplifiers, that is, amplifiers that output a current that is proportional to the input voltage (and hence ideally have an infinite source impedance). However, most loudspeakers are not designed to provide a flat frequency response when driven that way.

The power delivered to the load, which is usually a loudspeaker, is a function of available voltage and the loudspeaker's impedance. In reality, the loudspeaker's impedance may be regarded as a fixed resistance RL, and the average power dissipated in the load is provided by the canonical $P = V^2/R$, where R is the loudspeaker resistance and V is the root mean square (RMS) voltage produced by the amplifier.

The Messy Real World, Phase I: Voltage Limits

A voltage amplifier has limits, notably the power supply voltage. An amplifier is simply a modulator of the power supply, so in general, its peak voltage output cannot exceed the power supply voltage. (There are some exceptions, but even in those cases, there is a hard limit to how much voltage the amplifier can source.) Let's say an amplifier has ±50-V voltage rails and the loudspeaker has an 8-Ω impedance. The maximum sine wave power that can be delivered to the loudspeaker is then $V^2/R = (50)^2/(2)(8) = 156$ W. The "2" in the denominator comes from taking the RMS value of the voltage of a sine wave (50-V peak divided by $\sqrt{2}$). For a 4-Ω loudspeaker load, the same nearly ideal amplifier could deliver twice the power. For 2 Ω,

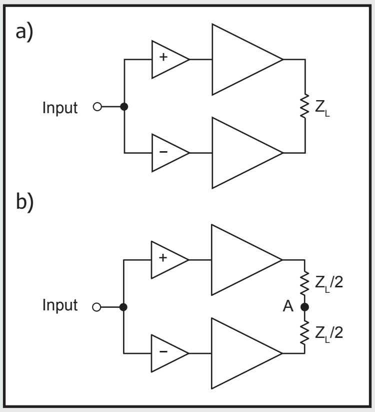

Figure 1: Bridge two amplifiers to make a single amplifier with higher voltage swing capability. The basic bridging topology is shown (a). The load impedance on the output of each amplifier in the bridge is half that of the load driven by a single amplifier (b).

the nearly ideal amplifier could deliver four times the power, and so on.

Suppose you want to increase the power of a nearly ideal amp into that 8-Ω loudspeaker. One way to do it is to raise the rail voltages. The increase in power to the 8-Ω loudspeaker will scale as the square of the voltage increases—a doubling of the rails to ±100 V will mean four times the power (625 W) can be delivered to the speakers. Unfortunately, this will double the voltage requirement for the transistors and double the amount of heat they have to dissipate. Both these consequences can add up to higher cost and poorer reliability.

A second and often better solution is "bridging" two amplifiers. In this process, a pair of amplifiers is dragooned into service (see **Figure 1**). The signal is fed with no change in polarity to one amplifier (see **Figure 1a**) and with reversed polarity to the other amplifier (see **Figure 1b**). Circuits to provide equal signals of opposite polarity are extremely simple to implement, often needing only a single transistor or op-amp. The load is connected between the "hot" terminals of the two amplifiers. This ideally allows double the voltage swing of a single amplifier.

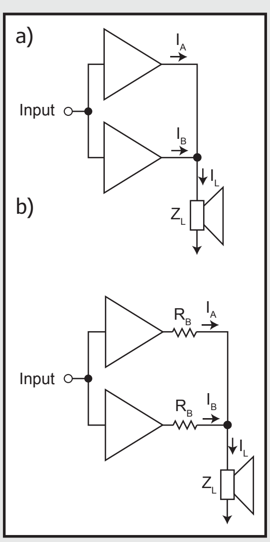

Figure 2: Parallel two amplifiers to make a single amplifier with higher output current capability. The basic paralleling topography—ideally $I_A = I_B$—enables all current to be equally shared and delivered to the load (a). Use ballast resistors to equalize current draw from each amplifier in the parallel pair (b).

Note that if you conceptually divide the load in half (see **Figure 1b**), by symmetry the midpoint is at 0 V at all times in the signal cycle. Hence, each amplifier is effectively driving a load of half the impedance of the same load without the bridge. This means that each amp now is forced by Kirchoff's current law to deliver twice the current as for unbridged mode, since the load and the two amplifiers are all in series.

The Messy Real World, Phase 2: Current Limits

I previously noted that, for a given output voltage, halving the load impedance doubles an ideal amplifier's delivered power. This is interesting because in the limit of a short circuit for a load, the power delivered would be infinite. Clearly there are limits—if you try to draw too much current out of a transistor, it will overheat and burn out, which is generally not desirable. Hence most professional amplifiers use some form of current limiting to protect the output devices. The other limits are the output MOSFET channels' resistance, the output filter's resistance, and the power supply's impedance, with the MOSFET resistance generally being the dominant factor.

One way to increase the maximum output current is to parallel two output stages (see **Figure 2a**). Ideally, each amplifier would source half the current, but reality is not always so kind. To provide some sort of feedback to equalize currents, ballast resistors are added to the amplifier outputs (see **Figure 2b**). The R_B ballast resistors work as advertised, but the downside is the power dissipated in them, reducing the maximum current that can be delivered to the load. Additionally, the resistors' effectiveness increases with increasing resistance—better balance, more wasted power. This is why the absence of ballast resistors in the FAST amplifiers is significant.

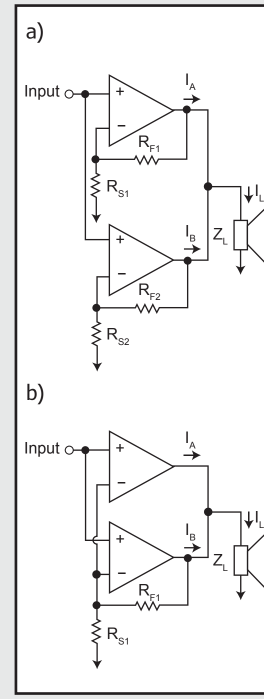

Figure 3: Feedback systems can be used for paralleled amplifiers. Conventional approach-tolerances in the feedback components mean that one amp drives current into the other (a). QSC's single feedback system is automatically implemented when channels are paralleled (b).

The Messy Real World, Phase 3: Channel Matching

Even the real-world examples given make an unwarranted assumption: that the two amplifier channels have identical gain. If they don't, then not only is there an imbalance in the delivered currents, but not all the current will be delivered to the load. **Figure 3a** shows a typical pair of paralleled amplifiers. The gains of each are determined by the ratio of R_F/R_S for each amplifier. If RF_1/RS_1 is not equal to R_{F2}/R_{S2} (and given real-world component tolerances, they are unlikely to be exactly equal), then the amplifiers will attempt to have different output voltages. Current will be driven from one amp to the other until the voltages are equal—or they catch fire.

Figure 3b shows QSC's unitary feedback approach. A single feedback loop corrects both paralleled channels, ensuring near perfect matching and a minimum of wasted current. The switching between a pair of feedback loops and a single one is automatically handled in the amplifiers' circuitry.

Photo 6: QSC's new amplifier platform was designed as a custom Class-D multichannel high-performance device with agile power distribution across one, two, three, or four channels via Flexible Amplifier Summing Technology (FAST). It also has a PowerLight universal switchmode power supply with power factor correction (PFC) for high efficiency and low weight.

electronic crossover capability (6-48 dB/octave, Bessel, Butterworth, and Linkwitz-Reilly), parametric equalization (up to five bands of parametric or shelf EQ), delay, and limiting (see **Photo 5**). What this means is that a portable equipment user has fewer items to lug around and that there's more flexibility in setting up the amplifier for varying speaker systems. Likewise, installed system users can configure the same amplifier for different requirements, which reduces the number of different types of amplifiers needed, simplifying installation design and implementation.

A nice feature is a group of presets for different brands of popular professional speakers (e.g., Peavey, Yamaha, JBL, EV, B52, and Cerwin-Vega) with optimized crossover frequencies and amplifier configuration to match nominal impedance, power, crossover, and delay requirements. Again, this simplifies setup for the non-expert user. The DSP capabilities for QSC's own speakers are more extensive, including FIR and dynamics (see **Photo 6**).

Photo 7: The QSC assembly line in Costa Mesa, CA, is set up in a sequential workflow arrangement to produce a product from start to finish by physically grouping tasks and machines to minimize unnecessary time and motion expenditures.

As discussed in the sidebar, you can optimize the amplifier configuration for a given loudspeaker impedance. The amplifier does this automatically if you give it the impedance and power. But unfortunately, the loudspeaker's impedance is not a fixed value and can, in fact, vary almost 10:1. So a sophisticated user will consider not only the nominal speaker impedance, but what the impedance is at frequencies that are likely to have the highest power consumption given the source signal's spectral balance. If a soprano is miked, the impedance at 600 Hz will be far more relevant than the impedance at 60 Hz.

Born in the USA

Although QSC is not unique in having design and engineering based in the US, it is one of the few companies that are actually manufacturing product domestically. Domestic manufacturing is unusual in electronics these days, especially consumer electronics. Regulations and labor costs have made offshore (usually China) manufacturing economically irresistible. The quality of facilities and work overseas has increased, so it's possible now (though not trivial!) to do world-class manufacturing to US-quality standards in Chinese technical hubs such as Shenzhen. China is no longer just a source of lower labor costs, restricted to making labor intensive goods; in fact, wage cost increases have caused many low-tech commodity companies (e.g., shoes and clothing) to relocate to other areas of Asia.

The trend toward parity in manufacturing costs highlights the insuperable difficulties associated with off-shoring, mainly logistics. "QSC is committed to developing and manufacturing professional audio products (e.g., signal processing, amplifiers, and loudspeakers) in the US," said Dale Sandberg, Product Manager for the FAST platform. "We have developed significant skill sets in this area and have invested heavily in the tools necessary to produce efficiently in the US. That is not to say that we do not believe in overseas production, but we choose to do so when it meets our needs."

According to Sandberg, QSC currently manufactures all models of both the PLD and CXD line in the US (see **Photo 7** and **Photo 8**). However, it is in the process of transitioning the PLD to an overseas manufacturer.

"It takes time to bring up manufacturing with the correct techniques and sufficient test resources. It was easier and much quicker for us to develop and prototype the amps in our plant here in the US than work with an overseas manufacturer," said Sandberg.

Besides speed of development, several other factors go into a decision to build a product in QSC's Costa Mesa factory versus overseas. Cost of goods is a consideration, as is their desire to continue manufacture in the US.

"We also have to think about demand planning. Some products tend to have a more consistent demand while others have greater variability," said Gary Tschetter, QSC's Vice President of Marketing. "For example, amplifiers intended for installation are subject to swings in demand that are driven by large projects such as stadiums, theme parks or big cineplexes. It's far easier for us to manage this demand when we are building these amplifiers here in Costa Mesa. Building amplifiers overseas means that forecasting lead-time is much longer. To maintain desired service levels, we would have to carry large quantities of safety stock. For some types of product, the cost of carrying safety stock can outweigh savings from overseas manufacture."

Sandberg agrees and looks to the future. "As is typical, we experience a new product ramp where the demand increases over a period of years then plateaus. The period is longer for some products (installation products in particular) where the product can increase in sales volume over five or more years before the plateau occurs. Production tries to predict and keep up with demand. I see these products succeeding in the marketplace and the demand increasing. I also see expansion of the platform with the development and production of new models. The cost of the product is not the only thing we consider. We produce more now in the US than we ever have and can see it increasing in the coming years."

Photo 8: Part of QSC's FAST amplifiers' assembly process includes automated parts placement.

Overall Impressions

Clearly, QSC has aimed to make a solid, reliable unit with great ease of use and flexibility and a reputable company standing behind it. While the new FAST amps aren't challenging the boundaries of networking and control, they provide a simple and understandable setup and appear to be a great choice to match up with QSC's speakers.

Resources

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