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## *APEC 2024 Highlights WBG Progress, Power Challenges In AI And Beyond*

*by David G. Morrison, Editor, How2Power.com*

At the recent IEEE Applied Power Electronics Conference (APEC 2024), a record crowd of over 6100 registered attendees gathered in Long Beach to hear talks from academia and industry on the latest developments in power electronics. From year to year, the main topics covered at APEC do not change radically, as the field itself tends to evolve slowly. But from one year to the next, certain subjects do emerge and grab the spotlight, and sometimes ongoing discussions in the industry take on a new tone based on recent developments. This year's plenary session offered examples of both as a speaker from Intel explored the impact of AI on power delivery requirements within the processor, while executives from two power semiconductor companies offered contrasting viewpoints on the future of GaN and SiC technologies. Meanwhile, in the exhibition, we saw concrete examples of the influence of AI on voltage regulator development, and how GaN power devices and SiC MOSFETs and modules continue to develop.

In addition to highlighting the AI and wide-bandgap themes noted above, this year's plenary continued the trend of presenting talks that illuminate either new or little-known applications for power electronics. In last year's plenary session, Patrick Chapman's talk on "Recycling, Refining, and Remanufacturing Battery Materials" was mainly explaining the complex and globally spread-out process through which Li-ion batteries are produced, and details of the recycling process. But within this discussion, he also explored the role that industrial power electronics plays in Li-ion battery recyclying.

This year, Daniel Friedrichs of Minotronics Medical kicked off the plenary talks by introducing the subject of surgical energy, where power electronics is not simply used to power medical electronics but rather is generating power in a form that is applied directly to human tissue or cells as a form or facilitator of treatment. He discussed both existing applications such as RF ablation of tumors and more futuristic ones such as a gene therapy for macular degeneration. The latter requires application of an electric field to cells, which allows the needed materials to be passed through the cell membrane in a process known as electroporation. Friedrichs discussed a number of different surgical energy applications and the challenges they pose for power supply designers.

Another illuminating and perhaps more futuristic talk was by two speakers from Zap Energy on "Fusion Energy is Coming: The Key Role of Power Electronics to Commercial Fusion." In their presentation, AJ Cantor and Matthew C. Thompson explained the fundamentals of fusion-based energy generation, the potential of their company's technology—which uses a technique called Z-pinch fusion—and how it can be applied to build power plants.

The speakers projected that 20 MW of drive power will produce 200 MW of thermal power from which 50 MW will be delivered to the grid. This process will require delivery of a massive current (on the order of 1 megaampl!) through a plasma to generate the magnetic field that produces fusion—so there's power electronics at the heart of the process. Additionally, power electronics will be required to run SCADA and other systems in the power plant. As futuristic as this sounds, the speakers projected that they expect to have a working power plant in 10 years.

Meanwhile, the plenary talks by Balu Balakrishnan, chairman and CEO of Power Integrations and Greg Lowe, CEO, of Wolfspeed brought us closer to the present with their discussion of wide-bandgap technologies. Balakrishnan was not strictly focused on WBG as the title of his talk suggests, "Innovating for Sustainability and Profitability: How innovations in efficiency enable us to do good for the environment while doing well as a business". In discussing this subject, the speaker gave his "golden rules for innovation and sustainability." In describing his fifth rule, "Reduce upstream impacts for sustainability" he gave his assessments of GaN and SiC technologies, both of which the company uses in their switcher ICs.

His key point was that "GaN requires substantially less energy to produce than SiC" and therefore the economics of power conversion ultimately favor GaN power devices. He noted that at one time the company was producing silicon carbide power devices, but realizing the amount of energy required for this production, decided to abandon SiC and "double down on GaN." He noted that the company does currently use silicon carbide in some of its switcher chips, because currently it can go to higher voltages and power levels.

"But sometime in the future GaN will get there," said Balakrishnan who offered the company's recent announcement of 1250-V GaN as an example of the progress that is being made in pushing GaN beyond its

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existing capabilities. Looking ahead he observed that "GaN is fundamentally less expensive to build than SiC" and that there are no fundamental barriers to GaN moving up in voltage and power, just the engineering efforts required to make these advancements.

On the other hand, Gregg Lowe's talk "The Drive for Silicon Carbide—A Look Back and the Road Ahead," which included some tributes to the company's late founder John Palmour, was much more bullish on SiC. Lowe reviewed the long road taken by Cree, now Wolfspeed, to bring SiC MOSFETs to market in 2011, and the skepticism that had to be overcome to make this happen given the challenges of manufacturing SiC wafers. He noted the success of SiC-based inverter in Tesla's Model 3, which represented a turning point, in the adoption of SiC in automotive. He added that "Today I cannot name one car maker that isn't using SiC in one of their models."

This observation lent support to his earlier claim that "the transition from silicon to silicon carbide is unstoppable." So too, the recent industry-wide investments in growing SiC capacity suggests that it's here to stay.

Regarding the issues of cost and sustainability that Balakrishnan had raised, Lowe did touch on this subject by discussing energy saved (by silicon carbide) versus energy invested to give examples of the payback to different applications. (But on this subject, his colleague Elif Balkas, CTO of Wolfspeed; previously went into much more detail in her plenary talks at last year's ECCE and WiPDA conferences.) Lowe also looked ahead in discussing some of the applications in industry and transportation where silicon carbide transistors will excel.

The debates over the roles of SiC and GaN have been ongoing, and these APEC 2024 plenary talks presented arguments to support the idea that both technologies are moving ahead. Similarly, there were signs of progress for both technologies in the exhibition. On the GaN side, there were numerous displays and demos highlighting the growing availability of GaN devices from many sources and the growing range of applications they are addressing. For those offering 650-V GaN, there were product examples of 3-kW server power supplies and multi-kilowatt GaN-based on-board chargers, dc-dc converters and even traction inverters, suggesting the opportunities for GaN adoption in EVs.

In discussing the high-power future for GaN, Charles Bailley, senior director, Worldwide Business Development at Navitas observed that his company has pioneered GaN-based power adapters up to 1 kW. But with their newer platforms such as GaNSafe, they will break the barrier to GaN going to higher power, which will enable them to address applications from1 kW to 22 kW. "Integrated gate drive, power packaging and short circuit protection. That's how we get to 22 kW," said Bailley. At their booth, product examples included a hybrid-GaN/SiC 6.6-kW bidirectional on-board charger that illustrated in part the advancement that GaN provides in EVs.

While Navitas is one of the more-established GaN players, some of the newer GaN companies are also looking to tap into higher-power applications. At Tagore Technology's booth, Chae Lee, president and CEO of this company, discussed the various product examples they had on display using their GaN devices. These included adapters for scooters or e-bikes, with power ratings from 85 W to 500 W. They also showed 300-W and 500-W power supplies for medical and industrial applications. Other applications featured at the Tagore booth were door locks and power tools.

Perhaps the key takeaway from these and other successes for GaN was, as Lee observed, that "the myth of GaN not being reliable is gone." Perhaps in part because of that, there is a path to move ahead to more applications. According to Lee, the next phase is 1 kW to 10 kW for AI servers, industrial robotics and EVs. For Tagore, this area represents a way to differentiate from other GaN device suppiers: "We focused more on the higher power apps," said Lee whose company offers GaN FETs, half-bridge power stages and FET-and-driver ICs—all as monolithic parts.

Another representative of a newer GaN supplier also commented on the opportunities at higher power levels. Andrea Bricconi, chief commercial officer, of Cambridge GaN Devices (CGD) stated in a recent announcement, "We are acutely aware of the increasing power requirements of industrial applications, and the need for high efficiency. For example, as the use of artificial intelligence (AI) proliferates, the power demanded by the exponential growth in power demanded by datacentres is growing almost exponentially. Other applications, such as solar inverters, amplifiers, transport and smart mobility, process control and manufacturing are also interested in GaN and the feedback we have received is that they love the simplicity of our 'Drive it Like a MOSFET' approach."

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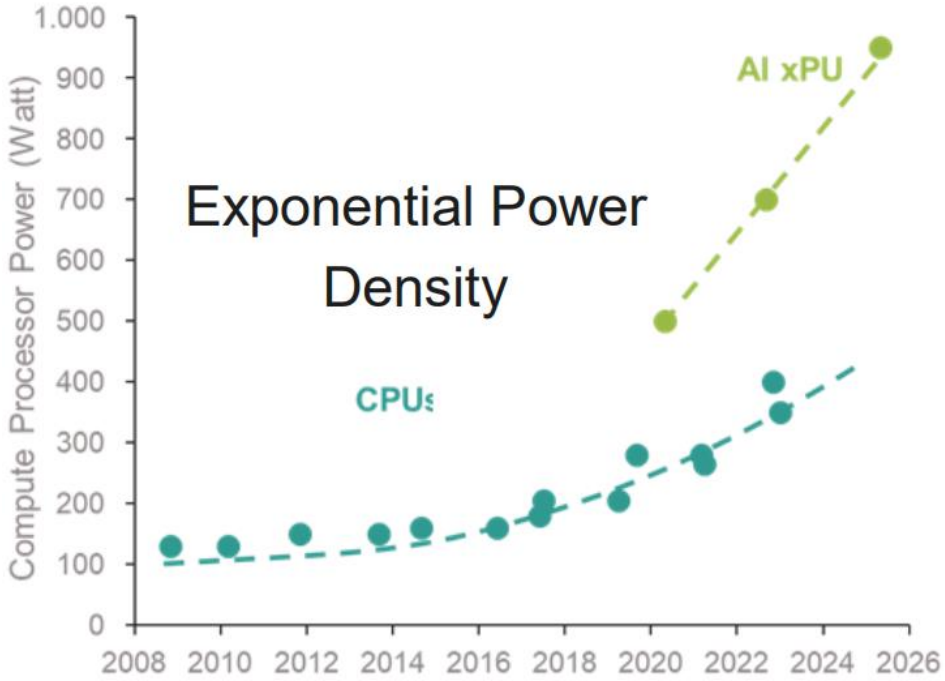
Lee and Bricconi's comments on AI, bring to mind a graphic that was presented by an Infineon speaker at the company's annual media dinner on Tuesday night at APEC. Calling it a step function increase in power, one of the presenters showed the following roadmap graphic for AI processor power (GPUs and others). This demand for density helps to explain why companies in the expo were showing 1000-A and higher reference designs for AI processors using the latest integrated power stages. The graph below suggests further innovation will be coming to keep pace with AI power demands.




On the other end of the GaN voltage spectrum, companies such as EPC showed that the lower-voltage GaN (40 to 400 V) continues to tap into an ever-growing list of applications. Also significant, the conference offered evidence that there is seemingly a rise in lower-voltage GaN device offerings from multiple vendors. For example, Infineon offers 40-V to 200-V GaN transistors; Innoscience, 30-V to 150-V GaN; Rohm, 150-V GaN; STMicroelectronics, 100-V GaN; and Nexperia, 100-V and 150-V GaN; and TI, 80-V and 100-V GaN power stages.

You'll find examples of the many GaN device applications as well as silicon (transistor and IC) and SiC (MOSFET and module) applications that were featured in the APEC 2024 expo in the following slide show. This sampling of APEC exhibits mainly illustrates the range and diversity of applications being addressed by power semiconductor companies, and highlights some of the themes prominent at this year's conference, like powering AI.

Following the slide show are several interesting product announcements made during APEC 2024 along with some other, newer products showcased in the exhibition. Some of these announcements are covered in greater detail in the Power Products section of this newsletter.

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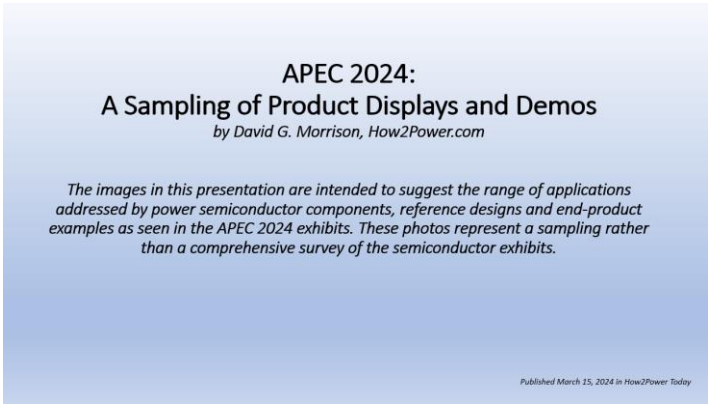


*(Click here or on image above to view the slide show.)*

## *Heard And Seen At APEC 2024*

### Switcher ICs Improve Efficiency For Multi-Output Power Supplies

Power Integrations announced the InnoMux-2 family of single-stage, independently regulated multi-output offline power-supply ICs. InnoMux-2 ICs consolidate ac-dc and downstream dc-dc conversion stages into a single chip, providing up to three independently regulated outputs for use in white goods, industrial systems, displays and other applications requiring multiple voltages. Elimination of separate dc-dc stages slashes component count, reduces PCB footprint and increases efficiency by as much as 10 percentage points compared to traditional two-stage architectures, according to the vendor.

Power Integrations introduced its original version of InnoMux in March 2019. However, that earlier version narrowly targeted LCD monitor applications, while this new version of InnoMux targets a broader array of applications thanks to a new "pulse-sharing" technique that it uses to route energy to the secondary outputs. For more information, see the product story in this newsletter.

### High-Density Power Modules Improve Performance And TCO For AI Data Centers

Infineon Technologies launched its TDM2254xD series dual-phase power modules that enable best-in-class power density, quality and total cost of ownership (TCO) for AI data centers, according to the vendor. The TDM2254xD series products blend innovation in robust OptiMOS MOSFET technology with novel packaging and a proprietary magnetic structure to deliver what's described as industry-leading electrical and thermal performance with robust mechanical design. This lets data centers operate at higher efficiency to meet the high power demands of AI GPU (graphic processor unit) platforms while also significantly reducing total cost of ownership (TCO), says the vendor. For more information, see the announcement.

### GaN FET Lowers On-Resistance To 1 mΩ

EPC introduced the EPC2361, a 100-V, 1-mΩ GaN FET in a 3-mm x 5-mm QFN, enabling higher power density for dc-dc conversion, fast charging, motor drives, and solar MPPTs. According to the company, this 1-mΩ typical value is the lowest on-resistance GaN FET on the market, offering double the power density compared to EPC's prior-generation products. Additionally, the maximum $R_{DS(ON)}$ x area of the EPC2361 is 15 mΩ*mm$^2$, which is said to be over five times smaller than comparable 100-V silicon MOSFETs. For more information, see the announcement.

### Solid-State Isolators Deliver Faster Switching With Lower Power Dissipation

Infineon Technologies introduced a family of Solid-State Isolators (iSSI). The drivers use coreless transformer technology to achieve faster and more reliable switching with circuit protection features not available in optically based solid state relays (SSRs).

Support for 20 times greater energy transfer and both current and temperature protection contribute to a higher reliability and lower cost of ownership, according to the vendor. The iSSI allows driving Infineon's OptiMOS and CoolMOS to reduce power dissipation by up to 70% of todays' solid-state relays using SCR and triac switches. For more information, see the announcement.

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### 1200-V SiC Modules Offer Cascode Benefits In Compact Package

Qorvo announced its first SiC products in modular packaging. These four 1200-V SiC modules—two half-bridge and two full-bridge—are offered in a compact E1B package with $R_{DS(ON)}$ starting at 9.4 mΩ. The highly efficient SiC modules target applications such as EV charging stations, energy storage, industrial power supplies and solar power inverters.

Moreover, these modules leverage the company's JFET-based, cascode technology to enable operation at higher switching frequencies. According to the vendor, its modules achieve 74% lower switching loss than comparable SiC MOSFET modules. The E1B package shares the same dimensions and pinout as industry-standard SiC MOSFET modules such as Infineon's Easy 1B and Wolfspeed's WolfPACK. For more information, see the announcement.

### 3.3-kV Plug-and-Play Gate Driver Supports Adoption Of High-Voltage SiC Power Modules

Microchip Technology introduced the 3.3-kV XIFM mSiC gate driver with patented Augmented Switching technology, which is designed to work out-of-the-box with preconfigured module settings to significantly reduce design and evaluation time. This plug-and-play gate driver is intended to help developers implement SiC solutions and fast-track the development process in medium-to-high-voltage applications in transportation, electric grids and heavy-duty vehicles. For more information, see the announcement.

### Reference Designs And Demos Highlight Benefits Of GaN Devices In Higher-Power, Industrial Applications

Cambridge GaN Devices (CGD) announced it is addressing higher-power industrial applications with its ICeGaN technology which has already proved itself rugged, reliable and easy-to-use in high-volume consumer devices, according to the vendor. At APEC 2024, the company introduced new reference designs and showed demos addressing the broad and diverse industrial market.

For example, as the result of a partnership deal struck last year with Neways Electronics, a 3-kW photovoltaic inverter uses CGD's GaN devices to boost the dc solar voltage to a stable dc link voltage. With a maximum efficiency of 99.22% due to zero-current switching, it exemplifies how CGD's GaN HEMT structure is simple for engineers to use, since it employs a standard silicon controller from Analog Devices. For more information, see the announcement.

### USB-C Reference Designs And Finished Modules Will Deliver More Than 95% Average Efficiency

Pulsiv, issued a "teaser" announcement that it plans to release a series of reference designs and assembled modules for USB-C applications that will deliver an average efficiency of more than 95% (from 10% to 100% load). This achievement, which minimizes energy waste under all operating conditions, has been developed in collaboration with GaN device maker, Innoscience and magnetics specialist, Frenetic.

Designs will be released throughout 2024 to support a new class of sustainable USB-C chargers, adapters, and in-wall sockets. The first 65-W solution is expected to be announced towards the end of March 2024. For more information, see the announcement.

### GaN Power Stages And Isolated DC-DC Modules

Texas Instruments displayed two power conversion device portfolios that were introduced just the week before APEC. TI's 100-V GaN power stages (LMG2100R044, a 100-V 4.4-mΩ GaN FET with integrated driver and protection and LMG3100R017, a 100-V, 1.7-mΩ GaN FET) feature thermally enhanced dual-side-cooled packaging to simplify thermal designs and achieve what's described as the highest power density in mid-voltage applications at more than 1.5 kW/in$^3$.

Meanwhile, TI's 1.5-W isolated dc-dc modules with integrated transformers (UCC33420-Q1 and UCC33420) are said to be the industry's smallest and most power-dense, helping engineers shrink the isolated bias power-supply size in automotive and industrial systems by over 89%, according to TI. For more details see the announcement.

To demonstrate performance of its new 100-V integrated GaN power stages, TI exhibited two reference designs demonstrating the performance and power density advantages of GaN-based designs. One was the TIDA-010090, a 30-A four-phase digitally controlled battery tester reference design, which employed a a GaN FET

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switching at 500 kHz. Another was the TIDA-010936, a 48-V, 16-A small-form-factor three-phase GaN inverter reference design for integrated motor drives.

The company also showed examples of opto-emulator based, isolated power supplies. These featured the company's ISOM8110 opto-emulator which was released last year. TI's opto-emulators, which use TI's isolation technology in combination with an $SiO_2$ dielectric material, offer low-cost analog isolation, like that of traditional LED-based optoisolators (or optocouplers) but with better bandwidth and better reliability than optocouplers. These opto-emulators support the use of isolated flyback and dc-dc converters in automotive applications.

## QR Flyback Controller Achieves High Power Factor And Efficiency

Among the newer devices shown at the STMicroelectronics booth was the HVLED101, a high-power-factor quasi-resonant flyback controller with valley locking and maximum power control. It can achieve 2% THD in QR flyback configuration. While the IC operates in quasi-resonant mode, one or more resonance valleys can be skipped to slow down the operating frequency and improve the system efficiency. The VL pin can be used to adjust the valley skipping levels, making it possible to achieve >90% efficiency. See the product page.

## 100-V Half-Bridge GaN Driver Is Flexible And Robust

Among the devices highlighted by Analog Devices was the company's LT8418, a 100-V half-bridge GaN driver with smart integrated bootstrap switch. This device was released at the beginning of this year. The LT8418 is flexible in that its split gate drivers allow for adjustment of both turn-on and turn-off behavior; and it has a low propagation delay of 10 ns.

Its control capabilities are also notable. The driver features tight matching of propagation delays—1.5 ns typ; high dv/dt immunity up to 50 V/ns and the ability to source 4 A peak and sink 8 A peak. The smart integrated boostrap switch along with undervoltage and overvoltage lockout make the driver robust. For more see the LT8418 page.

The company also featured its LTC7890 dual-phase and LTC7891 single-phase, 100-V synchronous stepdown controllers, which feature gate drivers specifically for GaN FETs. These devices, which were released in 2023 and 2022, respectively are among the few GaN-specific controllers in the industry. Both controllers simplify the application design while requiring no protection diodes or other additional external components compared to a silicon MOSFET solution. For more on these parts see the LTC7890 page and LTC7891 page.

## Adoption Of GaN Device In 45-W USB-C Charger Illustrates Company's Progress With GaN

ROHM Semiconductor announced the adoption of its 650-V GaN device (EcoGaN) in the C4 Duo, a 45-W output USB-C charger from Innergie, a brand of Delta. According to ROHM, its EcoGaN device contributes to greater application performance, reliability, and miniaturization by providing higher efficiency in power supply systems. According to Keng Ly, vice president of marketing at Rohm Semiconductor, this product example demonstrates that the company, which announced mass production of its first 650-V GaN devices last May, is actively participating in the market as a GaN device supplier. For more information, see the announcement.

## ESD Withstand-Capable Rectifiers Offer Both Polarity And ESD Protection

Taiwan Semiconductor announced a line of automotive-qualified rectifiers featuring ESD-withstand capability. The TSD series rectifiers simultaneously provide repetitive peak reverse voltage (VRRM) of up to 600 V as well as ESD protection of >10,000 V (per IEC-61000-4-2). Devices in the series have optional current ratings of 1 A, 2 A, and 3 A and operating temperature ranges from -40°C to ±175°C. All have a maximum forward voltage drop of 1.1 V and feature low-reverse leakage current and fast response time. For more information, see the website.

***For Further Reading***

1. "Zap Energy's Vision for Fusion Power" by Maurizio Di Paolo Emilio, Power Electronics News, February 19, 2024

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