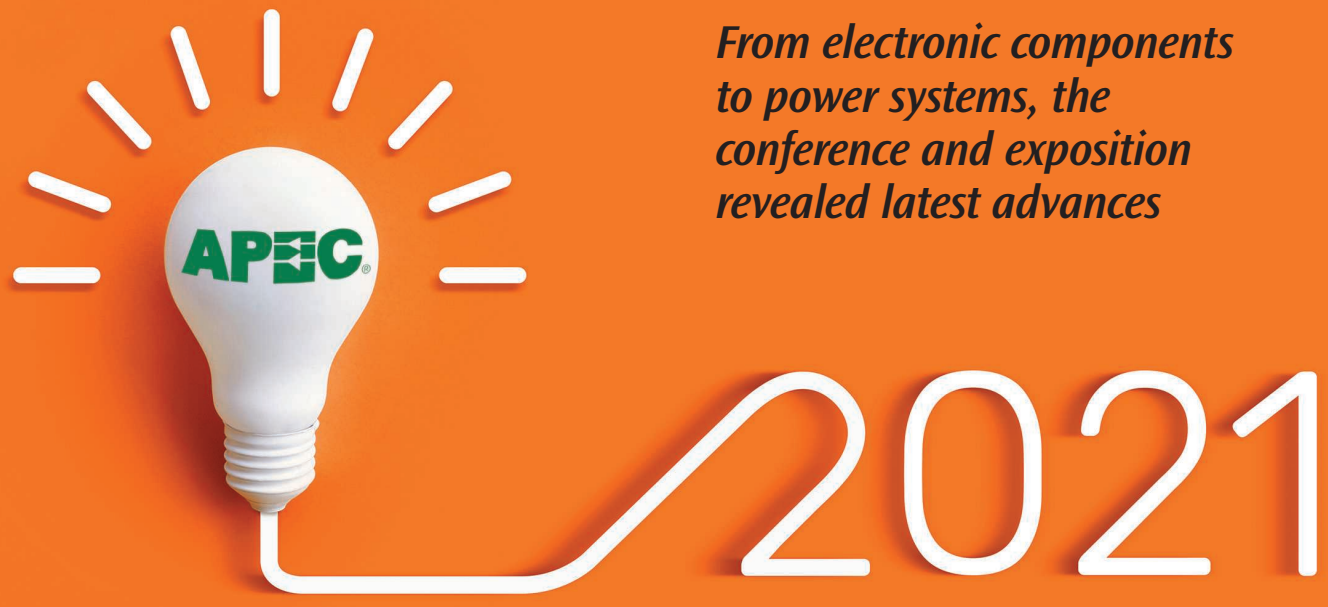

From electronic components to power systems, the conference and exposition revealed latest advances

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Virtual APEC 2021 Illuminates Emerging Technologies and Trends

by Ashok Bindra

For safety and well-being of conference participants, the IEEE Applied Power Electronics Conference and Exposition (APEC) was held virtually from 14–17 June, 2021, on the virtual event platform Social27, with on demand access starting the week of 7 June. The on-demand recordings include technical session lectures and dialogues (poster sessions), industry sessions, and professional education seminars. It was a mixture of live, on-demand, and recorded educational content with a virtual exposition, and plenty of opportunities to network.

For the second time, this premier event in applied power electronics was a virtual event sponsored by the IEEE Power Electronics Society (PELS), Industry Applications Society (IAS) and the Power Sources Manufacturers Association (PSMA). Recognized as the leading conference for practicing power electronics professionals, APEC 2021 brought together thousands of professionals from all corners of the world for online networking, learning and strategic business development. Tailored to meet the ongoing needs of international researchers and power engineers, the technical program included seven distinguished

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plenary speakers, technical sessions presenting peer-reviewed papers, industry sessions offering current topics in power electronics from industry sources, three RAP sessions, and 16 professional education seminars.

Plenary Session

Chaired by Dr. Stephanie Watts Butler, innovation architect at Texas Instruments (TI), with Dr. Pradeep Shenoy, manager in Power Design Services at TI, as cochair, the plenary session invited seven professionals to share their knowledge on six topics, which included electric vehicles, wide bandgap (WBG) semiconductors, WBG standardization, energy storage and power electronics, magnetics and power passives, and quantum computing. Traditionally, plenary talks are given on the same day. This year, the plenary presentations were spread across three days, Monday to Wednesday with two on each day.

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Welcoming the participants, the conference program chair Dr. Omer C. Onar of Oak Ridge National Laboratory kicked off the plenary session on Monday 14 June 2021 by inviting the first speaker Prof. Annette Muetze of Graz University of Technology, Graz, Austria to talk on "Auxiliary Automotive Drives Revolutionized by Power Electronics." In this talk, the keynote speaker discussed how these seemingly unnoticed small drives have been completely revolutionized by power electronics, where the beauty and power often emerge in rediscovering simplicity itself. Some examples explored in this talk include meeting the required EMI standards at reduced component counts, a simple drive redesign that can be considered during manufacturing that reduces the generated noise, as well as increasing drive efficiency by reducing the control to its essence.

Greeting all those attending, Prof. Muetze said that the millions of auxiliary drives used in automotive application have continued to remain one of the industry's best kept secrets hidden under the hood. Her presentation showed that with more than 100 of such auxiliary drives in typical mid-size and large executive cars (Figure 1), their role in enabling today's modern car's performances is of exceptional importance. "Given the additional design freedom and performance spaces opened up by the use of power electronics, the number of such small electric drives in automotive applications has at least doubled over the course of the past two decades," stated Prof. Muetze. Designed for performance, safety, and comfort, the focus today is on improving energy conversion efficiency, size, and cost, as well as meeting the electromagnetic emission, noise, and fault tolerance standards in these drives, noted the speaker. Because there is increasing interest in reducing noise in motors, the cogging torque has been reduced by nearly 70%, stated Prof. Muetze.

The second speaker of the session was Dr. Edoardo Merli, power transistor macro-division general manager and group vice president of STMicroelectronics' automotive and discrete group. Speaking on the topic "Wide Bandgap Technologies: Enabling a Broader Power Application Domain," he said physical limits prevent current silicon technology from achieving the

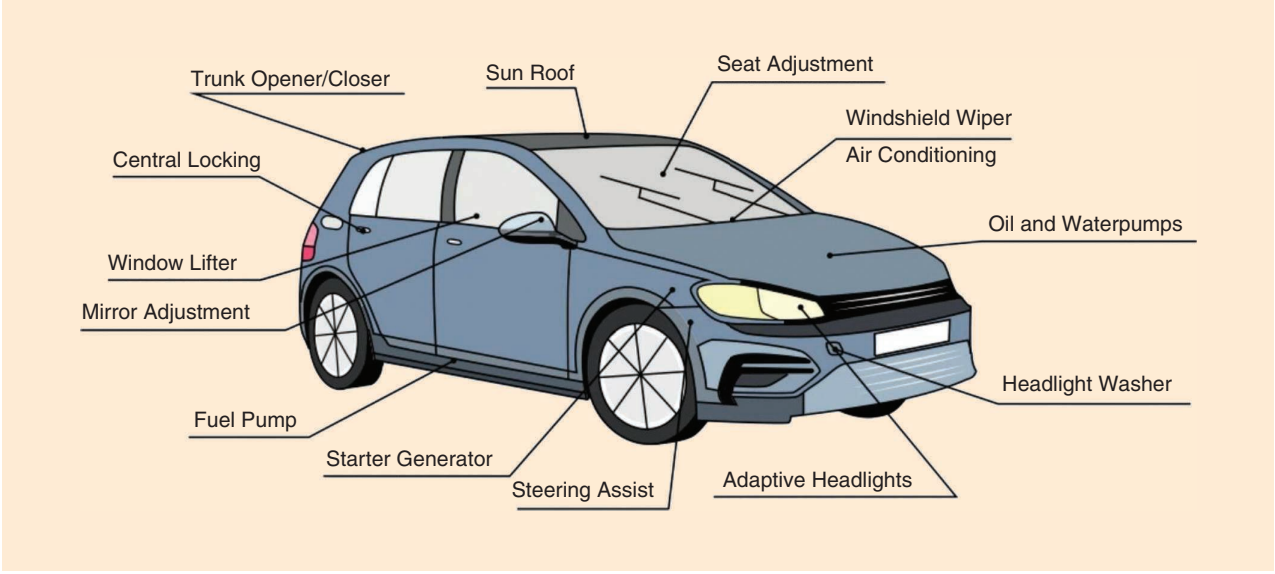

FIG 1 Modern high performance vehicles incorporate more than 100 auxiliary motor drives. Source: D klein

greater power density and miniaturization the market needs from power products to meet growing environmental concerns. Alternatively, WBG power devices are gaining traction in the market because of their energy efficiency and ability to address many of the environmental issues. For example, silicon carbide (SiC) and gallium nitride (GaN) devices, which enable superior overall performance, are helping manufacturers attain remarkable gains in applications like traction inverters and adaptors/chargers. Concurrently, he thinks silicon (Si) products will co-exist with the WBG products owing to their cost-effectiveness in some low-power applications or in systems where performance is adequate for the application. As a manufacturer of WBG and Si power products, ST is in a unique position to deliver power transistors suitable for an application, noted the speaker.

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On Tuesday 15 June, two more plenary presentations were delivered. While Dr. Butler, JC-70 chair, and Dr. Peter Friedrichs, JC-70 cochair and vice president SiC at Infineon Technologies, jointly investigated the WBG standardization efforts at JEDEC JC-70 committee, Dr. Stanley Atcitty, distinguished member of technical staff at Sandia National Laboratories, described the DOE energy storage programs on native American tribal lands. Under the title "Maturing Wide Bandgap Semiconductors Fosters Standardization," Dr. Butler analyzed the newly released GaN based standards JEP180 and JEP182, looking deeper into GaN $R_{DS(on)}$ and transient behaviors. These standards will show how standards for reliability, characterization, and datasheet parameters should be considered together, noted Dr. Butler. She added, JC-70 committee is now exploring similar standards for space and military applications. Likewise, speaking on the subject of WBG standardization, Dr. Friedrichs highlighted the threshold voltage and reverse recovery attributes of SiC devices and how recently published standards, JEP183 and JEP184, will enable users to accurately characterize them. Dr. Friedrichs also highlighted the on-going work aimed at standards for automotive applications.

There are currently 574 native American federally recognized tribes in the United States with a population of 6.79 million. Each tribe is a sovereign nation with its own government, traditions, culture, etc., and has a unique relationship with the federal and state governments. Tribal lands total about 5.8% of land area in the contiguous United States. These lands have utility-scale renewable

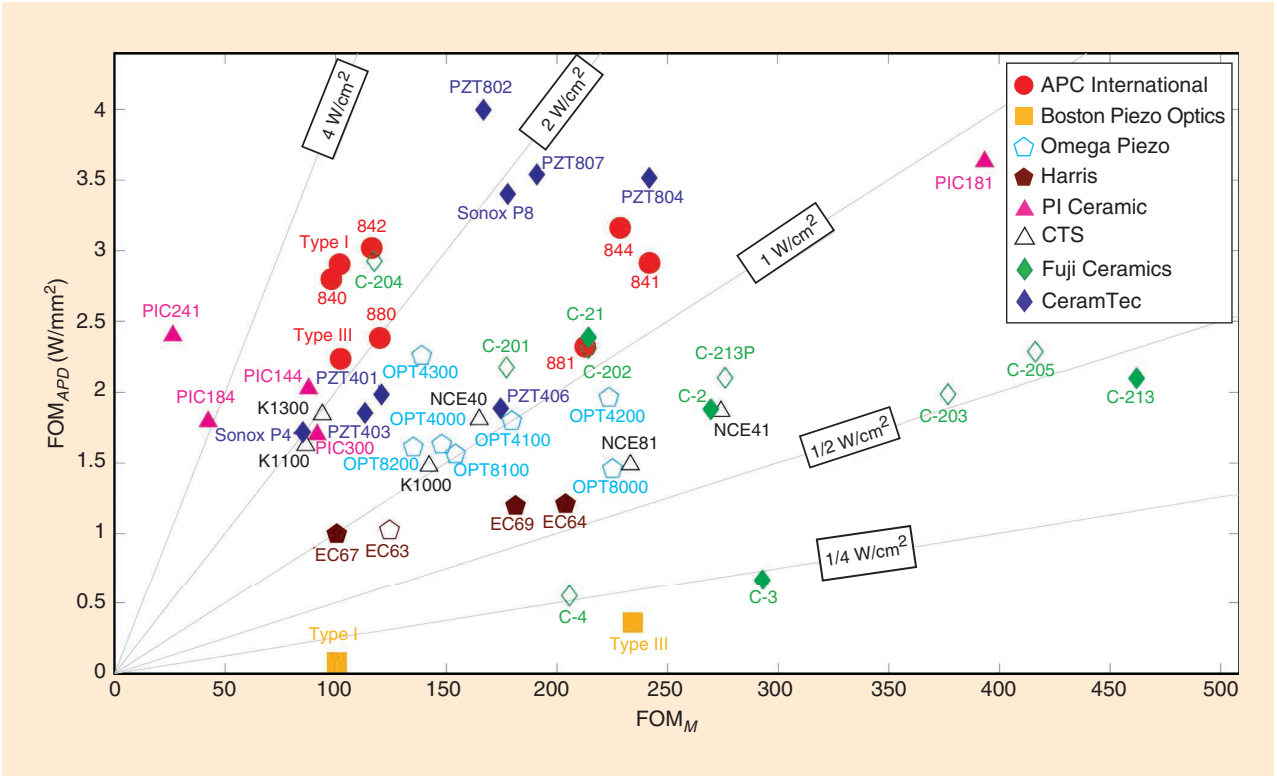

FIG 2 Piezoelectric materials for energy storage. Source: Jessica Boles, MIT

energy production of about 6.5% of the total U.S. national potential and yet 14% of households on native American reservations have no access to electricity, according to the Energy Information Administration. Greeting the attendees in the native Navajo language, Dr. Atcitty presented a background on native American energy sovereignty and provided examples of current DOE energy storage program projects in tribal lands.

The last two plenary talks were presented on Wednesday 16 June. Prof. Charles R. Sullivan of Thayer School of Engineering at Dartmouth, Hanover, New Hampshire, USA, and director at NSF Power Management Integration Center, gave an exciting talk on the present and future of magnetics and other power passives. While Dr. Heike Riel, an IBM Fellow and department head of science and technology, IBM Research, presented an enlightening talk on "Quantum Computing- The New Computing Paradigm." With advances in semiconductor switch technology, higher frequencies are becoming practical but magnetics is limiting the performance. Prof. Sullivan's talk discussed ways to overcome these limitations by proposing high-Q resonators, such as piezoelectric, that can replace conventional resonators built with discrete inductors and capacitors (Figure 2).

His presentation indicated that commercial lead zirconate titanate (PZT) based piezoelectric resonator can achieve power density of up to 100 W/cm^3 with efficiencies from 93% to 99%. By comparison, the keynote showed that PZT's energy storage capability is comparable to the best ferrite magnetic cores operating at 1 MHz or higher. However, Prof. Sullivan's talk suggested that lithium niobate is a better material and can surpass PZT in performance. To support his statement, he demonstrated a prototype operating at 6.8 MHz, and offering 98% component efficiency with power density of 148 W/cm^3. In summary, he said that piezo resonators are excellent passive energy storage components that scale well, but much work is needed. Likewise, LC resonant structures can also offer high performance and scale well to larger sizes. Furthermore, Prof. Sullivan proposed a multilayer self-resonant structure (MSRS) using thin aluminum foil. Offering very high-Q with minimal skin and proximity effects, this MSRS resonator was also implemented in a CMOS chip, operating at 48 MHz and 0.87 W with 86% peak efficiency. This effort is a joint collaboration with researchers at MIT, stated Prof. Sullivan.

RAP, Technical and Industry Sessions

The three RAP sessions offered interesting discussion on topics such as "Distributed versus. centralized control for microgrid and nanogrid," "Does high level of integration make power converters more reliable or not?" and "Where does the expertise for the next generation of magnetics come from? The Magnetics companies or the engineer designing the power supply? Chaired by Dave Maliniak of Evaluation Engineering, the panelists for the session on distributed versus centralized control of microgrid and nanogrid was a good mix of experts from the industry and academia. The general consensus at the end of the session favored distributed control. The second RAP session on the 16th morning focused on whether high level of integration makes power converters more reliable or not? This session was chaired by Indumini Ranmuthu of Texas Instruments, and panelists included Robert Pilawa-Podgurski ((University of California, Berkeley), Madhu Chinthavali (Oakridge National Labs), Sandeep Bahl (Texas Instruments), Huai Wang (Aalborg University), Babak Fahimi (University of Texas Dallas), and Francesco Carobolante (IoTissimo). Many

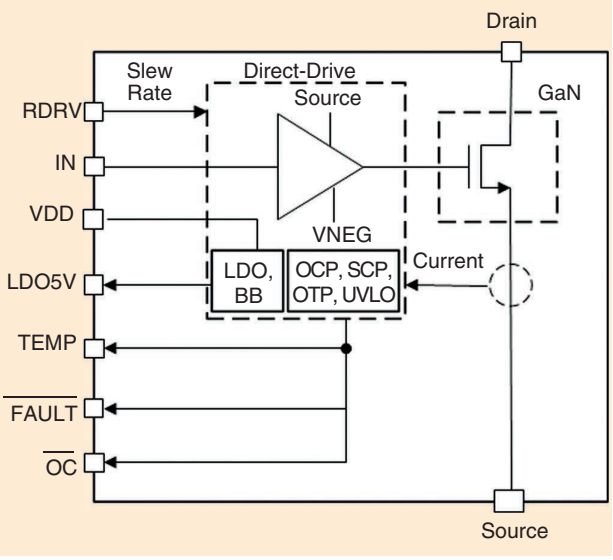

FIG 3 Automotive qualified 650 V GaN FET with integrated driver, protection and active power management. Source: Texas Instruments.

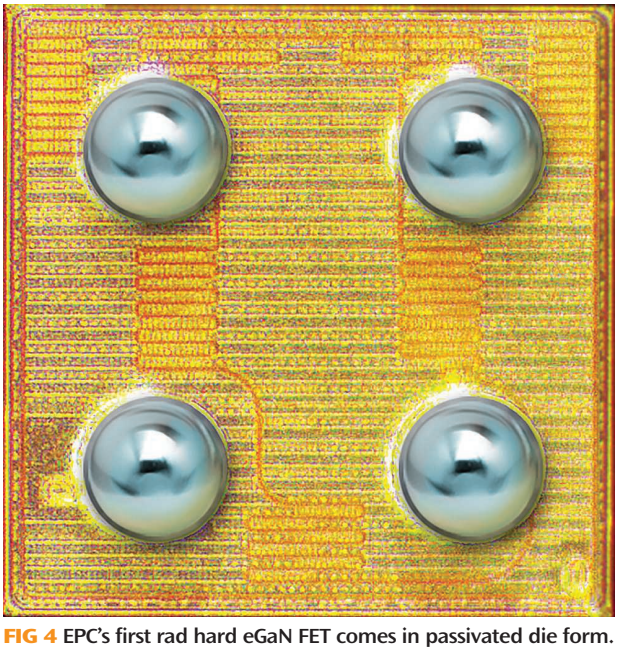

FIG 4 EPC's first rad hard eGaN FET comes in passivated die form.

believed that reliability at the system level and component level are debatable as there is no universal definition of integration and reliability. The third session on "Where does the expertise for the next generation of magnetics come from? The Magnetics companies or the engineer designing the power supply? The chair for this session was Eric Persson of Infineon and the panelists included Paul Yeaman (Vicor Corp.), Dan Jitaru (Rompower), Paul Greenland (Analog Devices), Jim Marinos (Payton Magnetics), Charles Sullivan (Dartmouth University), and Kevin Enser (Renco Electronics). The overall answer was mixed. Some picked power supply designer while others voted for the companies.

The technical program included peer-reviewed papers and recorded content that was available on demand one week prior to the virtual conference week. Topics varied from dc-dc/ac-dc converters to motor drives and inverters, and devices (SiC and GaN) & components. Additionally, it also included wireless power transfer, power electronics integration and manufacturing, and control.

In addition, the Industry sessions offered topics ranging from high frequency magnetics to packaging for next generation power electronics and integration in WBG semiconductors. Speaking of integration, several papers demonstrated the integration of GaN power stages and gate drivers

Virtual Exhibition

Finally, the virtual exposition revealed the latest products and technologies from manufacturers that are driving the industry. In the GaN arena, several manufacturers unveiled latest advances in GaN integration. Power Integrations, for example, displayed an off-Line CV/CC ZVS flyback integrated switcher IC with 750 V PowiGaN FET, active clamp drive and synchronous rectification. Labeled InnoSwitch4-CZ, it is tailored for 60 W ultra-compact USB PD 3.0 charger for mobile phones and laptop computers.

Similarly, Texas Instruments disclosed its first automotive 650 V GaN FET with integrated driver, protection and active power management (Figure 3). Designated

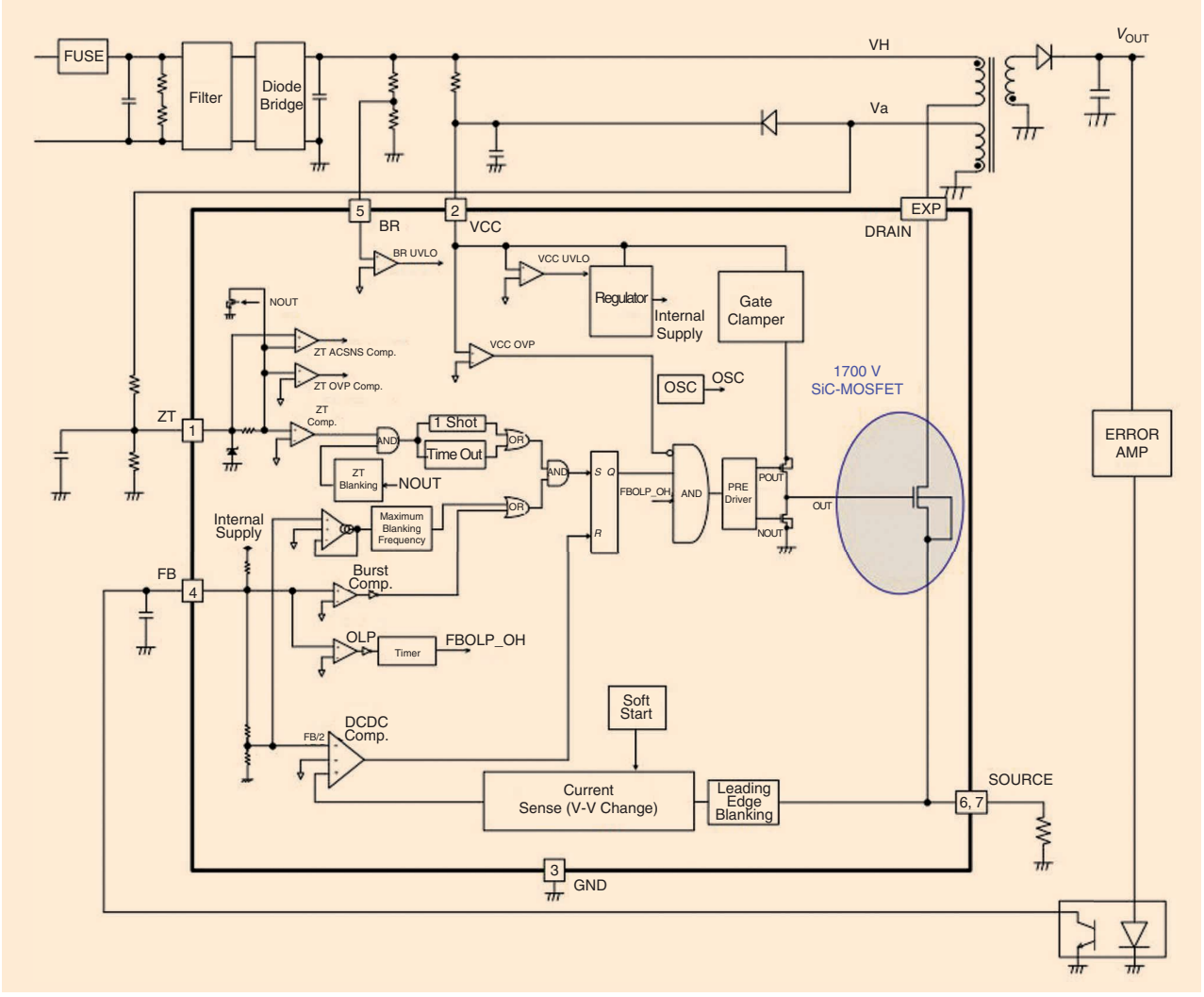

FIG 5 Complete ac-dc converter IC with a built-in 1700 V SiC MOSFET. Source: ROHM Semiconductor.

LMG3525R030-Q1, it reduces the size of electric vehicle (EV) onboard chargers by 50% compared to existing silicon or SiC solutions, claims TI. According to applications manager Ramanan Natarajan, "fast switching integrated gate driver enables a 59% reduction in the size of power magnetics in EV chargers. An industrial version includes a 600 V GaN FET.

Also, demonstrating 650 V GaN FET was Nexperia. The company announced volume availability of its second-generation 650 V power GaN FETs, offering significant performance advantages over previous technologies and competitive devices. With $R_{DS(on)}$ performance down to 35 mΩ (typical), the new power GaN FETs target single phase ac-dc and dc-dc industrial switched mode power supplies (SMPS), ranging from 2 kW to 10 kW, especially server and telecoms supplies that must meet 80 PLUS Titanium efficiency regulations. Meanwhile, the supplier also announced partnership with renowned automotive engineering consulting company, Ricardo, to produce a technology demonstrator for an EV inverter based on GaN technology. To boost production capacity at all its facilities while supporting research & development in GaN power ICs, the company announced an investment of US$700 million.

Efficient Power Conversion Corp. (EPC) unveiled its first low-voltage rad hard eGaN FET that has been specifically designed for critical applications in the high reliability or commercial satellite space environments. It is supplied only in passivated die form with solder bumps. The die size is 0.9- × 0.9-mm (Figure 4).

Die size: 0.9 mm × 0.9 mm

According to EPC CEO Alex Lidow, these devices have exceptionally high electron mobility and a low temperature coefficient resulting in very low RDS(on) values. The lateral structure of the die provides for very low gate charge (QG) and extremely fast switching times. These features enable faster power supply switching frequencies resulting in higher power densities, higher efficiencies and more compact designs.

Advances in SiC FETs

Concurrently, TI also released an automotive compliant 15-A isolated IGBT/SiC MOSFET gate driver UCC5870-Q1 for use in HEV/EV applications. Key features include adjustable "on the fly" gate drive strength, split driver outputs provide 15-A source and 15-A sink current.

Japan's ROHM Semiconductor introduced the industry's first ac-dc converter IC with a built-in 1700 V SiC MOSFET (BM2SC12xFP2-LBZ) in the TO263-7L package. The device is optimized for industrial applications, offering efficiency, shortening design time, simplifying the circuitry and reducing additional components by offering an integrated solution. These ICs also increase product reliability by minimizing the risk of component failure.

Eyeing EV market, ON Semiconductor announced a pair of 1200 V SiC MOSFET 2-pack half-bridge modules for charging applications. While the NXH010P120MNF1 is a 10 mΩ device housed in an F1 package while the NXH006P120MNF2 is a 6 mΩ device in an F2 package. The packages feature press-fit pins making them ideal for industrial applications and an embedded negative temperature coefficient (NTC) thermistor facilitates temperature monitoring. The new SiC MOSFET modules have been designed to work alongside driver solutions such as the NCD5700x devices, as well as the recently introduced NCD57252 dual channel isolated IGBT/MOSFET gate driver. It offers 5 kV of galvanic isolation and can be configured for dual low-side, dual high-side or half-bridge operation.

Others displaying their SiC products include UnitedSiC, GeneSiC Semiconductor, Mitsubishi Electric amongst others. Aiming to efficiently serve the EV on-board chargers and server/telecom power supplies applications, GeneSiC released its high performing 750 V SiC MOSFETs. Dr. Ranbir Singh, president of GeneSic said that the 750 V SiC MOSFETs are supported by fast turn-around and automotive-qualified high volume manufacturing to further enhance the value proposition.

New Magnetics

In the magnetics arena, makers like Bourns, Magnetics, CorePower Magnetics, Coilcraft and others continued to release new material and products to meet the demands of improved efficiency and higher saturation. Magnetics, for instance, described its new amorphous and nanocrystalline cores. While Coilcraft unveiled a new line of high performance power inductors with 40% lower dc resistance and extremely low ac losses for dc-dc converters switching at frequencies up to 5 MHz. Concurrently, suppliers like Bourns, Magnetics, and Standex exploited exhibitor seminars to display their capabilities. Bourns, for example, presented power and signal magnetics solutions in battery management systems (BMS) in session #ES5. In this session, Bourns products application engineer Kyle Moldenhauer talked about selecting the right transformer for a high-voltage signal isolation in BMS. Besides identifying isolation transformers for BMS application, he talked about safety and isolation, as well separation requirements based on safety standards. Additionally, he stated that topology selection affects transformer operation. Likewise, in session #ES16, "Magnetics' Next Gen Powder Core Materials, Bourns introduced new powder core materials, such as Edge and Kool Mu HF for best dc performance and higher switching frequencies.

Taking all the adversities into account, APEC organizers and vendors did a fantastic job in creating a successful virtual APEC 2021 for the power electronics community. With vaccinations against SARS-COVID-2 underway, international travel resuming, and large gatherings permitted, we all are looking forward to the in-person event in 2022, which will take place in Houston, Texas.

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