ISSUE: April 2020

What We Missed At APEC: Silicon Carbide Marches On And Other Power Product News

by David G. Morrison, Editor, How2Power.com

The Applied Power Electronics Conference's annual exhibition and exhibitor seminars present suppliers in the power electronics industry with the premier forum for showcasing and demonstrating new products, reference designs, and their customers' end products. These exhibits and seminars also are a forum for previewing future product launches and roadmaps, and sharing other company news. With the cancellation of the recent APEC 2020, due to the COVID-19 pandemic, exhibitors looked for new channels to convey their latest developments and plans. Some created new web pages or "virtual" exhibits to share their APEC 2020 news while many others scheduled online briefings with editors to get the word out. This article presents highlights from both those web features and briefings, bringing you some of the noteworthy power component news you might have seen at APEC 2020 in New Orleans.

As in recent years when APEC was held live, wide-bandgap developments featured prominently in this year's news. Recent gallium nitride (GaN) developments and customer product examples were again in evidence, but with new twists such as their creative use of multilevel topologies, and demos to show that GaN can compete at higher voltages and power levels. Meanwhile there are more integrated GaN devices and these are helping GaN making inroads in the vast adapter market where GaN can help shrink adapters and speed charging.

However, among the APEC-timed discussions, silicon carbide (SiC) seemed to steal the spotlight with the large number of SiC-related news stories and demos. As some vendors look to launch their fourth generations of SiC technology, SiC performance continues to improve, while at the same time, there are more and better options for their gate drivers. These developments come as SiC is moving beyond its initial successes in EVs and solar inverters, towards use in industrial applications. Meanwhile the electrical boundaries between where GaN, SiC and silicon are deployed continue to evolve and blur as different semiconductor suppliers adopt different strategies for addressing various application needs. Some of that strategizing is discussed here.

Perhaps less exciting but still impactful are the continued development of point of load regulators—monolithic ICs and IC-style modules, which highlight new controller capabilities, the latest generation silicon MOSFETs, and ever-more sophisticated packaging designs. It's been many years now since the semiconductor companies took over the nonisolated dc-dc converter market (the point-of-load regulators or POLs) from a previously diverse collection of power supply companies. Despite the many reports of the silicon MOSFET's demise, the low-voltage MOSFETs continue to eke out gains, which together with circuit and packaging improvements help to increase power density for POLs.

This article highlights the APEC 2020-inspired news from the following vendors.

- Power Integrations
- Rohm Semiconductor
- Infineon Technologies
- On Semiconductor
- United SiC
- Texas Instruments
- Efficient Power Conversion
- GaN Systems

You'll find additional power semiconductor developments that companies planned to show at APEC 2020 in the other Power Products articles that appear in this April 2020 issue of How2Power Today.

To share its developments, **Power Integrations (PI)** created a virtual version of its booth online. This virtual booth offers five videos discussing some of the company's key technologies and products. For example, in the first video: PI's CEO Balu Balakrishnan discusses why the company is using GaN in power supply ICs for adapters, which a general market trend, but also in chips for TV power supplies, and appliances. He explains what benefits GaN offers in each case. Balakrishnan also discusses the specific advantages of PI's GaN, particularly with respect to discrete GaN solutions. He also describes how PI's use of GaN is tailored to creating system solutions that include the gate drive and power protection circuitry to achieve robustness and ease of use.

In another video, product marketing engineer Aditya Kulkarni goes into more details on the benefits of applying PI's version of GaN, called PowiGaN, in PI's InnoSwitch3/Pro and LYTSwitch6 offline flyback switcher ICs. He also discusses other features of these ICs. For example, the benefits of InnoSwitch3/Pro include lossless current sensing and an I2C interface for precision control of output voltage and current. As an example of its capabilities Kulkarni cites an InnoSwitch3/Pro reference design that implements a two-stage, 100-W USB-PD reference design that is 90% efficient.

In a second video featuring Balakrishnan, PI's CEO discusses why PI entered the automotive market with its development of an automotive version of its iDriver, an IGBT driver for industrial apps. The new SiC SCALE iDriver is a gate driver specific to SiC power MOSFETs, and in this video Balakrishnan explains the challenges the SiC iDriver overcomes. First is its ability to turn off the SiC MOSFET quickly and safely, making sure the drain voltage never exceeds the breakdown voltage due to transients generated during turn-off. Secondly, the driver allows the designer to choose the positive and negative drive voltages to accommodate the different drive voltages required by the specific MOSFET (there's not much industry standardization yet). Finally, the driver must be able to provide more current to switch the MOSFET faster—iDriver provides 8 A to allow the MOSFET to be switched at 250 kHz.

In addition, iDriver's use of Fluxlink, PI's isolation technology provides a more rugged alternative to standard optocouplers. Fluxlink has a BV up to 8000 V, which offers plenty of margin for working with 800-V EV batteries. Director of training Andy Smith extends the discussion, providing more information SCALE iDriver and the value of Fluxlink in the automotive EV applications.

Another video features director of product marketing Chris Lee discussing the value of the 900-V breakdown voltage in its offline power supply ICs in accommodating the voltage transients, high surge and unstable mains voltages encountered in different regions of the world. Finally, senior product marketing manager Cristian Ionescu Catrina notes the benefits Bridge Switch motor driver ICs bring to inverter design such as reduced certification time and more-sophisticated fault diagnosis. Advantages and features of the new BRD 1167/1267 ICs for applications up to 400 W are discussed.

PI's virtual exhibit also provides a list of downloadable design example reports. To visit the virtual booth, see Power Integrations Virtual Booth - APEC 2020.

In their post-APEC briefing, **Rohm Semiconductor** discussed their plans to introduce the company's fourth generation of its SiC MOSFETs. Comparing the fourth-generation parts with the existing third-generation devices, Ming Su, technical marketing manager at Rohm, noted that the third-gen devices need 18-V V_{GS} to bring down conduction losses, while the fourth-gen devices will only require 15 V. These fourth-gen parts continue the company's progress in reducing on-resistance.

In migrating from a planar process in the second-gen devices to a trench process in the third generation, Rohm reduced the specific on-resistance by 50%. Now in the fourth-generation, they will cut on-resistance by another 50%, by further optimizing the trench structure of the device with a more optimum pitch size. These pending fourth-gen SiC MOSFETs will also feature significantly reduced switching losses and reduced reverse recovery time. In addition, parasitic turn-on, which occurs sometimes in the third-gen MOSFETs, has been minimized in the fourth-gen parts, says Su.

The new parts, which will be entirely produced on 6-in. wafers, will help customers improve their power system design challenges by lessening the usual design tradeoffs, For example, the fourth-gen SiC MOSFETs will offer lower on-resistance for a given chip size, so there is less need to trade efficiency for lower cost. Similarly, the new parts provide lower on-resistance without sacrifice in short-circuit withstand time.

Similarly, the minimization of parasitic turn-on and shoot through loses when dv/dt is increased, eases higher speed switching. Finally, the support for 15-V/0-V gate-drive voltages without the need for a negative supply, simplifies gate-driver design. These new parts will target applications such as solar power inverters, server power supplies and automotive traction inverters.

Rohm also previewed its announcement of the BM6112 isolated gate driver. This device, which is currently under development provides 3750 Vrms of galvanic isolation, an I/O delay of 150 ns and incorporates numerous protection and reporting features. However, its most notable feature is its 20-A source and sink capability. According to Mitch Van Ochten, application engineer at Rohm Semiconductor, "You would be hard pressed to find a stronger gate driver." Moreover, this strong output capability eliminates the need for a buffer transistor stage between the gate driver and gate, and with it up to five discrete components that would be needed to implement the buffer stage.

The BM6112 eliminates another external part by including a built-in temperature monitor that sends temperature as a PWM signal back to the primary and decodes it to output the baseplate temperature. According to Van Ochten, this function was previously offered as a separate temperature monitor IC. With this temperature measurement capability, the gate driver can now transmit both temperature and fault data across its isolation barrier.

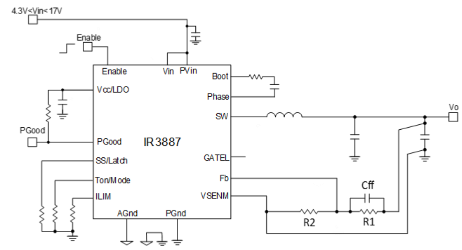
Other benefits of this device are that it's automotive qualified, has an active Miller clamp, and provides output state feedback for additional safety. A formal introduction of this part is pending, but in the meantime a datasheet is available online.

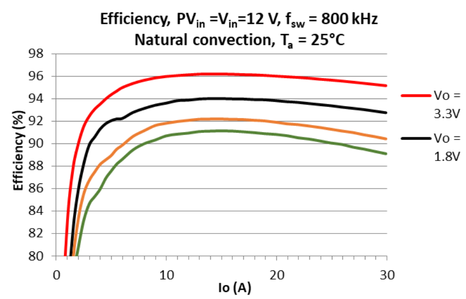
In **Infineon Technologies'** post APEC briefing, they highlighted a recently released family of point of load regulators the OptiMOS iPOL with Fast COT. Consisting of three devices, the 30-A IR3887M, the 25-A IR3888M and the 30-A IR3889M primarily target server, storage, and datacom/telecom applications, but are also useful for FPGAs and industrial apps.

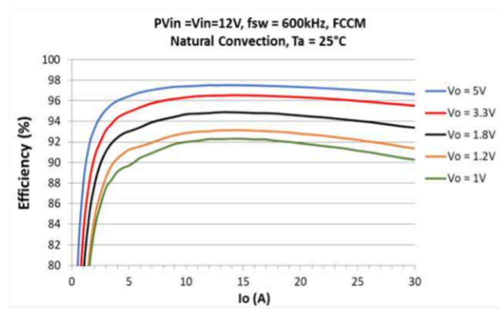
This family features a fast constant-on time engine that improves Vout regulation to save capacitors and allows higher fsw (up to 2 MHz) for increased density. In addition, it incorporates Infineon's OptiMOS 5 MOSFETs—the latest generation of the company's high-efficiency MOSFETs for switching applications. According to the company use of these latest-gen power MOSFETs enables benchmark efficiency in a small footprint.

The graphs below in the figure document the high efficiency that these POLs are capable of, while switching at high frequency (600 kHz and 800 kHz, in the examples) and operating with only natural convection cooling. According to Davood Yazdani, head of marketing for POL products at Infineon, these POLs can convert 12 V to 1 V with >92% peak efficiency, which is best in class today.

- 4.3-17 V input voltage, 2-17V with 5 V ext. bias
- ±0.5% voltage reference accuracy
- Best-in-class efficiency
- High power density
    - 30A in 4x5 mm package
    - Up to 2MHz switching frequency
- Fast Compensation free COT control engine
    - Ultra-fast transient
    - Stable with all-MLCC
    - Excellent line/load regulation

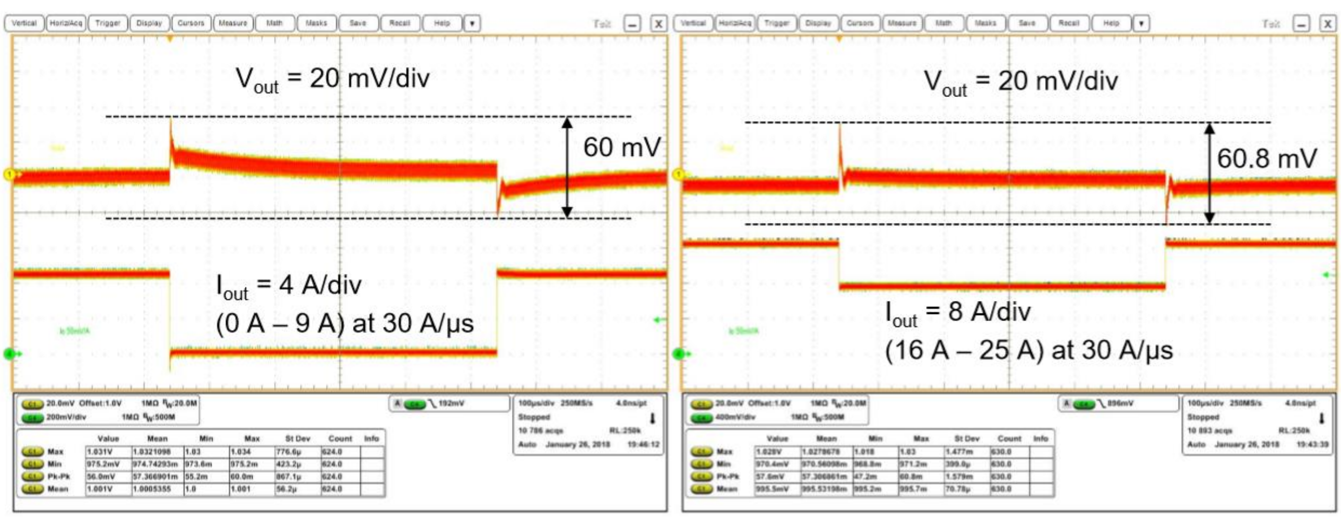






The IR3887M 30-A achieves high efficiency and small size using fast constant-on-time control.

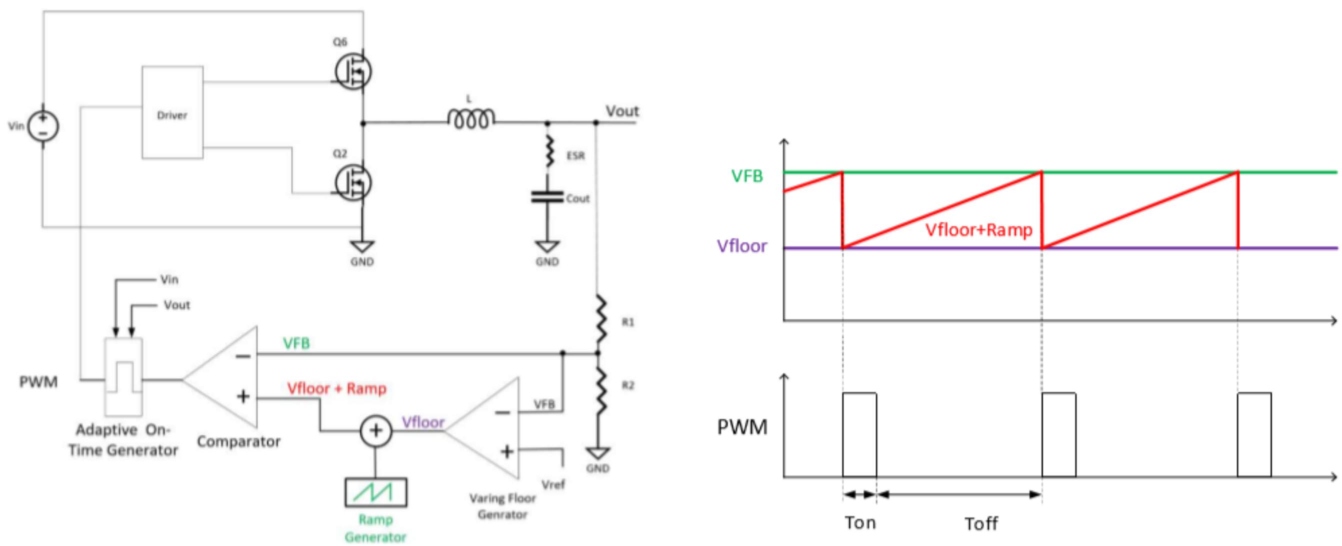
According to the company, server, storage and datacom applications are moving from voltage- and current-mode control in their POLs to constant-on-time control, both for its fast transient response and its simplicity of design. The figure below shows what the company describes as this family's "benchmark load transient performance." However, Infineon's implementation of COT offers the added benefit of good line and load regulation—attributes that are usually sacrificed with COT control. At the same time, there's no efficiency penalty with Infineon's COT engine.



Load transient response of the IR3889 30-A iPOL. Pvin = 12 V, Vout = 1 V, f_{SW} = 800 kHz, L= 150 nH, Cout = one 470-uF/2V + ten 22 uF + four 47 uF capacitors.

According to Yazdani, the key to this family's improved regulation is its use of a "floor generator" in generating the error signal to the pulse width modulator. A paper prepared for APEC offers the following description of this control scheme:

"The Fast COT [control method] introduces a varying Vfloor error-driven voltage [to] which a RAMP is added…, and applies the output voltage feedback directly to the COT comparator for ultra-fast response. Compared to a fixed reference in conventional COT, a varying reference Vfloor voltage in the control loop is beneficial for the transient response. Introducing an artificial RAMP solves jitter issues. Additionally, load and line regulation drastically improve since the error amplifier output varies the RAMP floor voltage (Vfloor) to place the peak of the RAMP at the optimal regulation point."

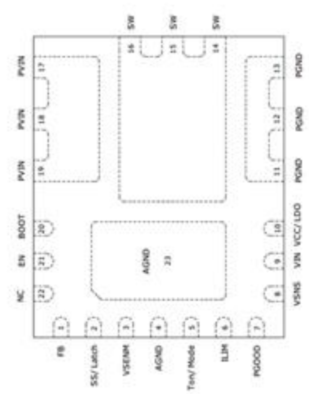
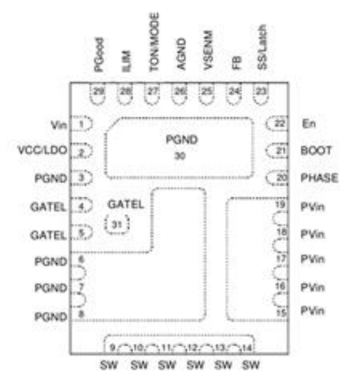
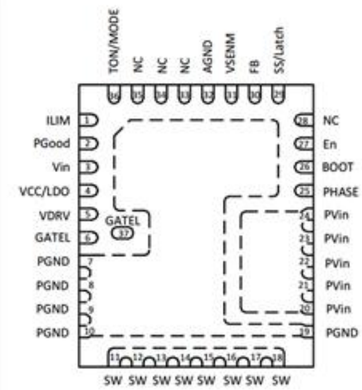


Infineon's Fast COT control scheme adds a ramp signal with a varying voltage floor to generate its error signal to the PWM.

The three family members are distinguished by different levels of performance, size and compliance. The 25-A IR3888M, which is assembled in a 5-mm x 6-mm PQFN with wirebonds, is compatible with the company's older iPOL products such as the IR3824/5/9, IR3826/A and IR3894/5. This device is also RoHS 2 compliant without exemptions.

On the other hand, the 30-A IR3887M and IR3889M, are optimized for power density and thermal performance respectively. Both parts allow direct connection of the boostrap cap to the phase node (rather than the switch node), which improves efficiency. And both feature a copper clip package, rather than wirebonds, which improves efficiency.

The IR3889M offers pin-to-pin compatible PMBus & SVID solutions, and like the IR3888M comes in a 5-mm x 6-mm PQFN. However, the IR3887M is offered in the smaller 4-mm x 5-mm PQFN, making this part the smallest POL available for its output current and I/O voltage capabilities, says Yazdani. The table below summarizes the differences between the three parts.

IR3888M	IR3887M	IR3889M
5x6 mm PQFN	4x5 mm PQFN	5x6 mm PQFN
25 A	30 A	30 A
▪ RoHS 2 compliance without exemptions ▪ Pin compatible to IR3824/5/9, IR3826/A and IR3894/5 ▪ V_{out} sensing for PGOOD, UVP & OVP ▪ 0.6 V reference voltage	▪ High power density ▪ Pseudo remote sensing ▪ Phase pin & Cu clip package for better efficiency ▪ 0.6 V reference voltage	▪ Footprint compatible with Infineon's PMBus & SVID POL products ▪ Pseudo remote sensing ▪ Phase pin & Cu clip package for better efficiency ▪ 0.8 V reference voltage
		

In another post-APEC briefing, Gerald Deboy discussed the benefits of GaN and explained the company's strategy for deploying it with respect to the adapter/charger market, which consists primarily of flyback converters. Infineon's power semiconductor portfolio for this market includes both silicon superjunction MOSFETs (the CoolMOS products) rated for 600 V and above, and enhancement-mode GaN power devices rated for 600 V (the CoolGaN products).

A major trend among adapters is the move to higher power output to enable faster charging of end products such as smart phones. There is also a trend toward higher density and flatter designs. According to Infineon, by deploying silicon superjunction MOSFETs in single-ended flyback topologies, using the existing CoolMOS devices as the main switch, adapter designs can achieve efficiencies ranging from 89% for a hard-switching RCD flyback up to 93% or better using an advanced form of ZVS flyback.

For those designs that need both the high efficiency plus higher density and a flatter adapter design, GaN devices offer an advantage because they allow the use of higher switching frequencies, which shrinks magnetics and capacitors, but also use of a planar transformer. In addition, GaN lends itself to greater device integration. So for these applications, the GaN power switches are deployed in half bridge-based topologies such as the active clamp flyback. This topology also employs ZVS, but unlike the single-ended flyback topologies, it is not limited by the transformer's leakage inductance, which contributes to losses. That's because the active clamp flyback recovers the transformer's leakage energy.

This last point is important because there's a tradeoff in charger designs of transformer leakage inductance and coupling capacitance. As the coupling capacitance increases, the touchscreen of the device being powered becomes electrified. To reduce this effect, the flyback transformer design is modified to reduce its coupling capacitance, but this raises the leakage inductance and hence the leakage energy and associated losses. However, in the half bridge ACF, the leakage energy is fully recovered, so raising the coupling capacitance is not a problem.

Deboy comments that as adapters/chargers migrate to higher power levels for faster charge capability, Infineon can satisfy 90% of the market requirements with its silicon SJ MOSFETs applied in single-ended flybacks. Then, for that 10% of the market that requires a GaN-based half-bridge for integration, higher switching frequency and flatter design, the company can provide its CoolGaN parts.

The table below lists the benefits of the different flyback topologies for adapter designs, and where silicon is recommended for use versus GaN. It also shows the different levels of efficiency. Although not spelled out in this table, the GaN-based designs can achieve about 0.3% to 0.4% higher efficiency than the silicon-based designs and highest power densities are 20 W/in^3 for silicon versus 22 to 24 W/in.^{3} for GaN.

While these gains by GaN are not trivial (especially the reduction in losses) there's a steep price penalty, which explains the 90% Si/10% GaN market breakdown. "With GaN you get 20% more density at 80% more cost," observes Deboy. Hence GaN is used in adapters where it's needed.

	Single-ended topologies (limited by leakage inductance of transformer)			Half-bridge based topologies
	RCD flyback	ZVS flyback	Advanced ZVS flyback	Active clamp flyback
Eff@90V_{AC}	89%	92%+	93%+	93% +
Pros / Cons	+Cheap +Simple -Limited efficiency	+ZVS switching + Adjustable frequency law	+ ZVS switching + Adjustable frequency law + partial recuperation of leakage energy	+ZVS switching + adjustable frequency law + recuperation of leakage energy
Main switch	CoolMOS™ Superjunction 700 V/950 V	CoolMOS™ Superjunction 600 V/650 V	CoolMOS™ Superjunction 600 V	CoolGaN™

Infineon's view of the high-density charger market is that both the single-ended and half-bridge-based flyback topologies will co-exist in this segment.

Integration is a key benefit of GaN and, across the adapter market, this capability is driving GaN adoption and mitigating concerns about GaN cost. Some like Power Integrations, are using GaN to achieve more integrated adapter solutions at higher power levels than with silicon-based solutions.

However, Infineon's approach is to offer SJ MOSFETs with their low R_{DSON} for designs that just need higher power. But for those that also need higher switching frequency (600 kHz and above) and flat form factors, they offer GaN. "We have a refined strategy that takes silicon as long as it can compete then goes to integrated GaN when it makes sense," says Deboy. For more information, see Infineon's APEC Product page.

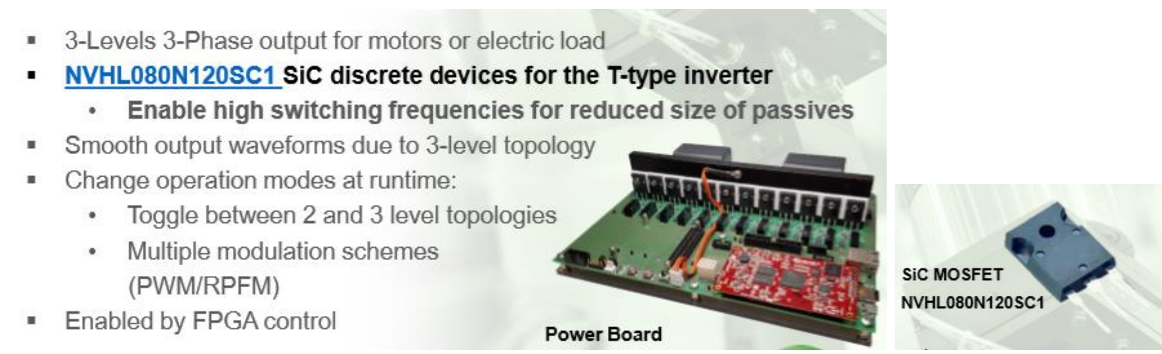
At APEC 2020, **ON Semiconductor** had planned to show a large number of product demos and these were the subject of the company's post-APEC 2020 briefing. But first they discussed the APEC-timed introduction of two new families of SiC MOSFETs targeting the usual applications in solar power inverters, on-board chargers for electric vehicles (EVs), UPSs, server power supplies, and EV charging stations.

The new 1200-V and 900-V n-channel SiC MOSFETs deliver faster switching performance and enhanced reliability when compared to silicon. A fast intrinsic diode with low reverse-recovery charge delivers a significant reduction in power losses, boosts operating frequencies, and increases the power density of the overall solution. The portfolio includes devices with $R_{DS(ON)}$ ranging from 20 to 80 mΩ in both surface-mount and through-hole packages.

High-frequency operation is further enhanced by the small chip size that leads to a lower device capacitance and reduced gate charge, Q_g, as low as 220 nC, reducing switching losses when operating at high frequencies. These enhancements improve efficiency and reduce EMI when compared with silicon-based MOSFETs, and allow for the use of fewer (and smaller) passive components. The 1200-V devices are rated at up to 103 A (I_D max.), while the 900-V devices carry ratings as high as 118 A.

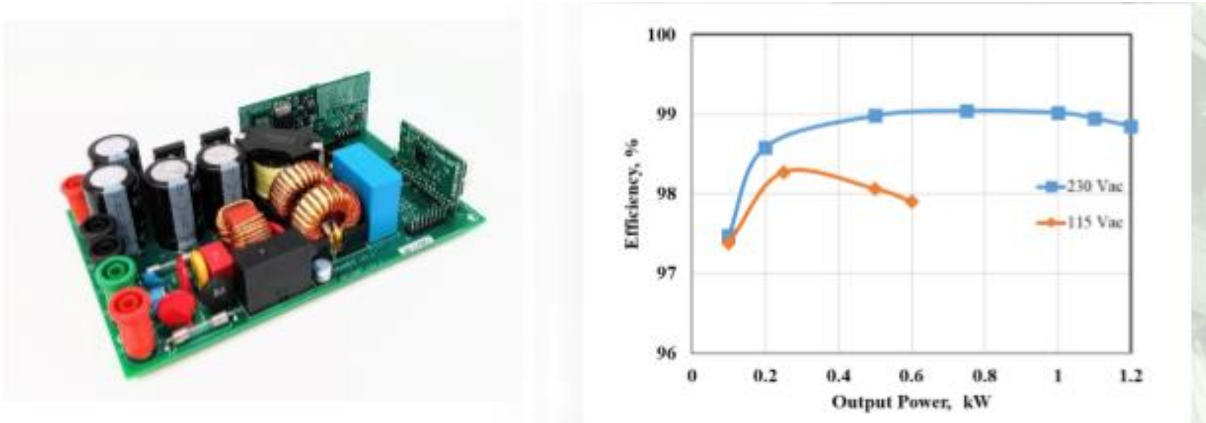
The highly robust SiC MOSFETs also offer higher surge ratings, improved avalanche capability and improved short circuit robustness when compared to Si devices, delivering the higher reliability and longer lifetimes that are essential in demanding modern power applications. A lower forward voltage provides threshold-free on-state characteristics that reduce the static losses that occur when the device is conducting.

Among the many demo boards that ON had planned to show at APEC was a T-type three-phase 10-kW inverter for motion control using the company's 80-mΩ NVHL080N120SC1 SiC MOSFETs. This board demonstrates the high-frequency switching of these MOSFETs, and how it enables use of smaller passives. The inverter is for advanced networked motor and motion control systems based on Xilinx Zynq SoCs and supports most of the widely used high-voltage and low-voltage motors up to 10 kW including ACIM, PMSM and BLDC types.

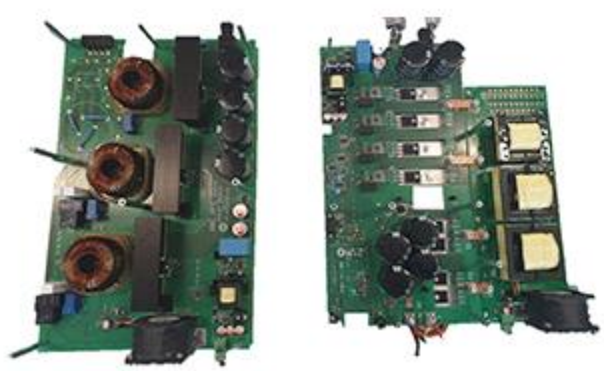


ON's T-type three-phase 10-kW inverter for motion control uses 80-mΩ NVHL080N120SC1 SiC MOSFETs.

ON's SiC MOSFETs were also featured in an 80 PLUS Titanium 1.2-kW TP-PFC board. This design was developed in collaboration with Solantro Semiconductor and uses their SA8000-N TP-PFC Controller. The totem-pole PFC is a cost-effective way to build 80 PLUS Titanium standard power supplies for data centers, computing applications and onboard battery chargers. Solantro's SA8000-N TP-PFC controller coupled with ON Semiconductor's NTBG060N090SC1 SiC MOSFETs helps to reach 99% efficiency and provides optimized switching patterns, reliable start-up, high power density and lower power losses according to ON.



An 80 PLUS Titanium 1.2-kW TP-PFC board featuring ON's NTBG060N090SC1 SiC MOSFETs achieves 99% efficiency.



An 11-kW three-phase on-board charger from ON combines SiC-based PFC and LLC converter stages.

Another SiC based demo board was an 11-kW three-phase on-board charger combining SiC-based PFC and LLC converter stages. This design, which uses the NVHL080N120SC1 80-mΩ/1200-V SiC MOSFETs and the NCP51705 integrated SiC driver, achieves above 98% efficiency. This eval board allows designers to swap out magnetics and includes a fan for cooling the inductors. The high efficiency of this design enables cost-efficient cooling methods.

The PFC is implemented as a three-phase voltage-source inverter using 1200-V SiC MOSFETs switched at up to 140 kHz. By using this OBC as a building block, this design can be scaled up to 100 kW to create a Level 3 EV charger. For more see https://www.onsemi.com/support/evaluation-board/sec-3ph-11-obc-evb.

The last demo with a tie in to SiC MOSFETs (but not just SiC devices) was a gate-driver evaluation system, which enables fast and reliable comparison of the dynamic performance and capabilities of the company's different gate-driver technologies and the selection of an optimal gate resistor. Up to six gate drivers can be evaluated at a time.

This eval system consists of a motherboard with daughter cards available for these gate drivers: the NCP51705, the FOD8334, the NCD57000 and the NCP51530. Users can also develop their own daughter cards using manufacturing files provided by ON. The mother board allows for external adjustment of switching frequency, replaceable passives (capacitive loads, resistance) for custom simulation and multiple test points.

ON's gate-driver evaluation system.

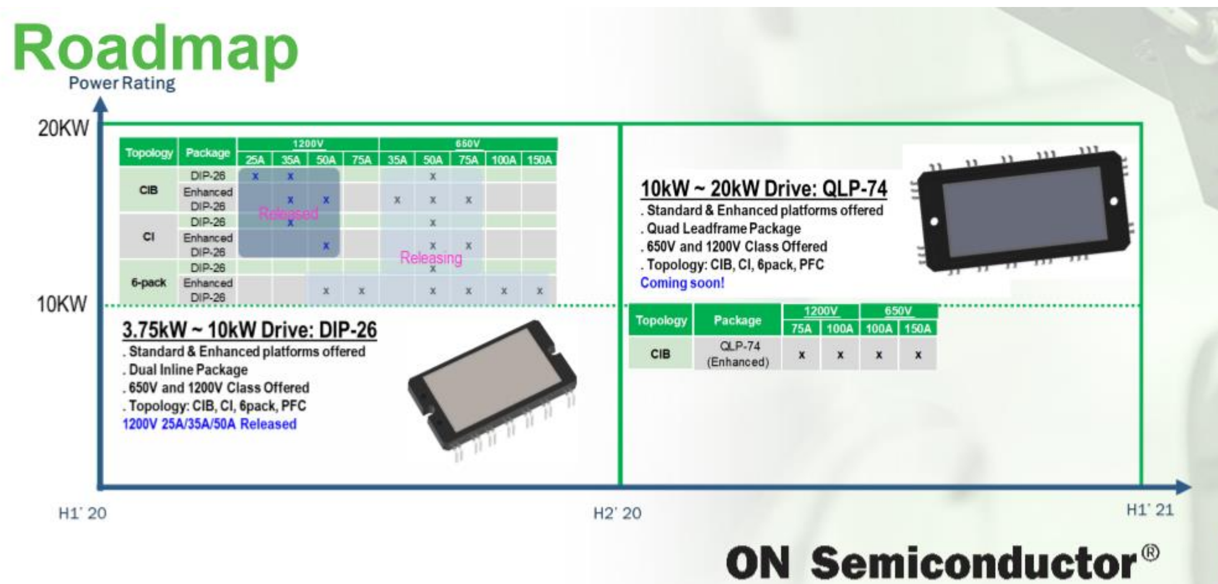
ON also highlighted a new packaging development, its transfer molded converter-inverter-brake (CIB) power module for industrial drives. The transfer molded PIM (power integrated module) offers improved reliability and thermal performance when compared with the gel-formed PIMs being replaced. Although the latter are more forgiving of thermal expansion, the transfer molded PIM, which is a plastic overmolded package, is ultimately more reliable, offers better heat transfer and is hermetically sealed.

Combining this innovative transfer mold process with optimized IGBT/FRD (fast recovery diode) design and advanced substrate technology, the new modules deliver longer lifetimes, higher efficiency and higher power density.

According to the vendor, the transfer molded PIM improves the module's thermal cycling lifetime by 10x and power cycling lifetime by 3x when compared with the normal gel-filled power module. Meanwhile, the volume of the module is reduced by 50%, which greatly increases power density.

These transfer molded PIMs borrow a concept applied with lower power modules developed for appliance applications, making it work at higher power levels for industrial motor drive and HVAC applications. One of the challenges in applying this concept is maintaining the spacing required for product certification. These new transfer molded PIMs achieve a clearance distance of 6 mm from pin to heatsink in accordance with IEC 61800-5-1.

So far the company has released 1200-V 25-A, 35-A and 50-A CIB and CI modules and 650-V class modules with current ratings ranging from 35 A to 150 A are on the way. These products are in DIP-26 packages that can be used in drives up to 10 kW. The company also plans to release modules in the QLP-74 package including 1200-V 75-A and 100-A CIB modules to accommodate power levels up to 20 kW (see the roadmap below).



Among the varied product demos and news discussed so far from Rohm and ON, a common thread was their discussion of SiC MOSFET developments. Although not covered here, Infineon also had planned to show its recently launched 650-V CoolSiC MOSFETs, which are discussed in a separate Power Products article in this issue. Another Power Products article describes Cree's new 650-V SiC MOSFETs.

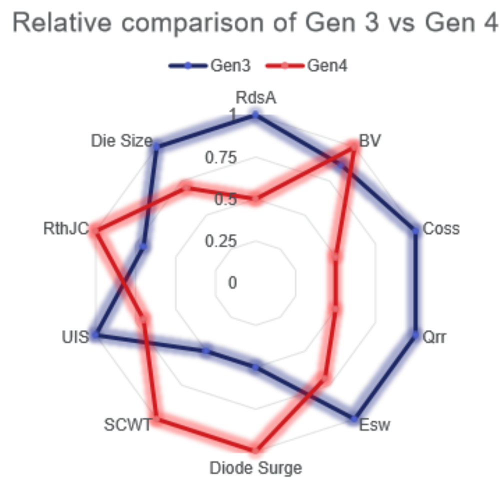
Another company that planned to showcase its SiC developments at APEC was **UnitedSiC**. The company, which makes SiC JFETs, and SiC cascode devices, which it refers to more generically as SiC FETs to stress their functional equivalence to SiC MOSFETs, was to preview its fourth-generation SiC technology at APEC. In this new generation of SiC devices, the company will expand its offerings from a 650-V V_{DS} max rating to 750 V, enabling their SiC FETs to be used in applications with 400-V and 500-V buses. At the same time, the new devices will maintain a 0-V to 12-V gate drive with a 5-V threshold voltage and maintain the ability to operate with standard MOSFET and IGBT gate drives.

Meanwhile, the Gen 4 devices will offer lower on-resistance per die area, and reduced reverse-recovery charge and turn-on/turn-off losses for a given on-resistance. They'll also lower C_{oss}/E_{oss} and C_{oss} (t_r). These improvements in dynamic characteristics will improve SiC FET efficiency in hard- and soft-switching circuits.

Other improvements in Gen 4 include improved third-quadrant diode surge characteristics, similar or better behavior when devices are paralleled, and improved device behavior in linear mode operation.

The table below compares a pending Gen 4 SiC FET with an existing Gen 3 device and offers a more general, relative comparison of the two technologies using a spider chart. The company plans to launch Gen 4 products in the second half of this year.

	6mohm, 750V	7mohm, 650V
Technology Generation	**Gen 4**	**Gen 3**
Vdsmax	750V	650V
Typical R_{on} at RT	6mW	6.7mW
R_{on}(175°C)/R_{on}(25°C)	2.08	1.6
Qrr at 400V, 1400A/us	462nC	840nC
Etot at 400V, 55A, RT, HB	560mJ	840mJ
Passed short-circuit time at RT	8ms	3ms
Passed 10us surge current of body diode at RT	1570A	773A
RthJC (°C/W) typ/max	0.21/0.27	0.15/0.19
Relative die size	0.65	1



Comparing United SiC's pending Gen 4 SiC FETs with their current Gen 3 products. According to United SiC CEO Chris Dries, the die size reduction in Gen 4 will enable the company to offer the new devices "at prices equivalent to silicon."

While United SiC's product portfolio until now has consisted solely of discrete SiC devices, they have worked with module companies who've used their die products to build SiC power modules. CEO Chris Dries says that the company is now working to produce its own modules as standard products and expect to release them to production in the second half of this year.

In their post conference briefing, **Texas instruments** discussed some of their recent POL power module introductions, provided an update on their GaN developments, and highlighted a recently introduced isolated power supply chip.

One device they called attention to was the recently introduced TPS546D24A, a 40-A stackable buck converter. Housed in a 5-mm x 7-mm QFN, this POL produces a 0.6-V to 5.5-V output, selectable via pin strap or 0.25-V to 6.0-V using the PMBus VOUT_COMMAND, while operating from a 2.95-V to 16-V input. This part is "stackable" to create a single rail with up to 160 A. "Stackable" sounds like a marketing spin on "current sharing," but there is a distinction.

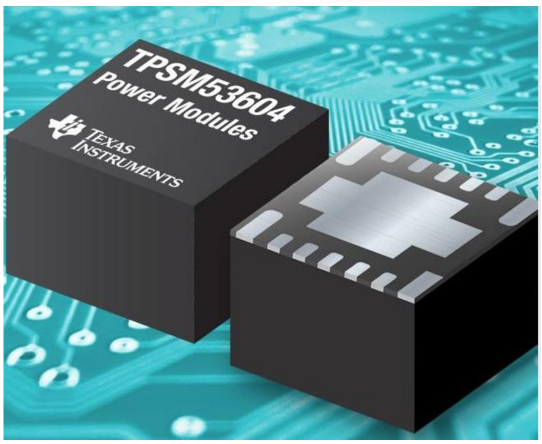
Because of the way TPS546D24A devices communicate with one another through back-channel communications (the BCX pins), the designer can address the stacked POLs as a single device via PMBus. Normally, making POLs share current via PMBus would require that the host controller address each POL individually. So in essence, "stackable" means multiple POLs can be treated as one, which is a convenient way to scale a design. The company also claims this part offers the highest efficiency of any 40-A dc-dc converter.

This part illustrates the progress that has been made in IC-style, point-of-load regulators (POLs). Rich Nowakowski, product marketing engineer at TI, observes that 15 years ago, a POL of this type could deliver only 6 A in a 28-pin TSOP. Better FETs, and improved heatsinking techniques such as a clip that flows heat from the low-side FET to the ground plane help this part to achieve its performance.

While the ability to deliver 160 A in a stackable device may be novel, the concept is not totally new for TI. Back in 2016, they introduced the TPS546C23, a 35-A, PMBus compatible buck converter, also in a 5-mm x 7-mm QFN, that was stackable to 70 A. (See "Stackable PMBus Converter Delivers High Current Density")

But generally speaking designers have not been using high-current IC-style POL to generate high current rails like these stackable bucks are capable of, especially the TPS546D24A. As Nowakowski observes "Today customers would use controllers and MOSFETs in a multiphase buck design." But that may change as more stackable POLs become available and TI plans to expand its stackable offerings by introducing lower current versions of the TPS546D24A in the future. For more about the TPS546D24A, see "40-A Buck Converter IC Is Stackable Up to 160 A".

TI also discussed another POL that was introduced last month, the TPSM53604, which they claim is the industry's smallest 36-V input, 4-A output buck power module. In contrast with the TPS546D24A discussed above, the TPSM53604 copackages the inductor. When combined with its external passives, this 5-mm x 5-mm QFN-packaged device can implement a complete POL solution in an 85 mm^2 footprint with a single-sided layout.



The TPSM53604 36-V input, 4-A output buck power module features a 5-mm x 5-mm footprint and 4-mm package height.

According to TI, designers using the TPSM53604 can shrink the size of their POL designs by up to 30% and cut losses by 50% in rugged industrial applications. The vendor also claims this device provides the smallest solution for the common 24-V input, 4-A applications with a standard QFN footprint.

This POL achieves its high power density through a combination of high efficiency (up to 95%) and its novel internal construction. According to Nowakowski, the device's routable leadframe enables more contact area to the customer PCB for enhanced thermal performance. This allows modules using a routable leadframe to be smaller than alternative package technologies for the same rated output power.

As mentioned above, this buck converter module co-packages the inductor with the converter chip. But whereas previous modules placed the inductor side-by-side or over the packaged chip, the TPSM53604 packages the inductor over hotrod die. This cuts the footprint in half to 5 mm x 5 mm.

Another new power supply module mentioned in this briefing was the UCC12050/40, a 500-mW isolated dc-dc power supply with high efficiency. Among its claims to fame, the part, which was introduced in February, is described as the first device to be developed with a new proprietary integrated tranformer technology. This internal transformer has very low primary-to-secondary capacitance and is optimized for low EMI.

Moreover, the company claims this device produces the industry's lowest EMI for a power supply IC. It targets transportation, grid and medical applications where "you have a power distribution challenge and need to get power across the isolation barrier," says Steve Tom, GaN product line manager for GaN Technology at TI. The part is designed to replace discrete power solutions that would normally be used in these types of applications.

In their post-APEC briefing TI also provided an update on their GaN developments. TI's GaN portfolio consists of 600-V GaN FETs specifying on-resistances of 150 mΩ, 70 mΩ, and 50 mΩ. These parts are currently in mass production and the company notes their use in high density designs in industrial, telecom, server, and personal electronics applications. However, as Tom notes, their development of GaN continues to follow the same principle that guided their initial forays into GaN: "Do what we can't do with silicon."

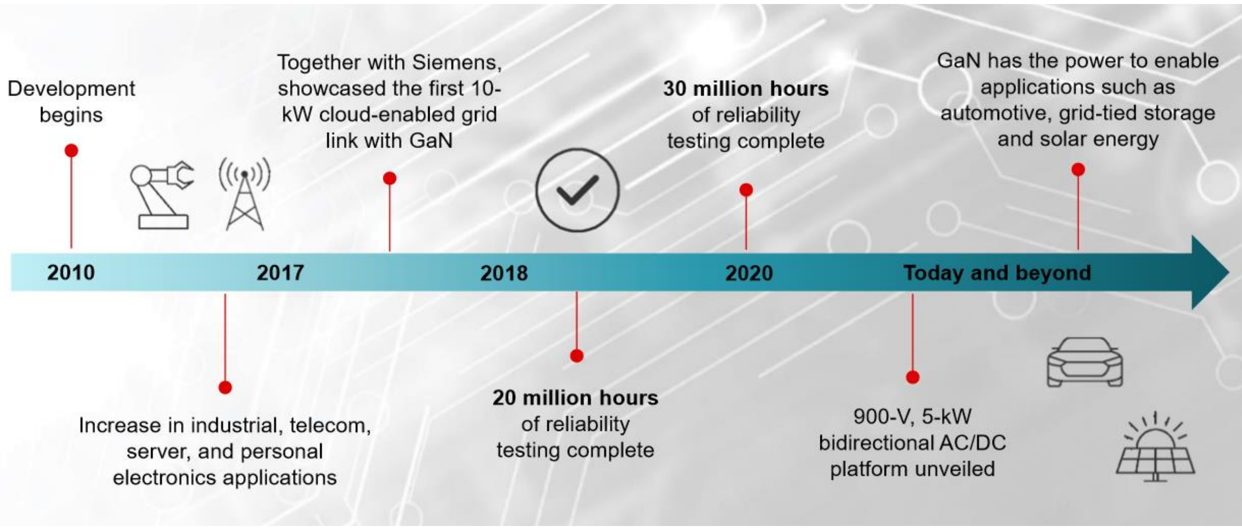
Tom notes three factors driving GaN adoption in the marketplace. First, GaN FETs can switch at twice the speed while achieving half the losses of silicon MOSFETs. Lifetime reliability, which was a question mark in the early days of GaN, is much less of a question now. Tom notes that GaN parts have been tested over 30 million device hours, exhibiting very good behavior and demonstrating their robustness.

Finally, GaN technology is driving integration, which drives down costs. "While the early devices were discretes, we've gone to integrated drivers to eliminate the parasitics. We do the driver in silicon to lower cost and improve performance by putting in lots of features including various forms of protection."

At APEC 2018, Siemens and TI demonstrated a GaN-based 10-kW cloud-enabled grid link that the company co-developed with Siemens. At this year's APEC, TI had planned to demonstrate its own convection-cooled 900-V, 5-kW bidirectional ac-dc platform. This platform further extends GaN in new applications such as automotive, grid-tied storage and solar energy.

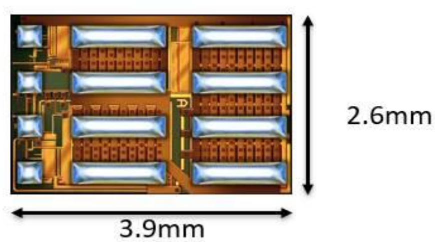
According to Tom, this design uses a multi-level topology to achieve 900-V operation and support buses up to 1.4 kV using the currently available 600-V GaN FETs. It achieves a peak efficiency of 99.2% and is said to achieve a power density 3X that of an IGBT-based solution. Tom notes that this design switches at 140 kHz, which represents an improvement over both SiC MOSFETs, which might switch at 100 kHz in an equivalent design and leapfrogs silicon IGBTs which would typically switch at 20 kHz in an equivalent design.

The timeline below highlights the TI GaN developments discussed here.



Another company discussing its latest GaN developments meant for APEC was **Efficient Power Conversion (EPC)**. Recently, Alex Lidow, CEO and co-founder of EPC, discussed his company's new power stage ICs, their development of GaN-based reference designs using a multi-level topology and various demos that were originally bound for APEC.

The recently introduced ePower Stage IC family targets high power density applications including dc-dc conversion, motor drive, and Class-D audio. The first device in this family is the EPC2152, an 80-V, 12.5-A power stage integrated circuit designed for 48-V dc-dc conversion. It integrates a driver plus eGaN FET half-bridge on a single chip. Circuitry includes an input logic interface, level shifting, bootstrap charging and gate drive buffer circuits. This results in a chip-scale LGA form factor device that measures only 3.9 mm x 2.6 mm x 0.63 mm.



EPC2152, a monolithic 80-V, 12.5-A half-bridge power stage IC with on-chip gate driver.

When operated in a 48-V to 12-V buck converter switching at 1 MHz, the EPC2152 achieves a peak efficiency above 96% with a solution that is said to be 33% smaller in its PCB footprint than an equivalent multi-chip discrete implementation. As noted above, this part carries a 12-A rating, but Lidow adds that it will deliver up to 15 A with airflow.

The EPC2152 is just the first offering in what will be a wide-ranging family of integrated power stages available in chip scale packages (CSPs) as well as multi-chip quad flat modules (QFMs). Within a year the family will be filled out with products capable of operating at high frequency into the 3- to 5-MHz range as well as high currents from 15 A to 30 A per power stage.

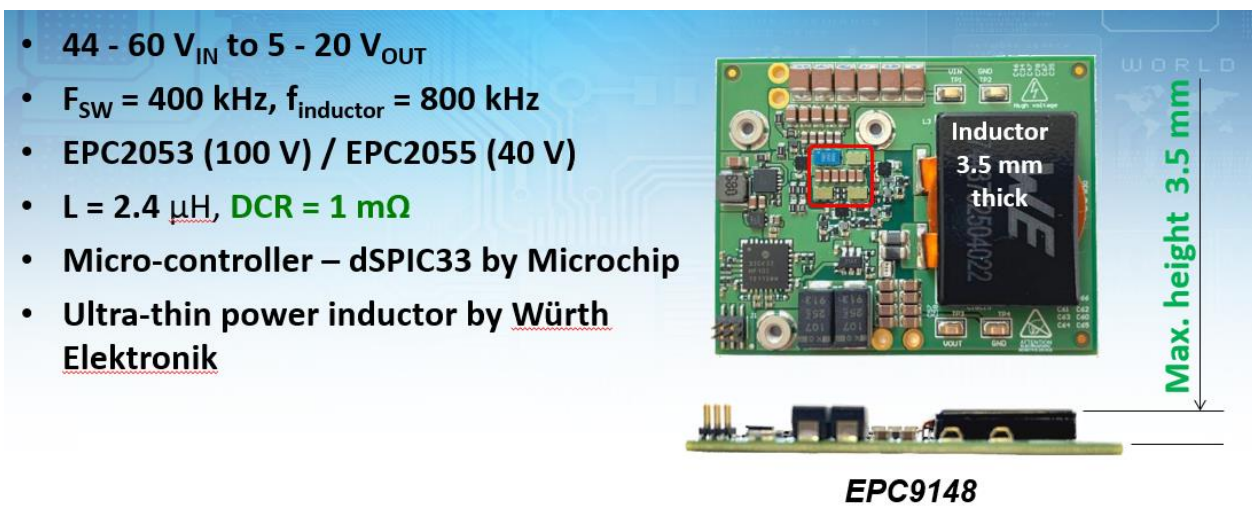
An even more interesting twist in the GaN news is EPC's development of a new multi-level dc-dc converter architecture using four eGaN FETs devices—one 100-V and three 40-V rated FETs. Typically multi-level power conversion is reserved for high-voltage, high-power applications (look at TI's 900-V, 5-kW bidirectional converter described above for an example of that), so a design below 100 V for a consumer application seems unexpected.

In this case, the application was a 56-V to 19-V, 250-W converter for gaming notebook computers. Because of their high power consumption, these computers require a higher supply voltage from the adapter (in the vicinity of 48 V) to limit the wire gauge required on the cable from the adapter to the notebook.

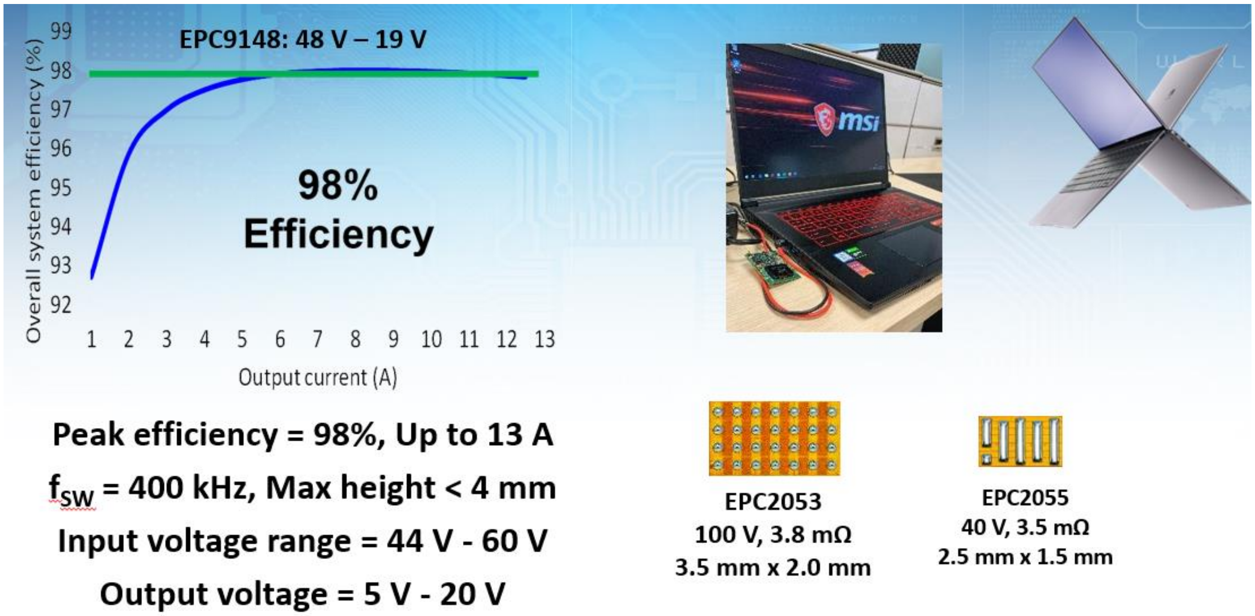
That voltage must then be stepped down within the laptop to the more familiar 19-V power bus. That's where this 56-V to 19-V multilevel converter comes in. Commenting on why this unconventional, but highly efficient design is needed in this application, Lidow observed that it's so "the laptop doesn't burn you as it sits on your lap."

He also noted that "the multi-level design allows you to go to small inductors," which helps with the height restrictions within the laptop. Lidow says that EPC initially tried to satisfy the requirements for this converter using a two-phase buck. But with its relatively bulky inductors, that design couldn't meet the thickness spec.

An eval board, key component and operating specs as well as efficiency measurements are shown below for this multi-level converter reference design, known as EPC9148.



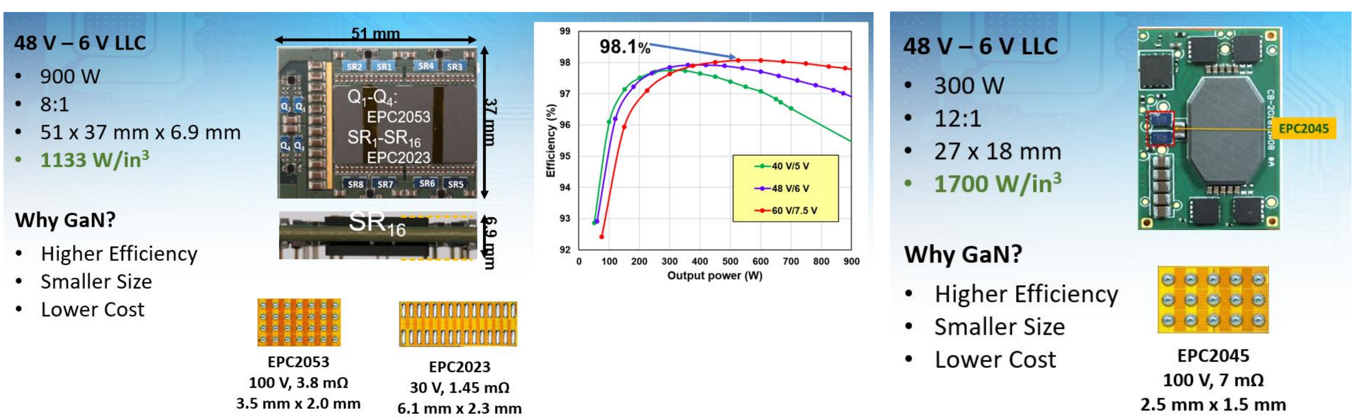
The EPC9148 GaN-based multi-level converter reference design steps down a 48-V bus to 19 V, delivering up to 250 W in a design thin enough to fit within a gaming laptop.



The EPC9148 reference design achieves its very high efficiency and low profile using one 100-V and three 40-V rated eGaN FETs.

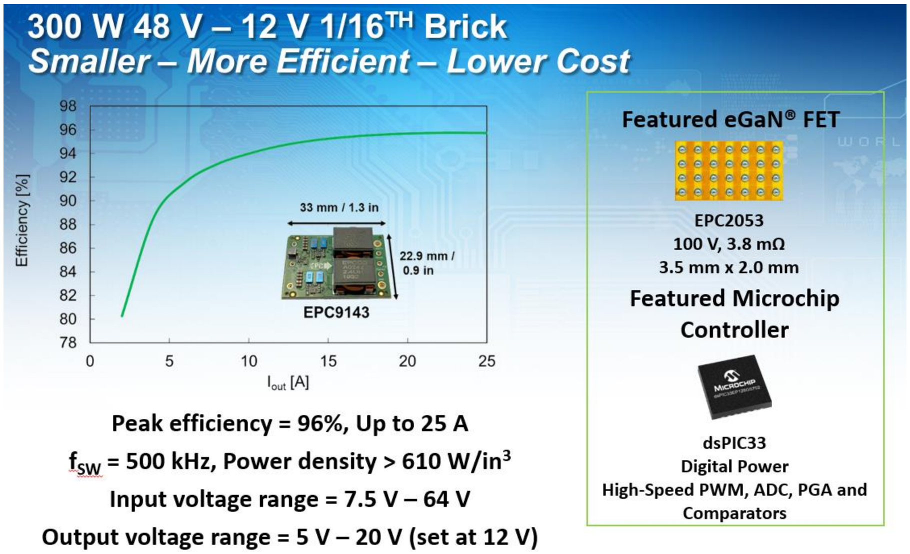
Lidow explained that another of EPC's APEC demos highlighted a radical new server architecture that NVidia and others are using to power graphics processors. Designers are using an LLC converter to step down 48 V to 6 V or 12, then using monolithic buck converters with on-chip MOSFETs to step that intermediate bus down to the rail voltages required by the processor. According to Lidow, this approach offers very fast transient response and higher system efficiency than other approaches.

An example 900-W LLC reference design using EPC eGaN devices is shown below with its eval board, key specs and efficiency measurements. Another LLC demo planned for APEC was a 300-W LLC converter built by Cyntec. That board is also shown. Note its high power density—1700 W/in^3.



GaN-based LLC converters step down 48 V to 6 V with high power density.

Another design example meant for APEC was a 48-V to12-V bidirectional sixteenth-brick dc-dc converter that achieves 610 W/in^3. This design is useful for legacy, server power designs that still need a 12-V bus. Lidow noted that there's also a variant for automotive.



Lidow also discussed a number of other applications where EPC's eGaN FETs are making inroads. One was a 500-W three-phase motor drive, which is described as a small, lightweight design. "Three chips and you have a motor drive" said Lidow. A demo board that works with any controller will be available by the end of April.

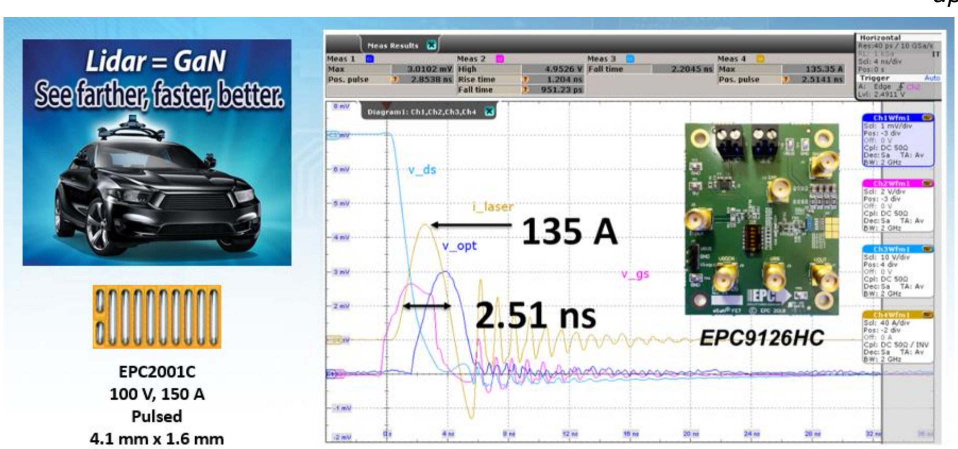
An initial application for this design (developed with partner Ingenia) was in robot arms, which required as light a design as possible. The figure below shows Ingenia's Everest NET 30/80 servo drive designed for robotic and industrial applications. It includes a GaN power stage using the EPC2022 100-V 3.2-mΩ FET. This drive requires small size to fit within robotic joints, high resolution torque sensing and smooth operation. With its high efficiency and high switching frequency, GaN helps achieve all three goals.

Ingenia's Everest NET 30/80 servo drive designed for robotic and industrial applications uses eGaN FETs.

Lidow said that drones represent another big application for GaN-based motor drives because they need both light weight and efficiency.

EPC also continues to find design wins in LiDAR as before. But there are new variations in the requirements that GaN is well suited to address. On the one hand, there are long distance LiDARs that need to see farther, more accurately. GaN's ability to generate very narrow pulses is helpful in these applications. For example, a direct time-of-flight LiDAR, spinning and scanning LiDARs, may need a 2.5-ns pulse, which is good enough to scan an image at 300 m with 2-cm resolution, said Lidow.

Meanwhile, indirect time-of-flight LiDAR is a technique being adopted in short-range applications such as driver alertness systems, cobots, UAVs and gaming. In these cases, the LiDAR puts out bursts of pulses to measure short distances of just a few inches. The pulse currents are lower than in direct time-of-flight, but the rise and fall times are faster. The pulses have to be very precise to accurately measure the phase difference.

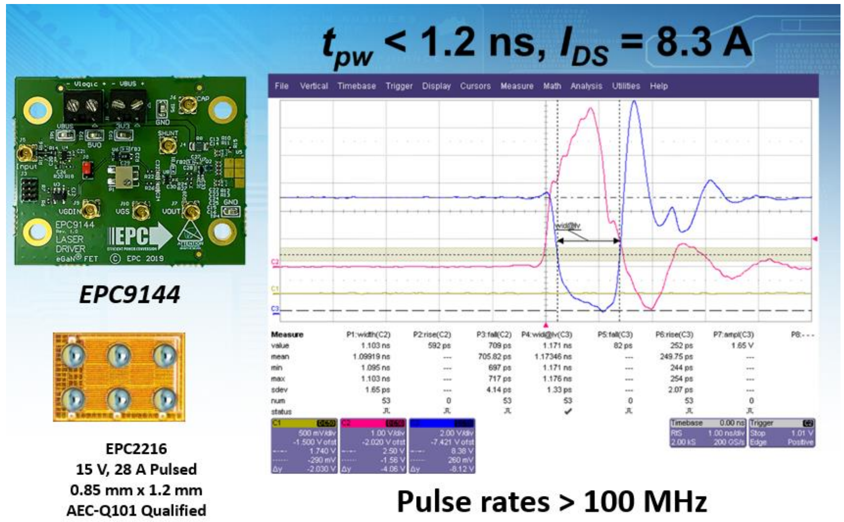


Using eGaN FETs to generate pulses for direct time-of-flight LiDAR.

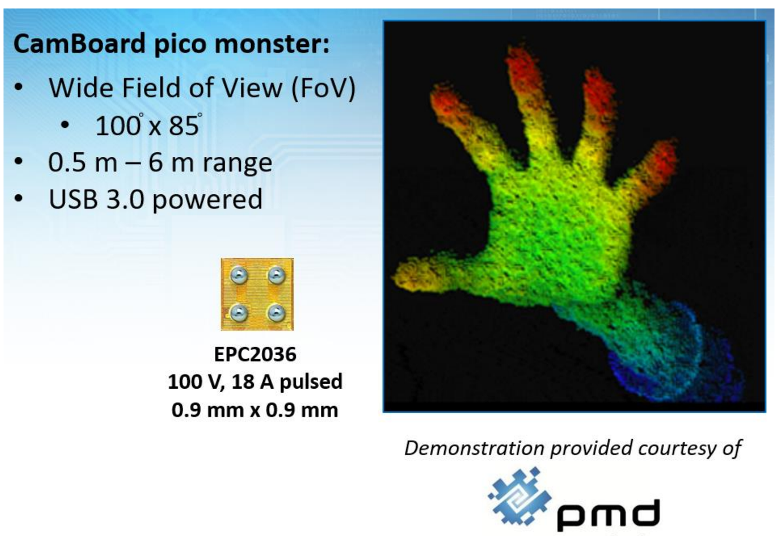
Another LiDAR example, the Flash LiDAR is about to explode in terms of its applications said Lidow. Flash LiDARs use VCSELs (vertical-cavity surface-emitting lasers) connected in parallel to generate a flash of light whose reflection is detected with a camera chip.

This is a very low-cost method of generating a 3D point cloud, said Lidow. Yet another LiDAR application for GaN.

EPC's customer PMD makes the camera chip for Flash LiDAR and an image obtained with their CamBoard pico monster 3D camera development kit is shown below.



Using eGaN FETs to generate pulses for indirect time-of-flight LiDAR.



An example of flash LiDAR.

While the GaN application examples discussed so far have mostly been terrestrial, with the growth of low earth orbiting satellites, EPC has also seen a surge in the application of GaN devices in space with about 13,000 GaN FETs deployed in space to date, said Lidow. Because rad hard MOSFETs tend to be older generation silicon parts, GaN FETs represent a leap forward in performance.

EPC has been working with partner companies such as Freebird and Renesas for several years, and their components for space have been well documented (see the news section of the H2P's Space Power page). Recently, **VPT**, a provider of power solutions for space and other hi-rel applications, used EPC GaN FETs repackaged in ceramic from Freebird to create a 95% efficient power supply for space. This dc-dc converter is pictured below.

A VPT dc-dc converter for space.

This design highlights an advantage of GaN in rad hard designs for space—they are immune to single-event effects. Low earth orbit applications like the small sats experience less gamma radiation than the bigger satellites at high altitudes, so there is a tendency to use non-rad hard (or just radiation tolerant) silicon MOSFETs in single-ended flyback converter designs. This topology is used because even if the primary-side switch experiences a momentary short circuit due to SEE the transformer in a flyback won't pass that short to the output.

Unfortunately, the more-efficient half bridge topology (whose benefits versus the SE flyback were discussed above) doesn't have this inherent protection so it's not used in this application. However, because GaN FETs have an inherent SEE immunity they won't suffer SEE-induced shorts, which makes using the half bridge in space feasible.

Another company with GaN-related news stemming from APEC is **GaN Systems**. Earlier this month they launched their Virtual Experience site displaying the latest technology innovations that are using their GaN devices. This web feature is an online showcase of new transistor products and power modules, reference designs and tools, and customer demonstrations, encompassing automotive, consumer, data center and 5G, and industrial applications.

Among the many items highlighted in the Virtual Experience are:

- An automotive EV onboard charger and dc-dc converter from Canoo and Brightloop
- An All-GaN-Vehicle featuring a GaN traction inverter, GaN onboard charger, and GaN dc-dc converter with work contributed by Toyota and others
- A class D audio evaluation kit containing an amplifier board and a companion SMPS board featuring superior sound, high performance, and high power
- A 3-kW data center server power supply and 48-V dc-dc power stage module
- A Siemens Simatic Micro-Drive factory motor controller offering increased efficiency, faster motor response time, and smaller size.

For more, see the "GaN Systems Virtual Experience"