ISSN: 1863-5598

ZKZ 64717
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Bodo´s Power Systems®

Electronics in Motion and Conversion

May 2025

EcoSiC

ROHM SEMICONDUCTOR

Compact SiC Module for High Power Density On-Board Chargers

PULSED INDUCTANCE MEASUREMENT

POWER CHOKE TESTER DPG10/20 SERIES

Inductance measurement from 0.1 A to 10 kA

KEY FEATURES

Measurement of the

- **Incremental inductance** $L_{inc}(i)$ and $L_{inc}(\int U dt)$
- **Secant inductance** $L_{sec}(i)$ and $L_{sec}(\int U dt)$
- **Flux linkage** $\psi(i)$
- **Magnetic co-energy** $W_{co}(i)$
- **Flux density** $B(i)$
- **DC resistance**

Also suitable for 3-phase inductors

WIDE RANGE OF MODELS

7 models available with maximum test current from 100A to 10000A and maximum pulse energy from 1350J to 15000J

KEY BENEFITS

- Very **easy and fast** measurement
- **Lightweight, small and affordable price-point** despite of the high measuring current up to 10000A
- **High sample rate and very wide pulse width range** => suitable for all core materials

APPLICATIONS

Suitable for all inductive components from **small SMD inductors** to **very large power reactors in the MVA range**

- **Development, research** and **quality inspection**
- **Routine tests** of small batch series and mass production

Technological leader in pulsed inductance measurement for 18 years

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ESL 7nH typical
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Content

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With our wide portfolio of high-quality components, a toolbox full of technical guidelines, our design platform REDEXPERT, books, and application-based content, we provide the right solution for every aspect of your design.

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www.we-online.com

Highlights
- Wide range of power inductors, input- and output capacitors, EMI solutions, thermal materials and electromechanical components
- Design platform REDEXPERT
- Application notes and reference designs
- Reference guide DC/DC converter handbook
- Ready-to-use simulation models

#PowerUp

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Free Subscription to qualified readers
Bodo´s Power Systems is available for
the following subscription charges:
Annual charge (12 issues) is
150 € world wide · Single issue is 18 €
subscription@bodospower.com

Printing by:
Dierichs Druck+Media
GmbH & Co. KG,
34121 Kassel, Germany

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Boring Power is our Future

On the day I flew from Munich to Atlanta to visit APEC, the last members of the TUM Boring team flew from Munich to Austin/Texas to take part in the "Not-a-Boring Competition 2025". To make a long story short: The TUM Boring team won by "digging" a tunnel measuring more than 22 m (by far a new record for the competition) while the six other finalists from Asia, Europe and the US did not "dig" beyond 2 m. All 19 members of the TUM boring team are students from three Munich-based universities (TUM, HM and LMU).

Before discussing the power electronics involved, I'd like to share some background information: About a year ago the members of the TUM boring team began work on their 2025 project – always in parallel to their studies in mechanical engineering, electrical engineering, mechatronics, engineering physics, computer science, geology, environmental engineering and business administration. Even though they are all students, they planned a project on an amazing scale, created the design, manufactured the machine and completed it in time for the 3 containers with 50 tons of equipment to be shipped. That alone is a masterstroke, but the fact that they also demonstrated the best technical solution despite various challenges and problems is simply magnificent. I am particularly impressed by the team's holistic approach, which brought together and coordinated so many disciplines at the same time and convinced various sponsors – from ABB to Liebherr and many others to a well-known airline and a frozen pizza company (students are always hungry). I believe that this practical experience of very close collaboration across all disciplines is worth more than (almost) all the lectures at university. By the way: Many of the team members have already received job offers from the sponsors.

In terms of power electronics they used four IGBT-based 7.5 kW frequency inverters and just one three-phase power supply. All the power electronics had to be very close to the motors in order to have very short feedback cables to the controller. So the electronics needed to work properly very deep inside the tunnel, and it did very well. For space and cooling reasons they had to modify the case of the inverters, for example. You can read more at www.tum-boring.com or on Instagram (tum_boring), where you'll get a better idea of the sheer size of this student project.

Bodo's magazine is delivered by postal service to all places in the world. It is the only magazine that spreads technical information on power electronics globally. We have EETech as a partner serving our clients in North America. If you speak the language, or just want to have a look, don't miss our Chinese version at bodospowerchina.com. An archive, of every issue of the magazine, is available for free at our website bodospower.com.

My green tip of the month:
Consider boring/drilling at home in order to use the temperature of the groundwater in a heatpump. This is not cheap, but remember that about 60 % of the energy consumption in an average household is needed to heat rooms and water.

Alfred Vollmer

Events

PCIM 2025
Nuremberg, Germany May 6 – 8
https://pcim.mesago.com

ECCE Asia 2025
Bengaluru, India May 11 – 14
https://ecceasia2025.org

SEMICON Southeast Asia 2025
Singapore May 20 – 22
www.semiconsea.org

ISPSD 2025
Kumamoto, Japan June 1 – 5
www.ispsd2025.com

CWIEME Berlin 2025
Berlin, Germany June 3 – 5
https://berlin.cwiemeevents.com

Battery Show Europe 2025
Stuttgart, Germany June 3 – 5
www.thebatteryshow.eu

PEMD 2025
Turin, Italy June 11 – 12
https://pemd.theiet.org

GPECOM 2025
Bochum, Germany June 11 – 13
https://gpecom.org/2025

iTEC 2025
Anaheim, CA, USA June 18 – 20
https://itec-conf.com

HMSR DA series

The new HMSR DA family of integrated current sensors designed by LEM is the first to include an ADC with a sigma-delta bitstream digital output.

High-resolution, ease-of-use and an output that follows the increase or decrease of the input with configurable delay, makes it easier to develop a wealth of control systems.

This makes the HMSR DA the first choice for standalone servo drives, robotics, high precision machines, automated guided vehicles (AGVs) and CNC machine tools.

www.lem.com

- **Current range 6-30 A_{RMS} continuous at 125°C**
- **75 A peak current**
- **Digital bitstream output with 10 MHz clock**
- **More cost-effective and compact than discrete alternatives**

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Nuremberg, 6 – 8 May 2025

LEM
Life Energy Motion

Robert Feurle appointed as CEO

Wolfspeed appointed Robert Feurle as Chief Executive Officer (CEO), effective May 1, 2025, following a comprehensive internal and external search by the Board of Directors. Feurle succeeds Thomas Werner, who is serving as interim Executive Chairman and will return as Chairman of the Board following the transition. Being a citizen of both the United States and Germany, Feurle will be returning to the United States where he previously spent a decade in executive roles at Micron Technology and will be relocating to the Company's headquarters in Durham, North Carolina, where he will work closely with Werner to ensure a smooth transition. Most recently, he served as Executive Vice President and General Manager of the Opto Semiconductors Business Unit at ams-OSRAM AG, where he was responsible for managing more than 10,000 employees in sites and factories around the world. Previously, at Infineon Technologies, Micron Technology, Qimonda, and Siemens, Feurle managed strategic initiatives that enhanced competitiveness and increased revenue growth in challenging global markets. Previously e. g. at Infineon Technologies, he strategically expanded market opportunities with product introductions in the field of IGBT and SiC technologies and leading a global business unit focused on competitive differentiation and profitable growth. He was also part of the team at Infineon supporting the proposed acquisition of the Wolfspeed operations in 2016. "His experience in market-driven technology innovation and strategic business scaling makes him uniquely suited to advance Wolfspeed's global leadership in silicon carbide technology", Wolfspeed says in a press release.

www.wolfspeed.com

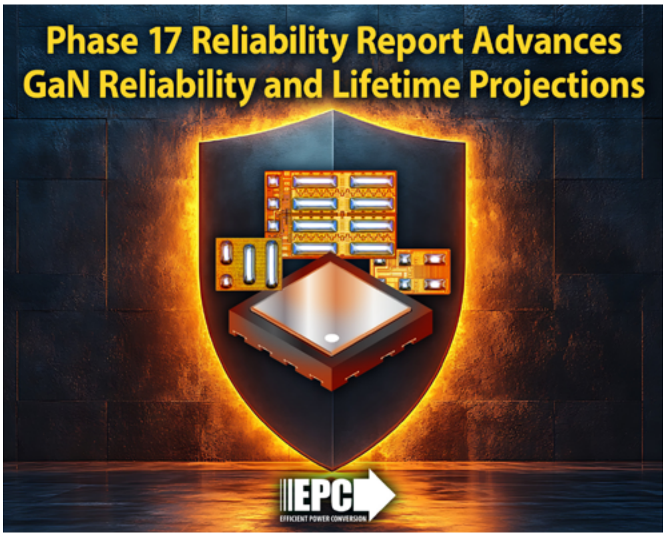
Subsidiary for the Benelux Region

Job van Galen takes over the management of the newly founded subsidiary of Plasmatreat in Eindhoven, the Netherlands. The company, which manufactures and develops atmospheric pressure plasma technologies for surface treatment, serves customers in Belgium, Luxembourg and the Netherlands directly from this office, and Job van Galen is Managing Director of the new subsidiary. Van Galen holds a Bachelor of Science in Engineering Physics (2017) from Fontys University of Applied Sciences. During his more than eleven years with an international electrical equipment manufacturer, he held various technical and strategic positions and worked with companies in the automotive, medical, semiconductor, consumer goods and energy sectors. In his new role at Plasmatreat, van Galen will be responsible for technical sales, the development of sustainable relationships and application development with valued customers. Atmospheric-pressure plasma technology makes it possible to precisely modify material surfaces, improve adhesion properties and create environmentally friendly alternatives to chemical pretreatment.

www.plasmatreat.de

Phase 17 Reliability Report: Advancing GaN Reliability and Lifetime Projections

Efficient Power Conversion (EPC) has released its Phase 17 Reliability Report, emphasizing GaN's position as a highly reliable technology for power electronics, automotive, AI, space, and industrial applications. The latest reliability report introduces expanded lifetime models, mission-specific reliability projections, and new physics-based wear-out mechanisms, providing engineers with more accurate and practical reliability data for GaN power devices. The key highlights of the Phase 17 Reliability Report include an expanded gate lifetime model that incorporates gate leakage current effects across voltages and temperatures, leading to enhanced impact ionization modeling as well as repetitive transient gate overvoltage testing which develops and validates a 7 V gate overvoltage rating, addressing resonance-like transient stress in real-world applications. Other highlights include enhanced drain overvoltage robustness, pulsed current rating data (extending testing to over 100 million pulses), a comprehensive thermomechanical lifetime model now including power cycling modeling and mission-specific reliability insights. EPC's test-to-fail methodology continues to push GaN technology beyond traditional silicon MOSFETs. By integrating real-world stress conditions into advanced lifetime models, the Phase 17 report allows for more accurate reliability projections for next-generation power applications.



www.epc-co.com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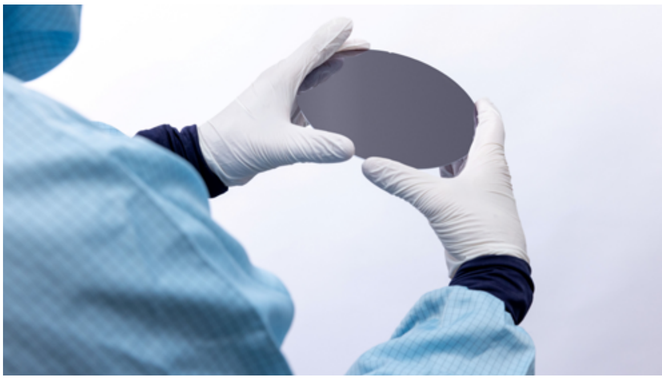
DETAILS

Developing a GaN Power Platform with a scalable outsourced manufacturing Model

IQE plc and X-FAB Silicon Foundries SE announce a Joint Development Agreement (JDA) to create a European-based GaN Power device platform solution. With an initial two-year scope of work, IQE and X-FAB will collaborate to develop a 650V GaN device. The agreement will leverage IQE's GaN epitaxy design and process expertise, along with X-FAB's proven technology development and device fabrication capabilities to offer an optimized technology-substrate combination for automotive, data center and consumer applications.



This collaboration will provide fabless semiconductor companies with an off-the-shelf GaN platform accelerating their innovation cycles and time-to-market. The technology will also serve as a foundation for future product development, extending beyond 650V to address the growing market demand for Power Electronics.

Jutta Meier, Interim Chief Executive Officer and Chief Financial Officer of IQE, comments: "We are excited to join forces with X-FAB to develop a world-class GaN Power foundry solution in Europe, providing outsourced optionality for our fabless customers. Building on our GaN epitaxy expertise and recent investment in additional GaN reactor capacity, this agreement aligns with our GaN diversification strategy, expands our customer reach, and accelerates time-to-market for GaN Power applications."

"By combining our long-standing expertise in GaN device fabrication and design enablement with IQE's epitaxy leadership, we are creating a unique, turnkey GaN Power platform," explains Jörg Doblaski, Chief Technology Officer at X-FAB. "In addition to our existing GaN technology, this collaboration provides a compelling alternative to existing supply chain models and strengthens Europe's position in next-generation power semiconductor technology."

www.xfab.com

Buy-back of GaN IP Portfolio

Burkhard Slischka (picture) and his co-founders Atsushi Nishikawa and Alexander Loesing have achieved a milestone for ALLOS Semiconductors by acquiring the GaN IP portfolio of AZUR Space. This strategic acquisition includes the buy-back of the GaN-on-Si technology for high power electronics (HPE) applications, which ALLOS originally sold to AZUR in 2020, along with several jointly completed innovations and resulting patent applications. With this acquisition, ALLOS' global IP portfolio has expanded to over 50 granted patents, with more to come, most of them essential for both GaN-on-Si for optoelectronics and HPE applications. This acquisition provides the company with the option to re-enter the GaN-on-Si high power electronics (HPE) market. "We believe that the unique features of ALLOS' 200 mm and 300 mm technology can significantly benefit in scaling up production while reducing unit costs", claims Burkhard Slischka, CEO of ALLOS Semiconductor. "In addition to standard silicon fab compatibility, these features include excellent crystal quality, best wafer uniformity, and award-winning breakdown voltages for undoped GaN. While we remain focused on micro-LEDs, we are open to collaborations with HPE players."

www.allos-semiconductors.com

GaN Technology Development and Manufacturing Agreement

STMicroelectronics and Innoscience announce the signature of an agreement on GaN technology development and manufacturing, leveraging the strengths of each company to enhance GaN power solutions and supply chain resilience.

The companies have agreed on a joint development initiative on GaN power technology, to advance the promising future of GaN power for consumer electronics, datacenters, automotive and industrial power systems and many more applications in the coming years. In addition, the agreement allows Innoscience to utilize ST's front-end manufacturing capacity outside China for its GaN wafers, while ST can leverage Innoscience's front-end manufacturing capacity in China for its own GaN wafers. The common ambition is for each company to expand their individual offering in GaN with supply chain flexibility and resilience to cover all customers' requirements in a wide range of applications.

Marco Cassis, President, Analog, Power & Discrete, MEMS and Sensors of STMicroelectronics declared: "ST and Innoscience are both Integrated Device Manufacturers, and with this agreement we will leverage this model to the benefit of our customers globally. First, ST will be accelerating its roadmap in GaN power technology to complement its silicon and silicon carbide offering. Second, ST will be able to leverage a flexible manufacturing model to serve customers globally."

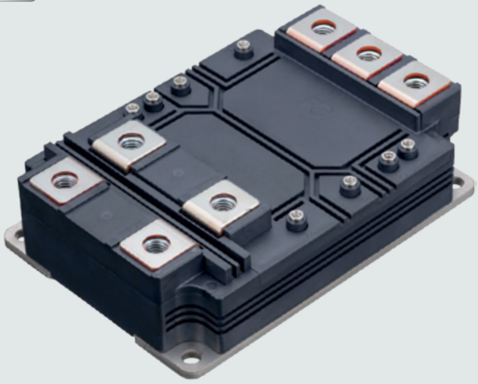
www.st.com

Fuji Electric
Innovating Energy Technology

High Power next Core (HPnC)

with Fuji Electric's X series 7G IGBT and SiC

X series 7G
All SiC



MAIN FEATURES FOR TRACTION & INDUSTRIAL APPLICATIONS

- **Latest chip technology**
  - Fuji Electric's X series IGBT and FWD with low losses
  - SiC – MOSFET: Super low switching loss energies
- **Available blocking voltages: 1700 V, 2300 V and 3300 V**
- **High reliability**
  - CTI>600 for higher anti-tracking
  - High thermal cycling capability with ultra sonic welded terminals
  - MgSiC base plate for traction version
  - Improvement of delta T_j power cycling capability by using 7G packaging technology
- **RoHS compliance**
  - Ultrasonic welded terminals
  - RoHS compliant solder material
- **Temperature detection**
  - Thermal sensor installed
- **Easy paralleling**
  - Minimized current imbalance
  - Easy scalability

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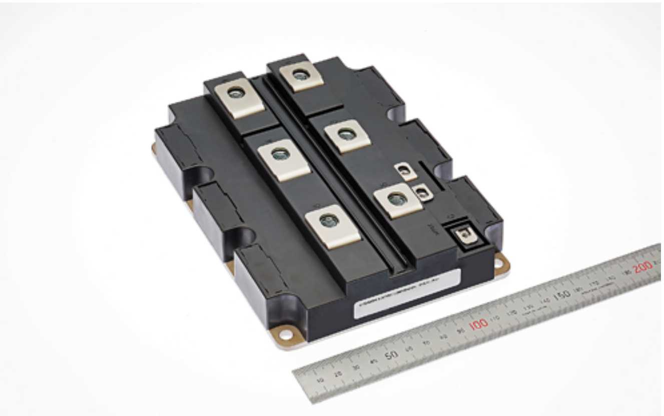
www.fujielectric-europe.com

HVIGBT Module Designed for Inverter Systems

Mitsubishi Electric Corporation announced that it will begin shipping samples of its XB Series high-voltage insulated-gate bipolar transistor (HVIGBT) module, a 3.3k-volt, 1500A high-capacity power semiconductor for large industrial equipment such as railway vehicles. By adopting proprietary diode and insulated gate bipolar transistor (IGBT) elements, as well as a unique chip termination structure, the module's improved moisture resistance will help to improve the efficiency and reliability of inverters for large industrial equipment operating in diverse environments. Mitsubishi Electric will exhibit the XB Series HVIGBT module at Power Conversion Intelligent Motion (PCIM) Expo & Conference 2025 in Nuremberg, Germany from May 6 to 8. The 3.3kV/1500A XB Series HVIGBT module uses IGBT elements incorporating Mitsubishi Electric's proprietary relaxed field of cathode (RFC) diode and carrier-stored trench-gate bipolar transistor (CSTBT) structure. In particular, the module reduces total switching loss by approximately 15% compared to previous models, contributing to higher efficiency in inverters. It also expands tolerance in the reverse-recovery safe operating area (RRSOA) by about 25% compared to previous models, further enhancing inverter reliability.



In addition, by using a new electric field relaxation structure and a surface charge control structure in the chip's termination area, Mitsubishi Electric has reduced the area's size by about 30% while achieving about 20 times greater moisture resistance than existing products, contributing to more stable operation of inverters used in high-humidity environments. By further improving the efficiency and reliability of inverters for large industrial equipment operating in various environments, the module is expected to contribute to efforts to achieve carbon neutrality.

www.mitsubishielectric.com

Joint Development of Automotive Components using GaN Semiconductors

Mazda Motor Corporation and ROHM have commenced a joint development of automotive components using GaN power semiconductors. Since 2022, Mazda and ROHM have been jointly working on the development of inverters using SiC power semiconductors under a collaborative framework for the development and production of electric drive units. Now, they have also embarked on the development of automotive components using GaN power semiconductors, aiming to create innovative automotive components for next-generation electric vehicles. Mazda and ROHM aim to materialize the concept and unveil a demonstration model within FY2025, with practical implementation targeted for FY2027.

www.rohm.com

Joining Advanced Magnetics for Power and Energy Development Consortium

ITG Electronics is partnering with the University of Pittsburgh Advanced Magnetics for Power and Energy Development (AMPED) Consortium. As a new research sponsor, ITG Electronics will support AMPED's mission to develop an expansive ecosystem and educational programs that drive advancements in soft magnetic materials and component technologies.

The AMPED Consortium, based at Pitt's Swanson School of Engineering, brings together industry leaders, academic institutions, and government agencies to address the pressing need for a next-generation, interdisciplinary workforce, as well as targeted research in magnetic devices such as transformers, inductors and electric vehicle motors. With global demand for efficient power solutions substantially rising, ITG Electronics recognizes the importance of investing in cutting-edge research and fostering collaboration across sectors.

"Joining AMPED exemplifies our commitment to pushing the boundaries of magnetic component innovation," said Martin Kuo, Managing Director at ITG Electronics. "By contributing to AMPED's research initiatives, we aim to accelerate the development of advanced magnetic solutions that will power the future of electrification and energy efficiency." AMPED's collaborative framework spans fundamental science to end-use applications; the organization works in tandem with various agencies, offices and programs to ensure real-world impact. Through this partnership, ITG Electronics will play a key role in shaping the future of power electronics and electromagnetics, helping to further technological breakthroughs in industries like renewable energy, electric vehicles and industrial automation.

www.ITG-Electronics.com

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Product Highlights from APEC 2025

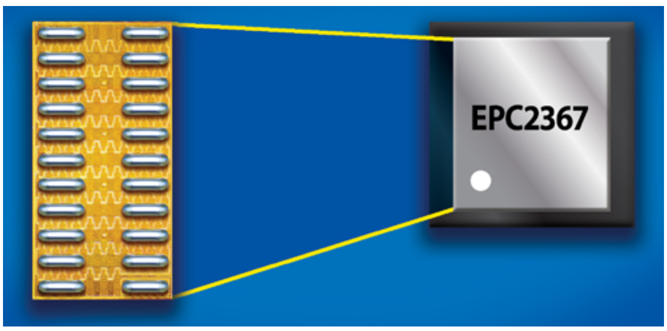
Some product news from APEC, which took place in Atlanta/Georgia (USA) from March 16-20, 2025: a lot of semiconductor solutions but also passive components and more.

By Alfred Vollmer, Editor-in-Chief, Bodo's Power Systems

APEC turned 40 this year and as Bodo and his team have done for several decades, our editorial team flew out to Atlanta to attend the event. Our calendars were fully packed with appointments, both on and off the show floor and, if we had not had our daily walk in the Georgia weather to and from the showground, we wouldn't have caught any sunlight at all! Holger and I had some great discussions, including new product announcements which we would like to share with you. And now, read on to discover the new product world of APEC 2025:

Infineon Technologies launched in Atlanta the next generation of high-density power modules which play a pivotal role in enabling AI and high-performance compute. The OptiMOS™ TDM2454xx quad-phase power modules are claimed to "enable best-in-class power density and total-cost-of-ownership (TCO) for AI data centers operators". The OptiMOS TDM2454xx quad-phase power modules enable true vertical power delivery (VPD) and offer a current density of 2 A/mm². In traditional horizontal power delivery systems, power needs to travel across the surface of the semiconductor wafer, which can result in higher resistance and significant power loss. Vertical power delivery minimizes the distance that power needs to travel, thereby reducing resistive losses enabling increased system performance. The OptiMOS TDM2454xx modules are a fusion of Infineon's OptiMOS 6 trench technology, chip-embedded package and low-profile magnetic design. Additionally, the OptiMOS TDM2454xx has a footprint that is designed to enable module tiling and improving current flow that enhance electrical, thermal and mechanical performance. The OptiMOS TDM2454xx modules support up to 280 A across four phases with an integrated embedded capacitor layer within a 10 mm² x 9 mm² form factor.

EPC introduced EPC2367 at APEC, a 100 V eGaN® FET with an $R_{DS(on)}$ of 1.2 mΩ for power conversion applications. Designed for 48 V intermediate voltage bus architectures, the EPC2367 advances the performance of power systems by reducing power loss, increasing efficiency, and enabling more compact and cost-effective designs. This device is claimed to "set a benchmark in performance



compared to both previous-generation GaN and traditional silicon MOSFET solutions”. Its footprint measures 3.3 mm × 3.3 mm (QFN package). According to EPC it also provides an “outstanding temperature cycling reliability”, which is said to be “4× the thermal cycling capability compared to previous GaN generations”. In a 1 MHz, 1.25 kW system, EPC2367 is said to reduce power losses while achieving 1.25× the output power compared to previous GaN and Si MOSFET alternatives. The EPC90164 development board (measuring 2” x 2” or 50.8 mm x 50.8 mm) is a half bridge featuring the EPC2367 GaN FET. It is designed for 80 V maximum operating voltage and 35 A maximum output current. The purpose of this board is to simplify the evaluation process of power systems designers to speed their product’s time to market.

Power Integrations has showed TinySwitch™-5 at APEC 2025, which extends the output power of the family of integrated off-line switcher ICs to 175 W. The TinySwitch-5 achieves up to 92 % efficiency using basic diode rectification and optocoupler feedback.

The control engine built into the TinySwitch-5 switcher ICs seamlessly manages switching frequency and power delivery to maximize efficiency, even at light loads. This enables power supplies that easily meet the light-load power consumption limit of 300 mW, set by the European Commission Energy-related Products (ErP) Directive 2009/125/EC, while still delivering up to 220 mW output power for display, controls and communications functions. An enhanced thermal package means that TinySwitch-5 ICs can deliver up to 75 W without a heatsink, and line under- and over-voltage protection ensures robustness for use in countries with unstable mains power. Reference designs are available for a 12 W single-output power supply, a 26.5 W dual-output power supply with high standby efficiency, a 36 W single-output power supply with high efficiency at light load and a 120 W power supply with 92 percent efficiency at 230 V AC.

Alpha and Omega Semiconductor released two surface mounting package options for its high power MOSFET portfolio. These GTPAK™ and GLPAK™ packages will first be available on AOS’

AOGT66909 and AOGL66901 MOSFETs, respectively. The GTPAK offered with the AOGT66909 is a topside cooling package designed with a large exposed pad for more efficient heat transfer. The topside cooling technology transfers most heat to the heat sink mounted on the top exposed pad. This feature allows the GTPAK to offer a more effective thermal dissipation route than going through the PCB board, allowing a lower-cost PCB, such as FR4, to be used. The GLPAK offered with the AOGL66901 is a gull-wing version of AOS’ TOLL package using AOS’ clip technology to achieve a high inrush current rating. The GTPAK and GLPAK packages feature gull-wing leads, enabling good solder joint reliability even for insulated metal substrates (IMS) applications.

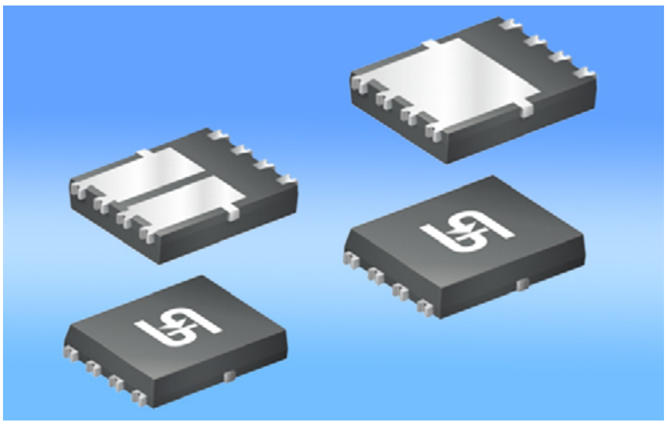
Microchip Technology launched its Electric Two-Wheeler (E2W) ecosystem in Atlanta, which is a suite of pre-validated reference designs that addresses key challenges in e-scooter and e-bike development, including power efficiency, system integration, safety and time-to-market. By offering automotive-grade, scalable solutions, Microchip enables manufacturers to build reliable electric two-wheelers at various power levels and feature requirements. Backed by design files, schematics, BOM (Bill of Materials) and global technical support, developers can decrease their time-to-market for the next-generation e-scooters and e-bikes. The E2W ecosystem comprises e. g. a BMS (Battery Management System) with intelligent power conversion and sensing and a 48 V to 12 V Power Conversion Reference Design as well as a 7.4 kW Single-Phase AC EV Charger Reference Design. A USB-PD Dual Charging Port is designed to provide fast, flexible charging for mobile devices. Furthermore, 350 W to 10 kW traction motor control reference cater for smooth acceleration, improved energy efficiency and precise control. Pre-integrated firmware and modular design simplify system development and reduce time-to-market. Several additional digital functionalities for system integration, smart vehicle control, intelligent touch displays and a connected user experience complement the ecosystem.

SemiQ gave the first official unveiling of the company’s 1700 V and 1200 V Gen 3 SiC MOSFETs at APEC 2025. SemiQ’s 1200 V Gen3 SiC was announced in February, delivering an improved performance with a smaller die size and at a lower cost. The series includes automotive qualified (AEC-Q101) options and Known Good Die (KGD) testing has been implemented across the series with verification at voltages exceeding 1400 V, plus avalanche testing to 800 mJ. Reliability is further improved through 100% gate-oxide burn-in screening and UIL testing of discrete packaged devices. The company’s 1700 V MOSFET family of MOSFETS and modules with AEC-Q101 certification is designed to meet the needs of medium-voltage high power conversion applications, from photovoltaic, wind inverters and energy storage to EV and roadside charging as well as uninterruptable power supplies, and induction heating/welding. These switching planar D-MOSFETs enable more compact system designs with higher power densities and have been tested to KGD beyond 1900 V, with UIL avalanche testing to 600 mJ.

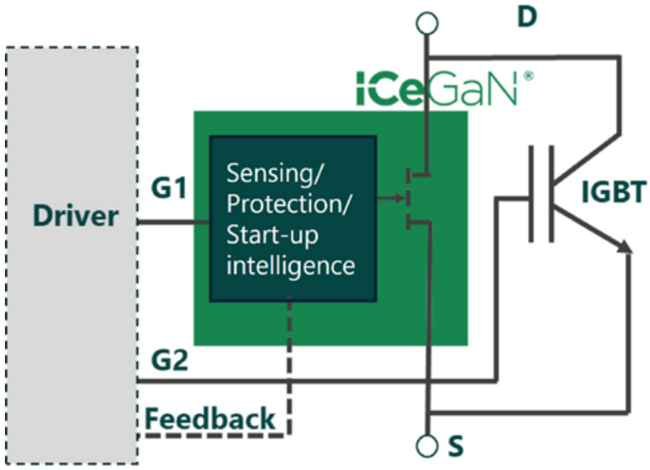
Navitas Semiconductor has announced at APEC 2025, that its portfolio of 3.2 kW, 4.5 kW, and 8.5 kW AI data center power supply unit

(PSU) designs exceed the new 80 PLUS 'Ruby' certification, focused on the highest level of efficiency for redundant server data center PSUs. The 80 PLUS certification program assesses and certifies the energy efficiency of internal PSUs in computers and servers. The 'Ruby' certification was announced in January 2025 by 80 PLUS's administrating body, CLEAResult, following its endorsement by the Green Grid consortium. 'Ruby' is the most rigorous PSU efficiency standard since the 'Titanium' certification was released 14 years ago. In comparison, Ruby sets an additional 1% system efficiency across all load conditions, except at 50% load (which requires a 0.5% increase), to achieve a new benchmark of 96.5% efficiency. At their APEC booth Navitas showed both its AI Power Roadmap and 80 PLUS Ruby-compliant demos.

Taiwan Semiconductor (TSC) has expanded its PerFET family of power MOSFETs with the addition of 80 V and 100 V versions. "Based on TSC's proprietary PerFET device structures and processes, these 80 V / 100 V N-channel power MOSFETs offer a best-in-class figure of merit (FOM: $R_{DS(on)}$* Q = 184) and an industry-leading 175 ºC avalanche rating", the company claims. The AEC-Q-qualified devices are suited for automotive power applications and other non-automotive commercial and industrial power applications. PerFET devices are housed in TSC-designed, industry-standard-size (5 mm x 6 mm) PDFN56U (single/dual) packages whose wettable flank improves solder joint reliability and AOI accuracy during PCB assembly. Six devices comprise the 100 V PerFET series, with single-output current ratings of 50 – 100 A and dual-outputs rated at 31 A. Target applications are 48 V automotive, SMPS, server and telecom, DC/DC converters, motor drives and polarity switches. The 80 V PerFET series also offers six devices. Single-output models feature current ratings of 33 – 110 A and 31 – 33 A for dual-output models. In addition to those targeted by the 100 V series, 80 V PerFETs are suitable for ideal diodes, USB-PD and type-C charger/adapters, UPS, solar inverters, LED lighting and telecommunications power applications.



Cambridge GaN Devices (CGD) revealed more details about a solution that will enable the company to address EV powertrain applications over 100 kW with its ICeGaN® gallium nitride (GaN) technology. Combo ICeGaN combines smart ICeGaN HEMT ICs and IGBTs in the same module or IPM, maximizing efficiency and offering a cost-effective alternative to expensive silicon carbide (SiC) solutions. The proprietary Combo ICeGaN approach uses the fact that ICeGaN and IGBT devices can be operated in a parallel architecture having similar drive voltage ranges (e. g. 0-20 V) and excellent gate robustness. In operation, the ICeGaN switch is claimed to be very efficient, with low conduction and low switching losses at relatively low currents (light load), while the IGBT is dominant at relatively high currents (towards full load or during surge conditions). Combo ICeGaN also benefits from the high saturation currents and the avalanche clamping capability of IGBTs and the efficient switching of ICeGaN. At higher temperatures, the bipolar component of the IGBT will start to conduct at lower on-state voltages, supplementing the loss of current in the ICeGaN. Conversely, at lower temperatures, ICeGaN will take more current. Sensing and protection functions are intelligently managed to optimally drive the Combo ICeGaN and enhance the Safe Operating Area (SOA) of both ICeGaN and IGBT devices. ICeGaN technology allows EV engineers to enjoy GaN's benefits in DC/DC converters, on-board chargers and potentially traction inverters. Proprietary parallel combinations of ICeGaN devices with SiC MOSFETs have also been proven by CGD, but Combo ICeGaN – which is now detailed in a published IEDM paper – is said to be "a far more economical solution". CGD expects to have working demos of Combo ICeGaN at the end of this year.



Pulsiv have won the PSMA's (Power Sources Manufacturers Association) first Global Energy Efficiency Award. The goal of the award is to recognize a "world achievement in system design to improve energy efficiency". During a ceremony at APEC 2025 in Atlanta, Georgia, USA, which coincided with the PSMA's 40th anniversary, Pulsiv were announced as the winner for their 65 W USB-C design, which delivers ultra-low operating temperatures and a peak efficiency of 96%. The judges evaluated finalists based on their total global im-

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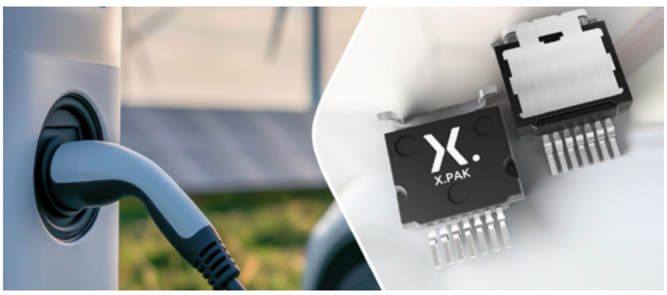
pact on the power electronics industry and where the focus was on energy efficiency, rather than renewables or electrification. David Chen, Chair of the PSMA's Energy Management Committee, commented: "The PSMA Energy Management Committee selected Pulsiv as the winner of our 2025 Global Energy Efficiency Award because its high-efficiency 65W USB Type-C reference design sets a benchmark for thermal performance and efficiency, while addressing the growing demand for fast-charging solutions in compact, heat-sensitive applications."

Empower Semiconductor showcased its scalable on-demand true vertical power architecture for artificial intelligence (AI) and high-performance computing (HPC) processors at APEC. Featuring Empower's proprietary FinFast™ technology, the Crescendo platform integrates all power components into a single thin device, enabling relocation beneath the processor and eliminating the requirement for large decoupling capacitor bank. "This shrinks the AI power supply by 5x and delivers on-demand kilowatt power with unmatched speed and accuracy while reducing power distribution losses by 5-20% from a traditional lateral current transmission", said Tim Philips, CEO and Founder of Empower. "Crescendo tackles one of the biggest hurdles in AI-driven data centers—how to deliver the increasing power demands of new processors with the efficiency, responsiveness, and compact footprint required." said Phillips.

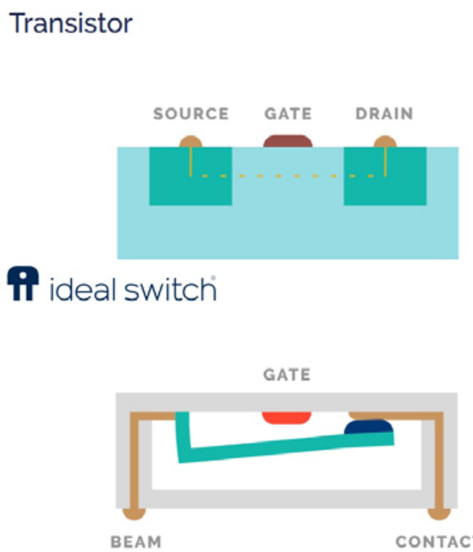
Renesas Electronics introduced all-in-one solutions for managing lithium-ion battery packs in a wide range of battery-powered consumer products, such as e-bikes, vacuum cleaners, robotics and drones. With pre-validated firmware provided, the R-BMS F (Ready Battery Management System with Fixed Firmware) will reduce the learning curve for developers, enabling rapid designs of safe, power-efficient battery management systems. Designed for lithium-ion batteries in both 2-4 and 3-10 cell series (S), R-BMS F solutions include Renesas' fuel gauge ICs (FGICs), an integrated microcontroller (MCU) and an analog battery front end, pre-programmed firmware, software, development tools and full documentation – all available in complete evaluation kits that are now ready to ship.

Nexperia showcased a range of industrial grade 1200 V SiC MOSFETs in a surface-mount top-side cooled packaging technology called X.PAK. This package, with a form factor of 14 mm x 18.5 mm, combines the assembly benefits of SMD with the cooling efficiency of through-hole technology, enabling better heat dissipation. The X.PAK package further enhances the thermal performance of Nexperia's SiC MOSFETs by reducing the negative impacts of heat dissipation via the PCB. Furthermore, Nexperia's X.PAK package enables low inductance for surface mount components and supports automated board assembly.



Texas Instruments (TI) debuted power-management chips to support data centers. The TPS1685 is claimed to be "the industry's first 48 V integrated hot-swap eFuse with power-path protection to support data center hardware and processing needs". The devices are rated for more than 6 kW. To simplify data center design, TI also introduced a family of integrated GaN power stages, the LMG3650R035, LMG3650R025and LMG3650R070, in industry-standard TOLL packaging.

Menlo Microsystems released to production the MM5230, a small form-factor, high performance RF switch. The MM5230 is engineered for high-power applications, supporting up to 25 W continuous and 150 W pulsed power. At the same time, its compact, 2.5 mm x 2.5 mm size means that the MM5230 can fit easily into a wide range of systems without taking up valuable board space. The switch operates seamlessly from DC to 18 GHz, and with its versatile Super-Port mode, extends to 26 GHz, making it well-suited for a wide variety of end applications. The contact design and materials, inherent in the Ideal Switch® technology, enable over 50 billion switching cycles typically. Being an RF device the insertion losses play an important role. With an on-state insertion loss of 0.3 dB at 6 GHz, the MM5230 minimizes signal degradation, which means that there is almost no loss in signal quality. With a typical IIP3 of 95 dBm, the MM5230 offers high linearity. The MM5230's Super-Port mode extends its frequency range from 18 to 26 GHz. The device fits for several high-demand industries, in application fields like defense and aerospace, test and measurement, medical equipment and wireless infrastructure.



Premier Magnetics showed the PM-CMCX5 Series, the first offering in the company's CM Guard Series™ of advanced-technology chokes. The CM Guard Series implements integrated magnetics technology to build common mode (CM) and differential mode (DM) attenuation into a single device. The PM-CMCX5 Series devices' performance features a strong winding-to-winding insulation of 5 kV, an operating temperature from -60 °C to +155 °C and low-

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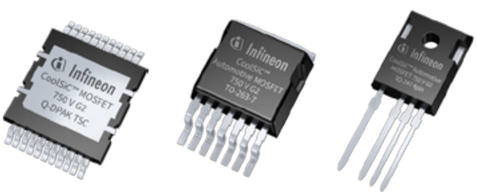
Target applications

- On-board chargers and HV-LV DC-DC converters
- eFuse and battery disconnect switches
- Automotive auxiliaries
- Solid-state relays and circuit breakers
- EV charging infrastructure
- Solar PV inverters and UPS
- Energy storage and battery formation
- Telecom and server SMPS



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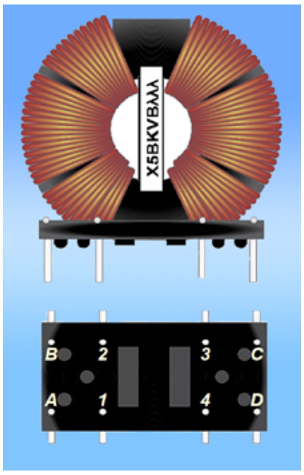
capacitive coupling to the core. The mechanical stability is achieved utilizing Premier Magnetics' proprietary Snap-In Technology to secure parts to the PCB without the use of epoxy during the assembly process. The PM-CMCX5 Series offers sixteen models with a selection of spread or compressed windings and common mode choke inductances from 0.5 to 30 mH.

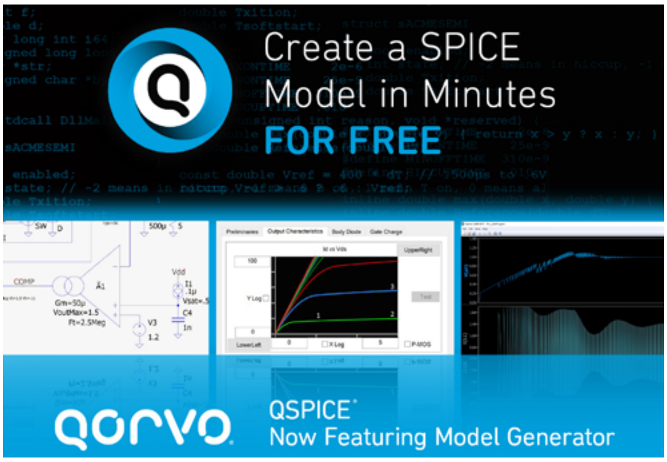


Danisense launched a Transducer Electronic Datasheet (TEDS) functionality at APEC which is suited for its range of current transducers to further streamline lab testing processes. For test engineers, the TEDS offers an enhanced set-up, making the whole processes very quick and easy. In addition, it improves the measurement accuracy in laboratory environments. With the introduction of its "augmented" TEDS, Danisense goes beyond the requirements of the IEEE 1451 standard by offering a wealth of additional data. While the IEEE standard only includes basic details such as transducer type, model, serial number, and turn ratio, Danisense's TEDS provides engineers with expanded parameters that are vital to improving overall performance and ensuring a seamless "Plug & Play" experience. The expanded parameters of Danisense's TEDS include offset data, as well as AC and DC calibration data, allowing engineers to implement compensation loops that enhance the transducer's overall accuracy and performance. Additionally, phase shift data is available, enabling the introduction of phase compensation strategies that extend accuracy over a broader frequency range. The company also incorporates power supply information within TEDS, setting power limits to avoid set-up errors and ensure precise calibration management by including calibration dates and alarms, so users can easily track and schedule regular calibration periods.

pSemi introduced a multi-level technology at APEC 2025, which is capable of fast battery charging in a low profile (<1 mm) application. The converter operates over an input range from 4.5 V to 18 V covering USB and wireless charging standards. In general, 4-level buck mode is enabled for higher input voltages, and 3-level buck mode for mid-to-low input voltages. Additionally, the device can be operated in fixed ratio, capacitor divider mode with divider ratios 2 and 3 when the input voltage is a programmable power source (PPS). Current delivery is up to 6 A per device, with the option to parallel devices to achieve faster charging times, in all operation modes using a 1 mm height inductor.

Advanced Energy Industries announced its Thyro-PX® Modular Solution, a fully configurable, distributed architecture that enables operators to build custom power control with liquid-cooled high-power stacks and external control units to meet their precise needs. The components are designed to meet the requirements of glass manufacturing, arc furnaces, rectifiers, and other high-current heating elements. Configuration options include separating control and power functions to minimize EMC issues. Thyro-PX's silicon-controlled rectifier (SCR) technology controls temperature and power. It offers precise phase angle control and improved efficiency, while reducing costs and CO_2 emissions compared to standard thyristors. Each Thyro-PX control unit can drive up to three high-power water-cooled Thyro-PX stacks. The Thyro-PX Modular Solution directly integrates with common field bus systems, achieving a current accuracy of 0.5%, with simple AC and DC configurations and a voltage range of up to 690 V_{AC} (750 V_{DC}), with 1,000 V_{AC} available on demand.

Qorvo showed an addition to its QSPICE circuit simulation software for the very first time in the US. Electronic designers can now create models for semiconductor components accurately, and in minutes instead of hours, using a tool included with the free QSPICE software package. This additional feature provides the capability to create circuit simulation models for discrete JFETs, MOSFETs and diodes using information commonly found in datasheets. Mike Engelhardt, the author of QSPICE, explained the modelling feature to the APEC visitors. In addition to analog simulation technology, QSPICE allows designers to simulate complex digital circuits and algorithms. Its combination of schematic capture and mixed-mode simulation make it a well-suited tool for solving increasingly complex hardware and software challenges.



ITECH's IT2806 High Precision source measure unit, which was shown in Atlanta, combines the capabilities of six devices in one (Voltage Source, Current Source, 6 ½ Digital Multimeter with DC-V, DC-I and R, Battery Simulator, Electronic Load and Pulse Generator). In the resistivity test, the IT2806 source measure unit can be switched to the constant current source mode, and the small voltage drop between the two middle probes can be measured at the same time as the output current The free PV2800 host computer software may be used to automatically obtain the results of resistivity measurements.

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PSMA

DC and Energy Stress Tests up to 4KV

Made in Italy proposal for high-power devices testing for automotive and energy storage sectors, for 5G and data centres

The Microtest Group launched the VIP ULTRA tester at the Applied Power Electronics Conference (APEC) 2025. VIP ULTRA, the new generation of Microtest's long-standing VIP Extended product, is the ATE (Automatic Test Equipment) designed for testing Wide Band Gap (WBG) devices made using compound semiconductors such as Silicon Carbide (SiC) and Gallium Nitride (GaN), which have proven to perform much better in power electronics requiring effective handling of high currents and voltages.

The devices made from WGB materials are gaining popularity, thanks to their greater energy efficiency, in the automotive and industrial sectors, especially in the development of technology for electric and hybrid vehicles, solar inverters, 5G infrastructures and data centres, which are increasingly required to support the computing demands of emerging AI (Artificial Intelligence) and ML (Machine Learning) applications.

Microtest has designed and developed the VIP ULTRA, a tester with enhanced operational flexibility, in response to the ever-increasing use of power electronics in the industrial sector. The VIP ULTRA offers various configurations, with resources capable of reaching voltages of 1.7KV (VIP ULTRA HV 1.7KV) or 4KV (VIP ULTRA HV 4KV) and currents up to 250A.

The VIP ULTRA stands as the only test platform on the market that can guarantee a complete set of tools for performing DC (Direct Current) and energy stress tests with extremely high parallelism (32 in the 1.7KV configuration and 16 with the 4KV). These innovative features make it particularly suitable for testing smart and high-power chips carried out at the silicon wafer level to ensure proper functionality of integrated devices before the cutting operation (chip dicing) required to isolate and subsequently assemble the integrated component itself.

"With VIP ULTRA, we are driving innovation in high-power device testing with a more efficient and market-advantageous test platform. An increasing number of applications, from the automotive sector to data centers, require electronic devices capable of efficiently handling high power levels. This demand also drives test platforms to evolve, supporting higher voltages while maximizing production capacity. Numerous private and governmental entities are investing in new factories, facilities, and research centers to develop new materials and technologies that address emerging industrial applications. While silicon was the dominant semiconductor a decade ago, it is now widely recognized that its combination with carbon enhances its suitability for modern market demands. With its extensive and solid expertise in the field, Microtest aims to meet the evolving market needs with its new VIP ULTRA tester. Microtest, with its long-standing expertise in the industry, is committed to addressing the challenges of a rapidly evolving market with the new VIP ULTRA tester," said Emiliano Consani, Head of the ATE Business Unit at Microtest Group.

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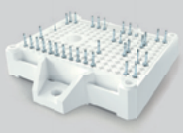

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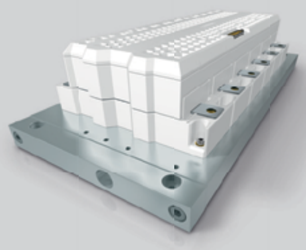

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Gen 4 Technology Platform delivers "Flexibility without Compromise"

When a new semiconductor technology is launched it normally comes with lots of promises and praises. However, design engineers need additional technical information beyond the mainstream marketing introduction. We have talked to Elif Balkas, who holds a Ph.D in materials science. She is CTO of Wolfspeed; here are her answers about the company's latest semiconductor generation:

By Alfred Vollmer, Editor-in-Chief, Bodo's Power Systems

Wolfspeed has launched its Generation 4 technology platform. What's new, what's special?

From its inception, the Gen 4 platform was designed to comprehensively improve system efficiency and prolong application life, even in the harshest of environments, while helping to reduce system cost and development time. And we intentionally focused on specific figures of merit and device performance specs to enable it. Let me give you a few examples.

We made significant improvements to holistic efficiency during the common switching behaviors. Our Gen 4 products improve conduction losses in hard and soft-switching applications. For example, systems such as traction inverters for EVs or industrial motor drives operate across a wide load range and spend a significant portion of its operating time at low power levels. Our Gen 4 platform helps to mitigate conduction losses with up 21% reduction in R_{sp} at operating temperatures. Reducing conduction losses improve efficiency across the load spectrum, translating to extended EV range, better energy ratings for HVAC systems, and lower cooling costs in server farms due to reduced heat dissipation requirements.

What about hard switching applications and durability?

Hard switching applications such as industrial motor drives, power supplies for AI data centers, and active front-end (AFE) converters for grid-connected systems will benefit from up to 15% lower switching losses. The reduction of switching losses offers two primary advantages. First, design engineers can increase switching frequency, enabling smaller, lighter systems. Alternatively, they can prioritize efficiency gains by reducing heat dissipation, lowering system-level costs through smaller heat sinks or reduced cooling requirements. These benefits are not mutually exclusive, giving engineers the flexibility to optimize designs based on their specific needs. These enhancements were made in parallel with the platform's 175 °C R_{DSON}.

Additionally, for system durability, we choose to focus on maximizing short circuit withstand time to give design engineers that extra safety margin. For some automotive applications, there is a need to push the system to its maximum and perform in overstress or overload conditions during a very limited time in its operation life. For those specific application use cases, we qualified our die products at 185 °C continuous operation and 200 °C limited life operation. The soft-body diode enables faster switching with less losses and ringing via a 27% reduction in V_{DS} overshoot. In addition, it also minimizes EMI during reverse recovery scenarios without trade-off to the recovery charge, streamlining the EMC Compliance process and allowing for smaller, lower cost EMI filters. And I would be amiss not to mention the improvements we've done to the cosmic ray immunity, that boasts up to 100X improvement in failure-in-time (FIT) rate compared to Wolfspeed Gen 3 devices.

Engineers are under permanent cost pressure...

...and we know this, of course. For us it is all about helping our customers to optimize systems cost by enabling to minimize the maintenance cost with more durable systems, shorten the production time and design cycles by moving to new architectures and platforms, and lower BoM by reducing the number of passive components.

Gen 4's ability to integrate a new soft body diode design significantly reduces EMI during reverse recovery, streamlining the process for EMI certification and allowing for smaller EMI filters. It's up-to 600 capacitances ratios allows for safer and cleaner switching at high dv/dt, without parasitic overshoots. Additionally, Gen 4 allows for up to 30% higher power output within the same footprint. In a practical example, a system engineer can reduce the count of SiC components by 30% in their design without any trade-offs to the system performance, which has a positive impact on system cost, weight and size.

What are the main target applications and markets of the Generation 4 platform?

The potential applications our Gen 4 platform can support are virtually endless. This technology will serve as the new foundation for Wolfspeed's long-term R&D roadmap of application-optimized power modules, discrete and bare-die solutions. It truly provides the flexibility for our customers to request products that prioritize performance benefits optimized for their specific application requirements, versus having to make tough tradeoffs based on the development platform limitations – whether you are working on power supplies for EVs, motor drives, energy storage, data centers for AI, or renewable energy applications. Currently our available portfolio of Gen 4-based parts consists of 24 individual part numbers varying in form-factor, voltage nodes and packaging options. Over the next year and a half Wolfspeed will be releasing Gen 4-based products across our entire portfolio including specifically optimized Gen 4 products for individual applications.

Are you already able to give us a first best practice example of a Gen 4 application?

Gladly. One example that right away comes to mind is EPC Power, a premier utility-scale inverter manufacturer. They have partnered with us to create the industry's first utility-scale string-style inverter that addresses a wide range of power and voltage levels. From the start of our work together, EPC Power has made it clear they wanted to create a new system that is low maintenance, easily serviced and mass produceable for rapid global deployment. I am going to touch on just one aspect of this successful partnership. The key to solve their design challenges was to utilize the newly released Gen 4 2300-V Wolfspeed Wolfpack™ modules in their new "M" inverters. The change has enabled the shift from a typical three-level architecture to a simplified 2-level power conversion system, reducing the driver count and control complexity. In addition, this solution significantly cut development time and cost by moving the system design from a legacy bus bar to lower cost PCBs.

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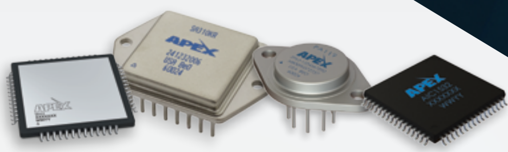

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Compact SiC Module for High Power Density On-Board Chargers

To achieve the goal of a carbon-free society, the electrification of mobility is of paramount importance. Lighter and more efficient electronic components play a major role in this process. On-board chargers (OBCs) are one example. How can compact transfer molded power modules meet the current requirements of OBCs?

By Imane Fouaide, Application Marketing Manager, and Christian Felgemacher, Senior Manager - Application Engineering, both ROHM Semiconductor

Development in the field of electromobility is progressing rapidly: electric powertrain systems are becoming ever more efficient and compact to increase vehicle autonomy and the range. An essential part of this development is the on-board charger (OBC), which must be highly efficient and at the same time have as little weight and volume as possible. This technical challenge must be addressed without exceeding cost limits.

The OBC is used for AC charging and requires a single-phase or three-phase voltage from the grid. With one phase, the charging power is limited between 3.6kW and 7.5kW, with three phases 11 kW to 22 kW are supported. The market currently relies on OBCs in the medium power range (11 kW) as a compromise between cost and efficiency. 22kW is mainly used in the premium segment. However, every OBC must also support single-phase charging to be able to charge the vehicle even at limited power. Increasingly, OBCs are also required to be bi-directional to enable vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) charging solutions.

Until now, the design of OBCs has been based on standard discrete devices from the market, in THD or SMD. Especially with SMD components, challenges arise as heat needs to be extracted through the PCB or by carefully attaching each individual package with suitable thermal interface material to a heatsink. With this approach, the development towards higher power density and the associated system compactness is reaching its limits. Power modules are showing promising advantages for new product generations.

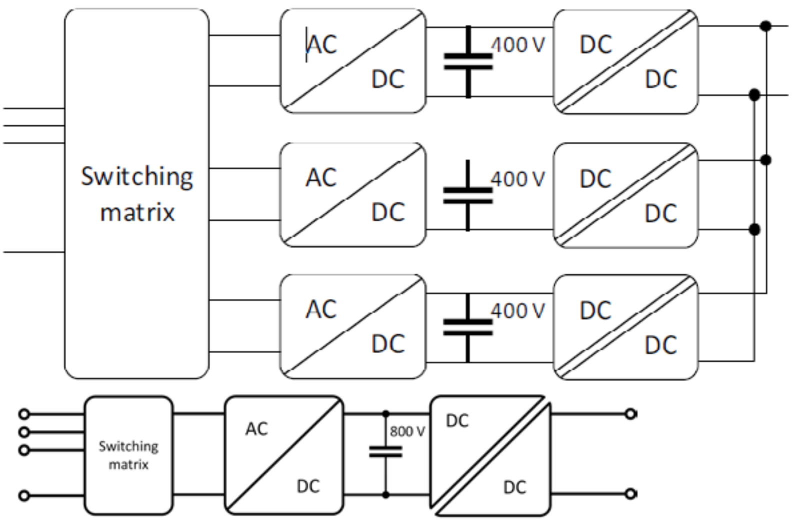

Figure 1: Modular (top) and centralized (bottom) architecture for OBCs.

Architecture and topologies

There are basically two main architectures for OBCs (Figure 1): The modular architecture is based on three identical single-phase blocks. In contrast, the centralized architecture is based on a three-phase AC/DC converter, which is also capable of single-phase operation. Both architectures can be realized with unidirectional as well as bidirectional topologies.

The modular architecture requires more components and leads to higher overall DC link requirements in terms of stored energy content and thus volume and cost. Also, the modular architecture results in additional need for gate drivers and voltage / current sensing. In comparison, the centralized architecture allows for more cost-efficient OBCs, as fewer components are required. The centralized solution is the first choice for OBC solutions with high power density.

SiC modules for higher efficiency and power density

Due to its excellent characteristics, SiC is ideally suited as material for power semiconductors in OBCs. ROHM's 4th Generation SiC MOSFET based on a trench structure offers very low on-state resistance. In addition, the extremely low Miller capacitance enables very fast switching which leads to reduced switching losses. Together, this reduces the overall losses, which in turn leads to reduced constraints on the thermal dissipation.

ROHM now extends the portfolio of SiC MOSFETs in the EcoSiC lineup with the new HSDIP20 modules, which are optimized for OBC applications. These modules integrate four or six SiC MOSFETs in a full bridge circuit. Compared to discrete components with the same chip technology, the modules offer several advantages.

The modules include Aluminum Nitride (AlN) ceramic to isolate the cooling pad from the drains of the MOSFETs. This results in a very low thermal resistance (Rth) between junction and case and eliminates the need for a TIM material that realizes electrical isolation between the cooling pad and the heatsink.

Thanks to the mold material, the various dies in the power module are electrically isolated from each other. This means that the chips can be placed much closer together than would be the case with discrete devices, where the creepage path on the PCB must be considered. This reduces the PCB footprint and increases the power density of the OBC solution.

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Less work at less risk

In addition to the technical advantages, the internal isolation facilitates the developer's work: In the module, the functionality of the electrical insulation is handled within the module. For solutions with discrete components, the isolation needs to be externally addressed. The modules are tested by ROHM before delivery, so no further isolations tests are needed during the OBC development phase. The modules thus reduce time and development costs and at the same time reduce the risk of isolations issues.

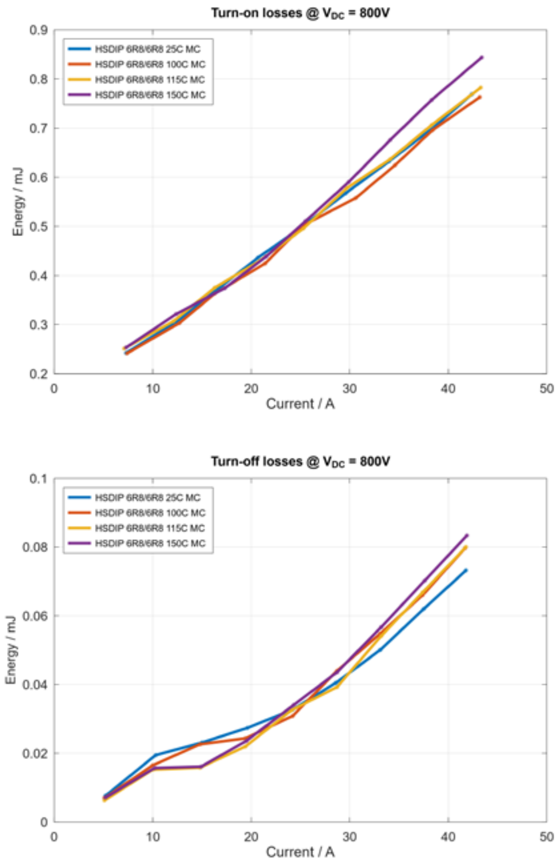


Figure 2: Turn-on and turn-off losses of the HSDIP Modules for different temperatures at a DC Link voltage of 800V.

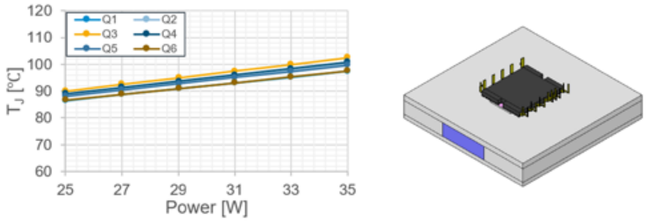


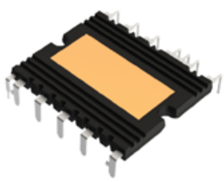
Figure 4: Simulation results of the thermal performance of the HSDIP modules.

The HSDIP20 modules also benefit from the additional advantages of the Gen 4 SiC MOSFETs: The 0V turn-off voltage reduces the complexity and costs of the PCB layout. As Figure 2 illustrates, the low switching losses of the Gen 4 SiC MOSFETs measured in HSDIP modules a DC link voltage of 800V for different temperatures.

Another advantage is the scalability: ROHM offers a broad lineup of $R_{DS(on)}$ values and topologies so that the modules can be used for different OBC power ranges. Six modules in 4-in-1-topology and six modules in 6-in-1-topology are available. In addition, a "hybrid" module in six-pack topology is available, which combines MOSFETs with different $R_{DS(on)}$ as a low-cost solution for totem pole PFC circuits to easily enable single-phase and three-phase operation with the same device. The modules are available in the same package regardless of the topology so that applications can be easily scaled. All power modules are qualified according to AQG324.

Thermal and switching characteristics

To illustrate the advantages of the HSDIP modules, the devices were characterized with simulations and measurements. The thermal performance of the modules is demonstrated using the six-pack module with 36mΩ, 1200V SiC MOSFETs. The simulation of a single module on a liquid cooled cold plate was carried out under the assumptions of 25 to 35W loss per chip, Ta=Tw=60 °C, TIM with a thickness of 20um and a thermal conductivity of 4.1W/mK. The power was injected simultaneously in the chips and then dissipated power vs. T_j of each device were plotted from the simulation (Figure 3).

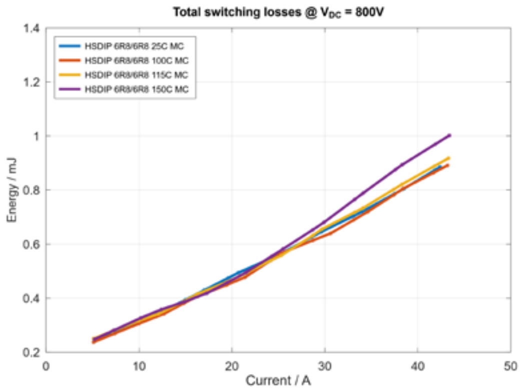
Part No.	Absolute Max. Ratings (Tj=25°C)			Topology	Module Package
	V_{DSS} [V]	$R_{DS(on)}$ [mΩ]	I_D [A]*1		
New BST91B1P4K01	750	13	90	4in1	 HSDIP20 [38.0mm × 31.3mm × 3.5mm]
New BST47B1P4K01		26	47		
New BST31B1P4K01		45	31		
New BST91T1P4K01		13	90	6in1	
New BST47T1P4K01		26	47		
New BST31T1P4K01		45	31		
New BST70B2P4K01	1,200	18	70	4in1	
New BST38B2P4K01		36	38		
New BST25B2P4K01		62	25		
New BST70T2P4K01		18	70	6in1	
New BST38T2P4K01		36	38		
New BST25T2P4K01		62	25		
New BST70M2P4K01*2		18*3 / 36*4	70*3 / 38*4		

*1: T_c=25°C V_{GS}=18V *2: Combines chips with different ON resistances
*3: Q1, Q4 pins *4: Q2, Q3, Q5, Q6 pins

Figure 3: HSDIP20 power module lineup based on 4G SiC MOSFET

With an optimized inner structure, the power module brings an advantage in thermal performances by keeping a very low thermal resistance per chip. The maximum junction temperature remains way below the 175 °C allowed for SiC MOSFETs, giving more room for increasing power density to address high power OBC requirements.

The switching loss behavior of the 6 in 1 module with 36mW, 1200V SiC MOSFETs was evaluated in a test board, that represents the AC/DC stage in an OBC application. The switching loss obtained in that measurement was already shown in Figure 2. The results of the evaluation of the switching losses by double pulse tests of this module also apply to the case of a bidirectional DC/AC stage considered here. Based on this data, a simulation of a bidirectional



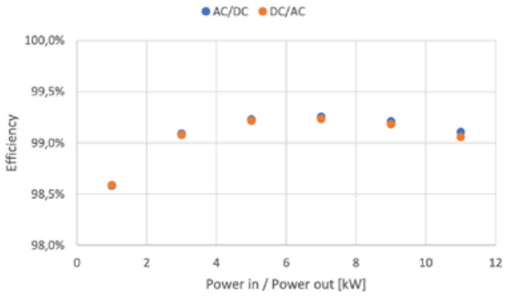


Figure 4: Simulation of the efficiency of the HSDIP modules in a bidirectional AC/DC stage of an OBC.

AC/DC stage for an 11 kW system was performed (Figure 4). The simulation results predict that an 11 kW AC/DC stage based on a 6 in 1 module with fourth generation SiC MOSFETs (36mΩ, 1200V) has an efficiency of about 99% at a switching frequency of 48 kHz and using a heat sink with forced air cooling. Only the semiconductor losses are considered.

Conclusion

Modules consisting of four or six SiC MOSFETs offer major advantages over individual devices when used in on-board chargers for electric and hybrid vehicles. Due to the higher power density, they enable a reduction in the size and weight of the OBC and lower the complexity of the design. ROHM's HSDIP20 modules integrate the latest EcoSiC MOSFETs. In simulations, they show excellent thermal characteristics and 99% efficiency when used in the AC/DC stage of a bidirectional OBC.

References

[1] M. Jankovic, C. Felgemacher, K. Lenz, A. Mashaly and A. Charkaoui, "Cost and efficiency considerations in On-board Chargers," 2022 24th European Conference on Power Electronics and Applications (EPE'22 ECCE Europe), Hanover, Germany, 2022, pp. P.1-P.9.

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Revolutionizing power electronics: GaN bidirectional switches

1 switch. 2 ways. Endless possibilities

Power electronics have evolved tremendously over the past decades, transforming how we generate, distribute, and consume electrical energy. In this energy chain, traditional unidirectional switches (UDS) have long been the backbone of power conversion systems, offering reliable performance for countless applications. These switches have served the industry well, enabling the development of increasingly efficient power management solutions. However, they come with inherent limitations that have persistently challenged design engineers in their quest for more compact, efficient, and cost-effective systems. This is where Infineon's bidirectional GaN switch comes into the play, changing the narrative.

By Natascia De Patre, Manager, Product Marketing, High-Voltage GaN, and Dr. Kennith Kin Leong, Lead Principal, Product Definition and Concept Engineer, High-Voltage GaN Bidirectional Switch, both Infineon Technologies

The limitations of traditional approaches

For years, engineers have grappled with the fundamental constraints of unidirectional switches. When bidirectional voltage blocking is required, designers must implement back-to-back configurations using multiple discrete components, leading to increased system complexity, larger footprints, and higher costs. These arrangements also introduce additional parasitic elements that compromise switching performance and efficiency. Furthermore, traditional three-terminal UDS devices lack the flexibility to control current flow in both directions independently, limiting their applicability in advanced power conversion topologies.

These challenges have become increasingly significant as the industry pushes toward higher power density, greater efficiency, and reduced system costs. The conventional approach of using back-to-back discrete switches in applications such as Vienna rectifiers, T-type converters, and HERIC configurations results in suboptimal designs that fall short of meeting evolving market demands. This has created a pressing need for innovative solutions that can overcome these fundamental limitations while delivering enhanced performance across a wide range of operating conditions.

Introducing the CoolGaN™ Bidirectional Switch (BDS) family

To address these challenges, Infineon has pioneered a groundbreaking solution: CoolGaN™ Bidirectional Switch (BDS) 650 V G5. This innovative device family represents a paradigm shift in power switch technology, offering unprecedented control and flexibility for next-generation power conversion systems. Unlike conventional approaches that require multiple discrete components arranged in back-to-back configurations, it provides a monolithic solution capable of actively blocking voltage and current in both directions.

Infineon's CoolGaN Bidirectional Switch portfolio caters to a wide range of voltage requirements. With the 650 V portfolio housed in TOLT and DSO packages, and 850 V options available soon, the company also offers lower voltage options, starting from 40 V. These lower voltage GaN switches are used in consumer electronics, where they serve as battery disconnect switches.

CoolGaN BDS 650 V G5 features a revolutionary common drain design with a double gate structure, leveraging Infineon's proven rugged Gate Injection Transistor (GIT) technology. This unique architecture enables the use of the same drift region to block voltages in both directions, resulting in a significantly reduced die size compared to conventional back-to-back arrangements. The compact, integrated design not only saves space but also minimizes parasitic elements, enabling faster switching speeds and improved efficiency.

Technical innovation: four-quadrant operation

What truly sets the high-voltage CoolGaN BDS family apart is its unprecedented four-quadrant control capability. Unlike traditional three-terminal unidirectional switches, the BDS features four active terminals plus an additional substrate terminal. This configuration enables four distinct modes of operation: two traditional ON/OFF modes and two diode modes, providing designers with an unprecedented level of control flexibility.

In the bidirectional OFF mode (switch mode OFF), the device blocks voltage in both directions when zero or negative voltage is applied to both gates, effectively functioning as an open circuit. Conversely, in the bidirectional ON mode (switch mode ON), current can flow freely in both directions when both gates are activated, similar to a standard MOSFET in the on-state. These modes alone provide significant advantages over conventional solutions, but the true innovation lies in the two additional diode modes.

The diode modes—reverse blocking (RB) and forward blocking (FB)—allow the BDS to selectively block voltage in one direction while permitting current flow in the opposite direction. In diode mode RB, the device blocks voltage from bottom to top but allows current flow from top to bottom. Conversely, in diode mode FB, it blocks voltage from top to bottom while allowing current to flow from bottom to top.

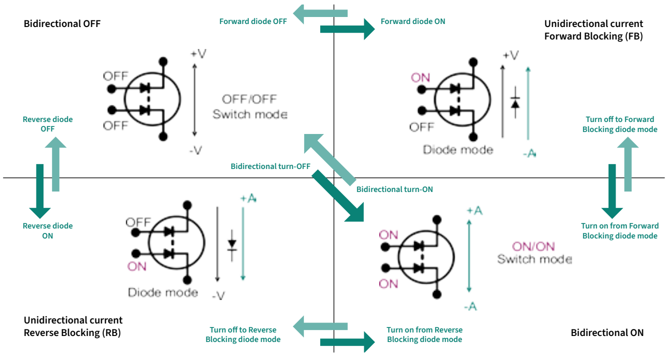

Figure 1: The four modes of operation and ten possible transitions of the CoolGaN™ Bidirectional Switch 650 V G5, highlighting its unique capabilities and flexibility

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These modes are particularly valuable for soft-switching operations where the voltage blocking direction is known, ensuring safe discharge of output capacitance and optimal performance.

Engineering excellence: integrated substrate voltage control
A significant technical challenge in designing CoolGaN BDS was managing the substrate voltage. In traditional UDS designs, the substrate is typically tied to the source to prevent back-gate effects that reduce 2DEG (two-dimensional electron gas) charge concentration. However, the common drain configuration of the BDS, with its two sources, made this approach impractical. Simply floating the substrate would lead to uncontrolled potential and detrimental back-gate effects.

To overcome this challenge, Infineon developed an innovative monolithically integrated substrate voltage control circuit. This ingenious solution dynamically connects the substrate to the source with the lowest potential, ensuring optimal performance without requiring external support circuitry. This integrated approach enables the BDS to operate effectively in both soft and hard switching modes, adapting to various application requirements for optimal performance and efficiency.

Performance characteristics: data-driven excellence
CoolGaN BDS demonstrates exceptional performance across a wide range of operating conditions. One of the key parameters for evaluating its performance is the source-to-source resistance ($R_{ss(on)}$), which directly impacts conduction losses and overall efficiency. The static $R_{ss(on)}$ approximately doubles as the temperature varies from 25°C to 150°C (Figure 2), highlighting the importance of temperature considerations in system design. Notably, unlike some SiC MOSFETs that may exhibit a negative temperature coefficient at low temperatures, CoolGaN BDS maintains a positive coefficient even down to -40°C, ensuring reliable operation across its entire temperature range.

Adjusting the steady-state gate current can optimize $R_{ss(on)}$ by up to 3%, improving performance at the cost of higher gate current loss. Additionally, increased gate current can boost saturation current by 60% or more, balancing efficiency and performance in system design.

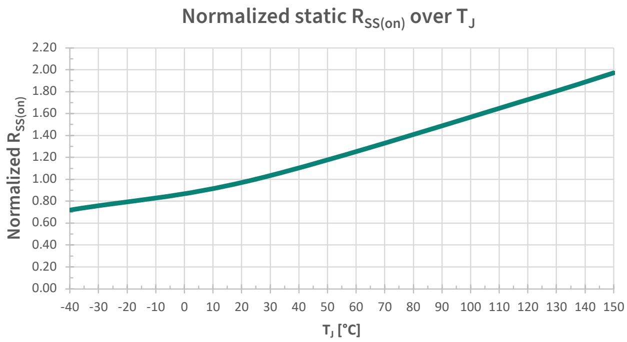

Figure 2: Normalized Rss(on) value of the CoolGaN BDS across the entire operational temperatures

Dynamic $R_{ss(on)}$ provides a realistic measure of the performance of CoolGaN BDS during continuous switching, influenced by blocking voltages, switching frequencies, and temperature. A modified self-compensated double diode drop On-state Voltage Measurement Circuit (OVMC) was used in a boost converter setup with the BDS as the low-side switch and a high-side SiC Schottky diode in Continuous Conduction Mode (CCM).

At 50 kHz and 100 kHz hard switching, dynamic $R_{ss(on)}$ remained close to its static value, with only a 5-7% increase. Higher frequencies increased dynamic $R_{ss(on)}$ due to shorter measurement periods. Temperature also affected dynamic $R_{ss(on)}$, but CoolGaN BDS showed stable performance across typical conditions, ensuring predictable behavior in end applications. This stability highlights

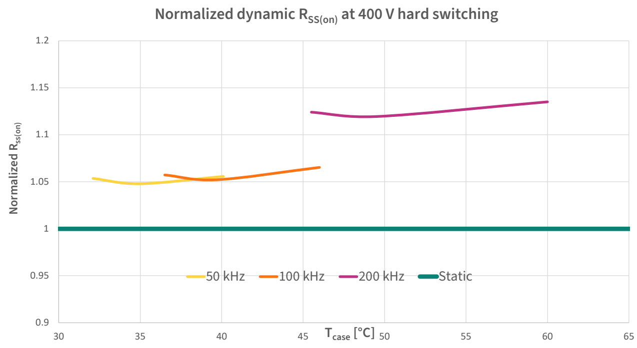

Figure 3: Normalized dynamic $R_{ss(on)}$ with different switching frequencies over case temperatures

the device's robust design, making it suitable for high-frequency and thermally demanding environments.

The soft-switching performance is even more impressive, as depicted in Figure 4. At 110 V, 500 kHz, the dynamic $R_{ss(on)}$ is approximately 5% higher than the static value, while at 400 V, it rises by roughly 16.5%. This variation with AC grid voltage suggests that using the AC voltage as an average value across the cycle is a practical approach for system design optimization. Moreover, even as switching frequencies increase from 100 kHz to 300 kHz, the normalized dynamic $R_{ss(on)}$ rises only marginally to 1.06 or by just 6% (see Figure 5), highlighting the benefits of soft switching in minimizing the impact of frequency on performance.

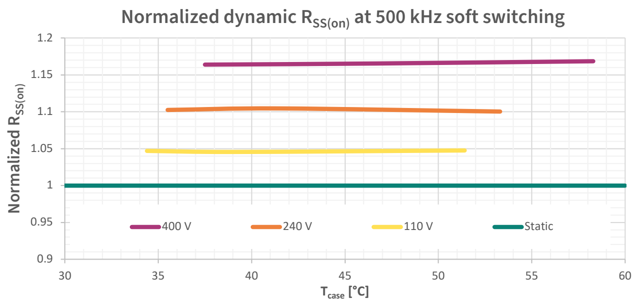

Figure 4: Normalized dynamic $R_{ss(on)}$ with different blocking voltages at 500 kHz over case temperatures

Figure 5 shows the normalized dynamic $R_{ss(on)}$ for CoolGaN BDS under soft switching at 400 V against case temperatures. At 100 kHz, dynamic $R_{ss(on)}$ is approximately at 1 with static value and rises slightly with frequency, reaching only 1.06 at 300 kHz. This minimal increase highlights the benefits of soft switching in minimizing frequency impact and enhancing efficiency.

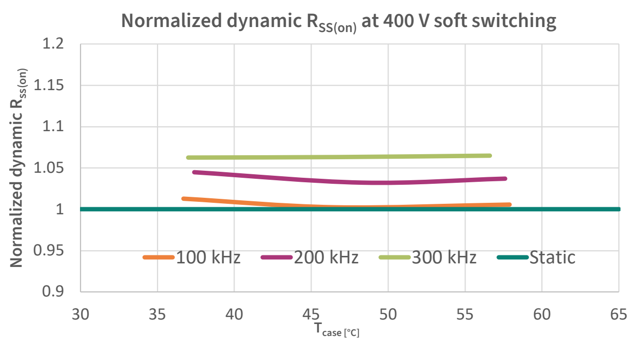

Figure 5: Normalized dynamic $R_{ss(on)}$ with different switching frequencies at 400 V input over case temperatures

Switching losses: precision measurements
Accurately determining switching losses is crucial for evaluating the efficiency of wide-bandgap devices like CoolGaN BDS. Currently, there is no known method to accurately separate turn-on and

turn-off losses for the BDS. While soft-switching losses are very low, turn-on losses are not zero due to contributions from the substrate voltage control circuit and C_{OSS} hysteresis losses. Consequently, all switching losses are expressed as switching loss per cycle in microjoules, encompassing both turn-on and turn-off losses.

For hard-switching measurements (Figure 6), a boost setup operating in Continuous Conduction Mode (CCM) was employed, with conduction losses deducted from calibrated thermal losses. Testing at 500 kHz revealed losses scaling proportionally with turn-off current and input voltage.

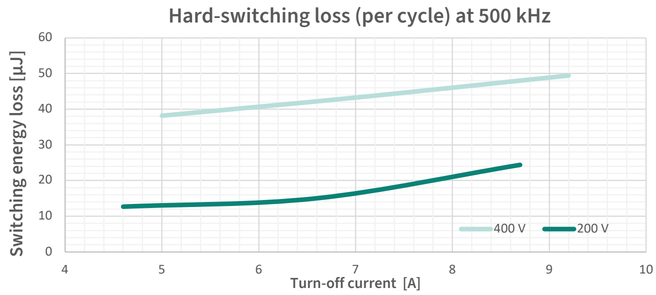

Figure 6: Hard-switching losses per cycle for CoolGaN® BDS 650 V G5 (IGLT65R055B2) at 500 kHz at two different input voltages

Soft-switching evaluations (Figure 7) used a half-bridge configuration in triangular current mode across three voltage levels (110 V, 240 V, and 400 V), demonstrating significantly reduced losses compared to hard switching. This comprehensive per-cycle data enables designers to accurately predict thermal requirements and optimize efficiency in practical applications, despite the inability to isolate individual switching events.

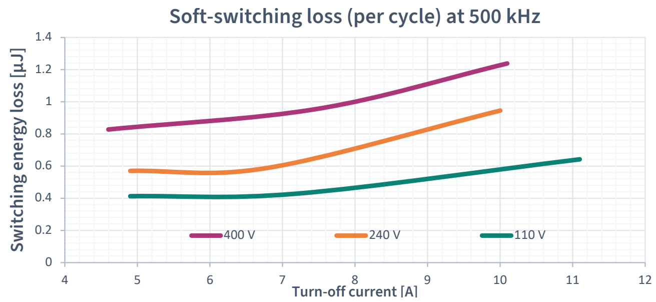

Figure 7: Soft-switching losses per cycle for CoolGaN BDS 650 V G5 (IGLT65R055B2) at 500 kHz at three different input voltages

Design considerations: BDS vs. back-to-back (B2B) comparison
When evaluating CoolGaN BDS, it is essential to compare them against traditional back-to-back (B2B) configurations and not against a single UDS.

CoolGaN BDS demonstrates a superior Figure of Merit (FoM) compared to Si and SiC B2B configurations, offering over 85% lower $R_{ss(on)} \times Q_G$. This results in significantly lower energy losses per cycle, making it ideal for high-frequency applications.

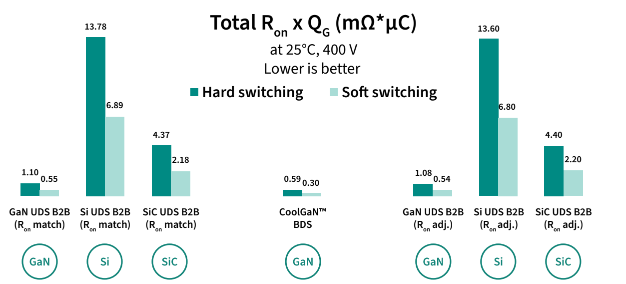

Figure 8: FOM comparison of BDS and B2B configurations by technologies

Gate driving and supplies
CoolGaN BDS is a common drain device featuring two gates controlled in reference to its own source, each with its own kelvin-source terminal for the return path of the gate drives. This BDS uses the GIT technology, which requires an RC interface for each gate to control the turn-on and steady-state gate current gate.

A key benefit of the RC interface is its ability to generate a natural negative gate voltage during turn-off, a recommended practice for all discrete GaN switches. For the BDS, each gate requires its own isolated gate driver as well as an isolated auxiliary supply. Although the total number of auxiliary supplies depends on the specific circuit topology, some nodes can share a common supply.

Gate driving
Infineon offers a comprehensive portfolio of EiceDRIVER™ Gate Driver ICs with a variety of isolation levels, voltage classes, protection features and packages. The ICs are available in single channel configurations, as shown in Table 1.

Product code	Isolation type	Configuration
1EDB7275F	Basic	Single channel
2EDB7259Y	Basic	Dual channel
2EDR7259X	Reinforced	Dual channel

Table 1: EiceDRIVER™ Gate Driver ICs

These driver ICs form the optimal combination with CoolGaN BDS to achieve high efficiency, robustness, and power density in high performance applications. Visit www.infineon.com/gatedrivers for more information about EiceDRIVER product families and available evaluation boards.

Isolated auxiliary supply
Creating an isolated auxiliary supply for CoolGaN BDS can be achieved through various methods, each with its own trade-offs. The straightforward approach of small, isolated DC/DC modules is a costly option. A more cost-effective alternative is to design an isolated auxiliary supply directly on the PCB using pulse transformers.

Although this may consume more PCB space, this pulse transformer approach reduces the costs of an isolated auxiliary supply while providing a high degree of flexibility and customization. By leveraging the 1EDN7512G driver IC and a pulse transformer, designers can create a compact and efficient isolated auxiliary supply that meets the specific needs of their application.

Transforming applications: Practical benefits
CoolGaN BDS is poised to revolutionize a wide range of applications, offering significant advantages over conventional solutions. One of the most immediate benefits is the ability to replace back-to-back discrete switches in existing designs. In applications such as Vienna rectifiers, T-type converters, and HERIC configurations, the BDS provides a more integrated, efficient, and cost-effective solution.

Perhaps even more exciting is the potential to enable single-stage DC/AC conversion in solar micro-inverters and other single-stage isolated topologies. By allowing bidirectional voltage blocking in a single device, the BDS simplifies circuit designs, reduces component count, and enhances efficiency. This leads to more compact, cost-effective solutions that are quicker to bring to market, providing a competitive edge in today's fast-paced industry.

The single-stage isolated AC power conversion application demonstrates several key advantages: improved efficiency through fewer conversion stages, reduced sizes, and lower costs with the use of high-frequency transformers. Additionally, it also shows enhanced flexibility enabling voltage scaling, frequency conversion, and natural bidirectional power flow. While challenges such as switching losses, EMI, control complexity, and component stress must be addressed, CoolGaN BDS provides the foundation for overcoming these obstacles and developing next-generation power conversion systems.

Conclusion: Pushing the boundaries of power electronics

CoolGaN BDS 650 V G5 represents a significant leap forward in power switch technology, addressing long-standing challenges and opening new possibilities for power conversion system design. By integrating bidirectional blocking and conduction capabilities into a single monolithic device, it reduces component count, simplifies design, and enhances performance across a wide range of applications.

The innovative four-mode operation, combined with the integrated substrate voltage control circuit, provides unprecedented flexibility and control for next-generation power systems. The exceptional performance characteristics, meticulously quantified through advanced measurement techniques, enable designers to accurately predict and optimize system behavior in real-world applications.

As the power electronics industry continues to push for higher efficiency, greater power density, and reduced costs, CoolGaN BDS stands as a testament to Infineon's commitment to innovation and engineering excellence. By challenging conventional approaches and developing groundbreaking solutions, Infineon is not just addressing today's design challenges but also laying the foundation for tomorrow's power conversion systems.

For design engineers looking to stay at the forefront of power electronics technology, CoolGaN BDS offers a compelling solution that combines technical innovation with practical benefits. Whether you are designing solar inverters, power supplies, motor drives, or other power conversion systems, this revolutionary technology provides the tools you need to create more efficient, compact, and cost-effective products that meet the demands of today's market while preparing for the challenges of tomorrow.

Voltage class, product generation, and package type				
$R_{SS(on)}$ typ. (mΩ)	40 V G3 WLB	650 V G5 TOLT	650 V G5 DSO	850 V G5 DSO
110		IGLT65R110B2		
55		IGLT65R055B2		IGOT85R055B3*
35		IGLT65R035B3	IGOT65R035B3	IGOT85R035B3*
25			IGOT65R025B3	IGOT85R025B3*
15			IGOT65R015B3*	IGOT85R015B3*
6	IGK080B041S			

Figure 9: CoolGaN Bidirectional Switch (BDS) 2025 portfolio;
** indicates products in the roadmap*

Discover more about CoolGaN BDS 650 V G5 on www.infineon.com/gan-bds-hv and see how this cutting-edge solution can revolutionize your next project. The future of bidirectional switches is here, and it is CoolGaN BDS.

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Increasing Power Density using Low Voltage eGaN FETs in High-Voltage Sever Power Supplies – Part 2: The Multi-Level Totem-Pole PFC converter

By Michael de Rooij, Alejandro Pozo, Marco Palma, Andrea Nicotera, Francesco Musumeci, all Efficient Power Conversion, and Carlo Lombardi and Andreas Reiter, both Microchip

Introduction

In part one of this series, we gave a brief introduction to the multi-level totem-pole PFC topology and how it can improve power density in server applications. In this second part we dive deeper into the design details of such a solution and present experimental results for a 240 VAC input to 400 V_{DC} output, 5 kW PFC system.

Figure 1 shows the block of the PFC converter that comprises an input EMI filter that includes an in-rush current limiting circuit, the main PFC converter stage and output bulk capacitor bank.

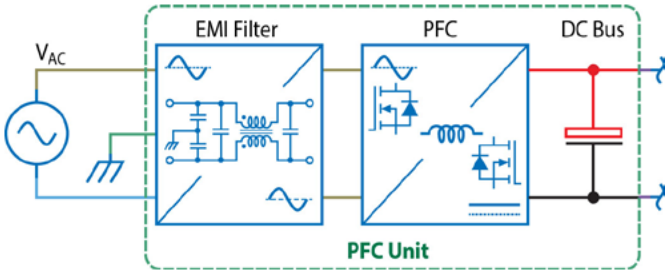

Figure 1: Block diagram of the PFC converter.

Design Overview

The ORV3 standard [1] constrains and drives the physical design because a power supply solution needs to fit within a window of 40 mm height and 70 mm width, and length up to 630 mm. One end of the unit is assigned to the grid input and the opposite end, the DC output.

The first step in the design is to identify the largest components, so that the layout of the solution can be planned, which in this design are the output bulk capacitors. Their choice is critical to meet both electrical specifications and mechanical fit. It is also preferable to limit the number of assembly steps, which will keep production costs low. In this design, short, vertical, mountable capacitors were chosen that do not require lead bending or vertical mounting interface boards. A total of five capacitors, each with a diameter of 30 mm and a height of 35 mm, are required.

The second design consideration is the EMI filter. This is a critical part of the design and must be allocated in an electromagnetically "quiet" zone for it to work effectively. It is inherently located at the front end of the converter and can therefore share space with the bulk capacitors, which are considered electromagnetically quiet.

The last large circuit in the design is the converter stage, which will inherently be in the output zone. This part of the design is where some creativity may be employed to fit the circuit within the remaining area and volume.

In addition to allocating circuit and function zones, the design must also determine paths for cooling. There are two main options for cooling, which are 1) forced air through the length of the unit and 2) side wall cooling, primarily relying on heat-spreading using the enclosure. This forces some larger semiconductors to the outside of the board for easy access to the side walls.

Experimental System.

A 5 kW experimental unit was designed, built, and tested as shown in Figure 2. The assembly comprises four boards: a) A mother board with EMI filter, bulk capacitors, in-rush limiting circuit, and housekeeping power supply, b) a multi-level GaN Card, c) a flying capacitor and control interface card, and d) a controller card (dsPIC33CK from Microchip).

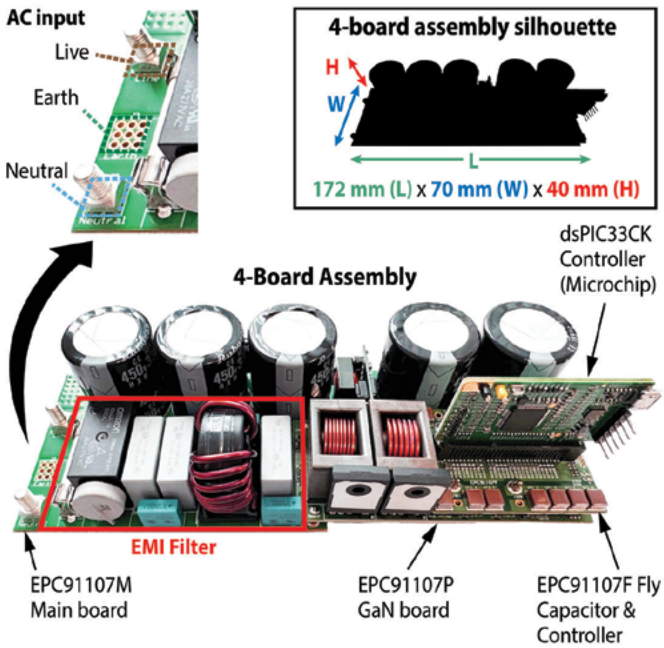

Figure 2: Photo of the 5 kW Multi-level Totem-pole converter EPC91107KIT assembly.

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The 240 V_{AC_RMS}, 50/60 Hz grid is connected on the left side of the board and the 400 V_{DC} load on the right side of the board (not visible in figure 2). The core of the design is the multi-level GaN card. It is the most complex part of the board and includes both the high and low frequency bridges. Figure 3 shows the details of the GaN card with specific circuits and components highlighted. The choice of high switching frequency GaN FET is the 200 V rated, 3.5 mΩ typical R_{DSon}, EPC2304 [2]. Micro-sized isolation power supplies [3] were selected to power the gate drivers, and together with single isolated gate drivers, significantly reduced the complexity and operation of this design.

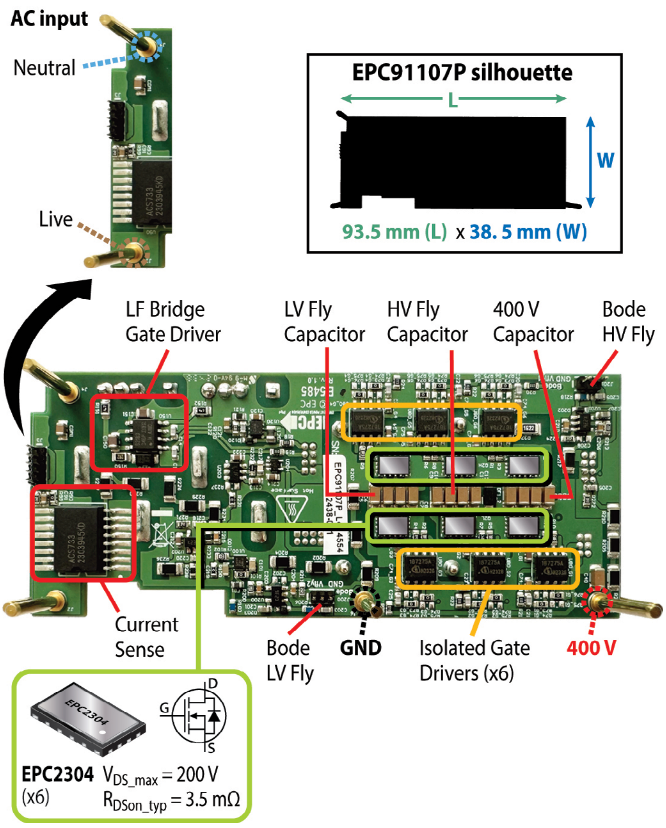

Figure 3: Photo of the multi-level GaN Card with various components and circuits highlighted.

The GaN card measures just 92.5 mm by 38.5 mm and includes all the required measurement feedback circuits to operate the converter.

The 4-level converter requires only a total PFC inductance of 13.8 µH to achieve the same ripple current as a 2-level converter with a PFC inductance of 130 µH. This low inductance enables the use of standard off-the-shelf inductors. For this design, the PFC inductor was split into two distinct inductors of 7.5 µH and 6.2 µH, respectively [4], and chosen for their smallest total footprint. The inductors have different self-resonant frequencies (SRF) of 29 MHz and 25 MHz, respectively, which is sufficient to ensure that high dv/dt's from the switch cannot easily pass to the input, where the EMI filter would need to attenuate them.

The low PFC inductance results in a higher current loop response, requiring a high-frequency bandwidth current sensor. In this design, an isolated, 1 MHz bandwidth, hall effect current sensor was chosen [5].

Controller Overview

The control of a multi-level totem-pole PFC is essentially the same as that of a traditional 2-level configuration with some minor differences. Figure 4 illustrates the overall control block diagram, which comprises an outer voltage control loop, an inner current control loop, and a grid frequency phase-locked loop (PLL). The PLL locks onto the grid by detecting the zero voltage crossings and generates a sinusoidal reference that is used in both the voltage and current control loops.

The outer voltage control loop determines the error between the setpoint and the operating point, which is fed into a compensator to determine the current magnitude reference. The voltage controller further includes a zero-order-hold (ZOH) function with the primary purpose of holding the determined current setting at a fixed value for the subsequent grid cycle, which ensures zero distortion of the current reference during the grid period. The current magnitude setting is then multiplied by a sinusoidal reference to yield the AC current reference.

Similarly, the current control loop determines the error between the AC current reference and the measured current that is fed into the current compensator to determine the duty cycle reference for the system. To ensure fast response and minimal phase error, the sinusoidal reference is scaled to the measured grid voltage and fed into a feed-forward functional block that estimates the operating duty cycle. This calculated duty cycle is summed with the current compensator output, and thus the current controller now only needs to determine the small deviations from the setpoint.

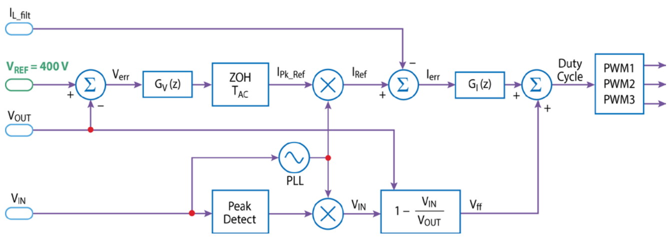

Figure 4: Controller block diagram for the multi-level PFC converter.

The 4-level converter inherently self-balances the voltages on the flying capacitors because the PFC inductor current is continuous [6] so there is no need to add an active flying capacitor voltage balancer controller. Due to the inherent nature of the PFC controller that operates with a fixed reference over an entire cycle, this inures under load transients too.

Experimental Results

The experimental unit shown in Figure 2 was tested and the measured waveforms of the AC input voltage, inductor current, DC output voltage, and switch-node with respect to neutral are shown in Figure 5 with the converter operating from 240 V_{AC_RMS} and delivering 5.03 kW into a 400 V_{DC} load. The waveforms clearly show that the flying capacitors are operating at their respective levels, and the inductor current is essentially following the grid voltage. The experimental system was sourced using a programmable AC source hence the near perfect sinusoidal input voltage.

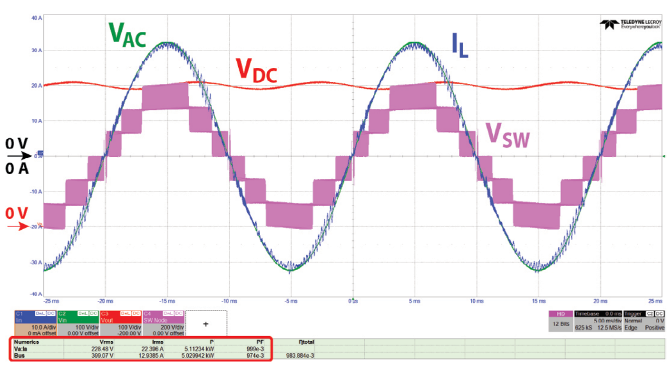

Figure 5: Waveforms with the converter operating with V_{in} = 240 V_{AC_RMS}, V_{out} = 400 V_{DC}, P_{out} = 5.03 kW.

Due to the low inductance of the PFC inductance, the controller requires higher precision in the PLL to determine the zero-crossing point of the grid voltage. This is necessary to ensure minimal current spikes around the zero crossing that can lead to unnecessary losses.

Figure 6 shows the efficiency and current Total Harmonic Distortion (iTHD) results of the PFC converter operating from 240 V_{AC_RMS} and with 400 V_{DC} load. The efficiency exceeds 98% from 60% to 100% load. Similarly, the iTHD is below 5% from 40% to 100% load power.

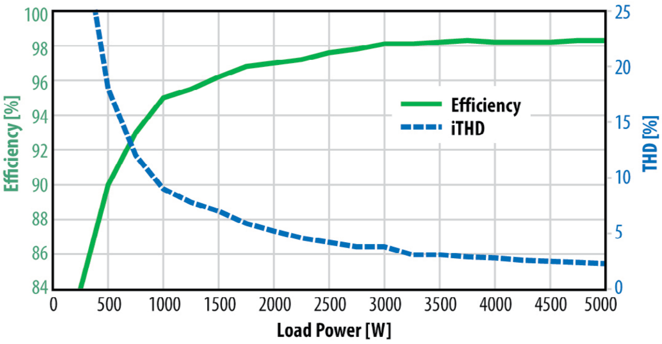

Figure 6: Efficiency and iTHD results with V_{in} = 240 V_{AC_RMS}, V_{out} = 400 V_{DC}, operation.

Conclusions

This article presented a 5 kW 4-level PFC converter that employs 200 V-rated EPC2304 GaN FETs, resulting in a high-power-density, low-cost, and high-efficiency solution. Experimental results demonstrate the performance achieved by the solution without the use of any special techniques or hardware, where the efficiency exceeded 98% above 60% load and the iTHD was below 5% above 40% load.

In the next and final part, we'll go into the details of the cascade isolation converter.

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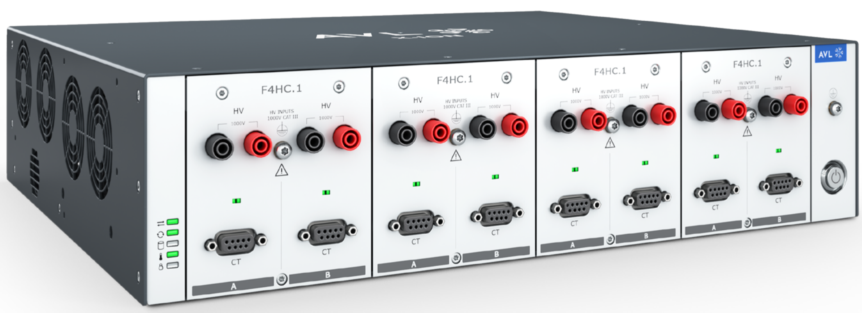

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Web Simulation: Broadening Access to Power Electronics Modeling

Browser-based simulation tools for power electronics offer advantages over traditional desktop software. They eliminate installation requirements while providing powerful simulation capabilities accessible to anyone with a web browser. Engineers or lecturers can easily share existing models through interactive online courses. The web platform also serves as an effective channel for creating interactive demonstrations to showcase and market power electronics semiconductors.

By Lukáš Meduna, Plexim GmbH, Switzerland

Introduction

The development of power electronics systems and devices begins with system-level simulation and rapid prototyping, making power electronics simulation tools like PLECS useful for modern workflows. Electrical engineers refine their models through multiple iterations before reaching the final design. However, sharing these models interactively outside of the development group with non-technical colleagues might be a hurdle, as it usually involves installation of necessary simulation software for every involved person. The new PLECS Web-Based Simulation 2.0 (PLECS WBS) offers a simple way of transforming an existing PLECS model into a fully functional online simulation platform accessible through any browser and on any device.

Figure 1: Example of web simulation showing identical model running on desktop and mobile devices

Interactive teaching courses

Interactive power electronics simulations are more commonly an important part of complex power electronics studies. They bridge the gap between abstract theory and complex equations on one side and physical experiments on the other.

Through interactive simulations, students and researchers can manipulate simulation parameters and as shown in Figure 2, observe and interact with the resulting waveforms. This hands-on approach helps students develop an intuitive understanding of converter operations, control strategies, and system stability. For example, students can immediately see how changing duty cycle affects output voltage in the buck converter topology.

Complex transient behaviors or fault conditions that are hard to observe in a physical setup can also be simulated directly within the online course. Students can safely explore scenarios like load transients or component thermal profile without risk to equipment. Based on the design stage or test case, advanced analysis tools such as AC sweep, Impulse Response, or Multitone Analysis can be employed to characterize power electronic systems.

The lecturer can reuse existing PLECS models and create online simulations, each targeting specific course topics. This allows students to focus on core concepts rather than technicalities such as software installation and manipulation. PLECS WBS can be embedded directly into existing e-learning applications, making the experience seamless for users across different devices and platforms.

The direct engagement with power electronics development can lead to increased interest and participation in the subject matter.

Semiconductor online test benches

Determining optimal parts is an important aspect of the prototyping phase in power module development. Approximating semiconductor performance, efficiency, and thermal characteristics from manufacturers' data sheets presents a tedious challenge.

By embedding interactive simulations on their websites, manufacturers allow engineers and potential customers to explore component functionalities in real-time, improving customer experience and effectiveness. Customers can select from common topologies for different converter types (AC-DC, DC-DC, DC-AC) and customize circuit properties such as Input/Output Voltage or Rated Power according to their application. They can then place devices within the recommended operating range into individual slots on the selected topology and simulate under varying conditions based on their needs. Comprehensive simulation results, including junction temperature, efficiency, and turn-on/off losses, can help customers select optimal semiconductors.

Figure 2: PLECS WBS scope

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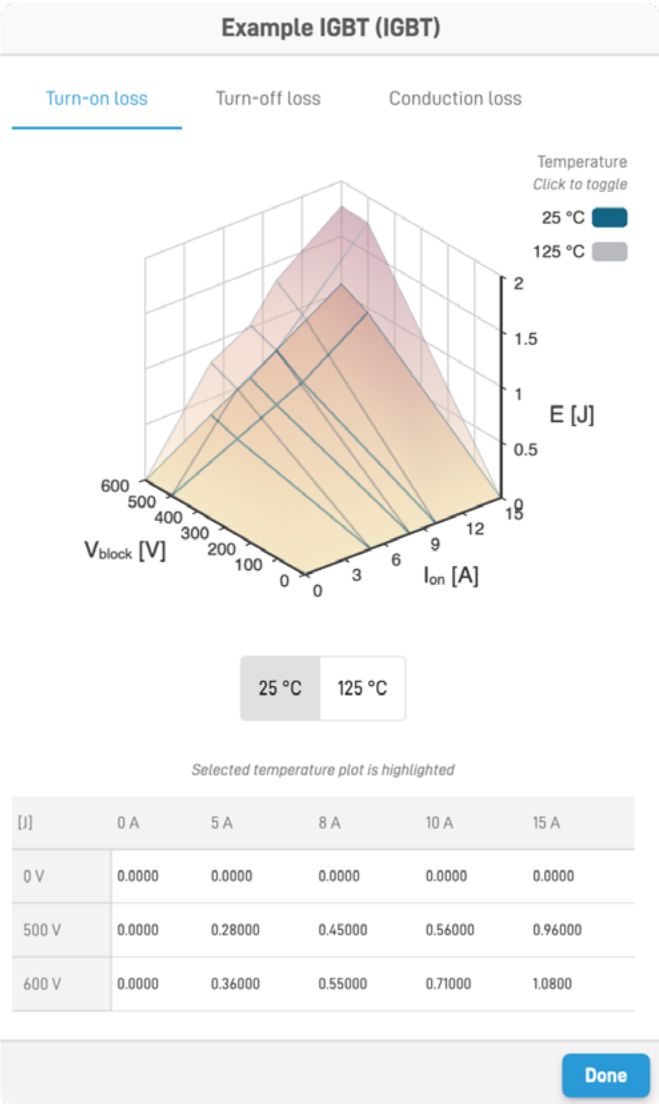
This concept can even be expanded to mission profile testing. Because PLECS WBS uses PLECS simulation capabilities, the web simulation can be part of a broader toolchain during development, facilitating precise assessments of semiconductor performance. Manufacturers' thermal descriptions and semiconductor models can be later used both in PLECS offline simulation or even in hardware-in-the loop real-time simulations using RT Box.

The complete capabilities of PLECS at your fingertips on a web page
PLECS WBS operates in conjunction with a headless PLECS server. This implementation leverages the complete PLECS computational engine rather than a simplified browser alternative, preserving the advanced solver technology, comprehensive component libraries, and detailed thermal simulation capabilities that power electronics professionals require. The architecture ensures server-side execution of computationally intensive processes while maintaining PLECS's numerical robustness and speed. PLECS WBS users receive identical simulation results to those provided by the desktop application, with no compromise in model complexity, accuracy, or performance that would otherwise be introduced by browser-based limitations.

Simulation parameters can be presented to and set by the visitor in multiple ways, either embedded in a schematic or as a separate comprehensive table. Special focus is placed on thermal simulation, where users can upload and preview thermal description files, as shown in Figure 3. Many well-established semiconductor manufacturers already provide thermal models of their parts.



[J]	0 A	5 A	8 A	10 A	15 A
0 V	0.0000	0.0000	0.0000	0.0000	0.0000
500 V	0.0000	0.28000	0.45000	0.56000	0.96000
600 V	0.0000	0.36000	0.55000	0.71000	1.0800

Figure 3: Turn-on losses of an example IGBT

Simulation results can be displayed in custom-defined result tables, with out-of-range values automatically highlighted. The waveform can be observed in interactive scopes. Simulation parameters can also be exported and shared, enabling easily replicable simulations.

From a model to a Web-Based Simulation in just a few steps
Developing a complex power electronics model, such as the one shown in Figure 1, is a non-trivial task. Creating a separate copy of the model specifically for web simulation from scratch would require significant effort. Therefore, each web simulation is defined by two key components:

the PLECS Model and the WBS Design, where the WBS Design file defines the interactions between the web simulation and the actual PLECS model.

In the previous version, PLECS WBS 1.0, the WBS Design file had to be written by hand as a JSON file. This was especially demanding for complex models, where just one syntax error could result in a non-working web-based simulation. Additionally, to view and test the WBS Design, a local web server had to be installed and set up separately.

With the introduction of the Web-Based Simulation Designer in PLECS 4.9, both the design process and local testing have been streamlined and simplified. The WBS Designer offers an intuitive interface for creating WBS Designs, as shown in Figure 4., thus eliminating the need for manual writing. It is also a convenient tool to preview and test any WBS Design without requiring additional software.

The WBS Designer is launched from and communicates directly with PLECS Standalone. Any existing PLECS model can be opened, and its corresponding WBS Design can be created. The WBS Design creation process begins with the root schematic of the PLECS model, allowing the engineer to dynamically add components from the PLECS model into the WBS Design. With complete access to the PLECS model, the WBS Designer offers an easy way for seamlessly selecting scopes, schematics, and other components to incorporate into the web simulation.

Conclusion
PLECS Web-Based Simulation provides a simple and effective way to make power electronics simulations more accessible to a wider audience. Visitors can run interactive simulations anywhere without needing to install any software.

WBS Designer is available with a PLECS Standalone license. The web simulation can be evaluated in demo mode using the same PLECS Standalone license. Afterwards, the PLECS WBS license can be purchased to remove the demo limitations and unlock full functionality. Embedding PLECS WBS into any existing website is effortless, including matching the host site's design.

PLECS WBS presents a valuable extension to your existing PLECS workflow. Learn more and try it out yourself at our website.

Figure 4: Detailed view of the WBS Designer interface with its corresponding PLECS model

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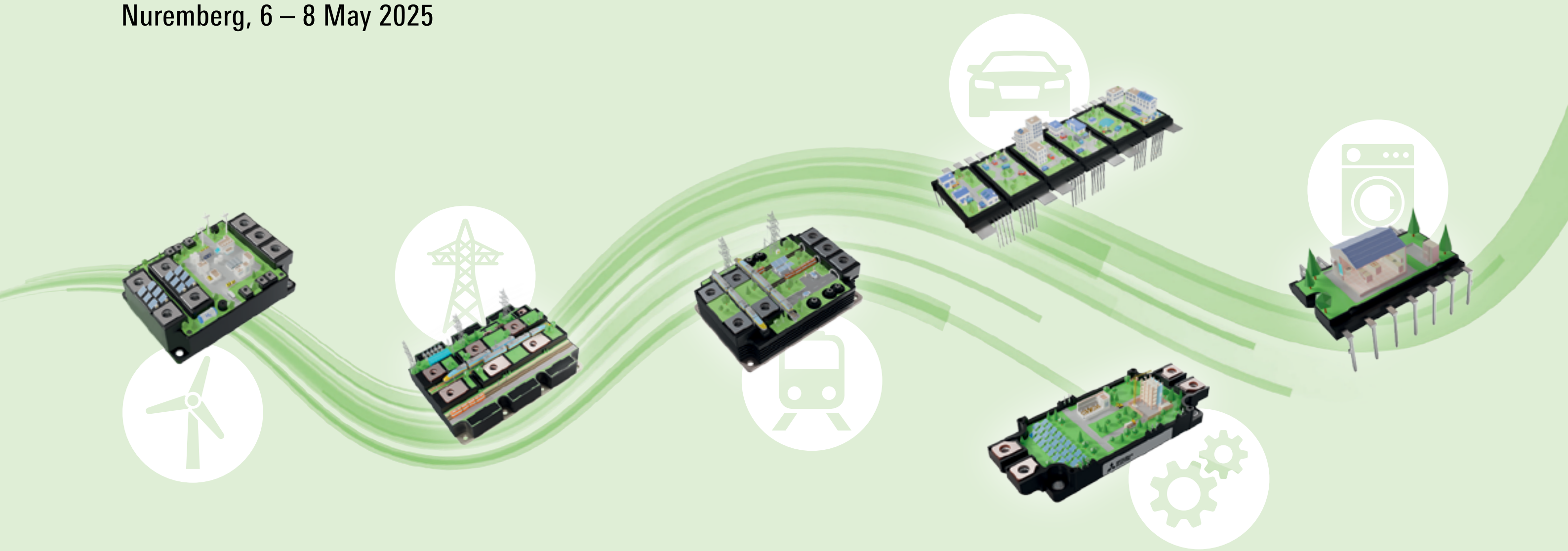

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Traction Inverter Functional Safety Design with SiC-Based Auxiliary Power Supply

The design and implementation of a low-power auxiliary power supply within traction inverters are critical for ensuring the functional safety of electric vehicles. SiC MOSFETs can play a critical role in flyback converters used to convert a high-voltage DC input to low-voltage DC outputs. How does such a system look like?

By Ehab Tarmoom, Applications Engineering Manager High-Power Solutions Business Unit, Microchip Technology

In traction inverters, a low-power auxiliary power supply, typically a flyback converter, plays a crucial role in converting the 400 V or 800 V High-Voltage DC (HVDC) input to a Low-Voltage DC (LVDC) output. This auxiliary power supply serves as a backup during fault conditions, ensuring the electric drive system remains in a safe state by mitigating risks to vehicle occupants from hazardous conditions due to faults in the electric machine or traction inverter electronics.

Traction Inverter Functional Safety

Maintaining vehicle controllability is paramount from a safety perspective. Faults that impede a driver's ability to control the vehicle are identified in the ISO 26262 Functional Safety (FuSa) Hazard Analysis and Risk Assessment (HARA). Several safety goals derived from the HARA are related to torque, such as preventing unexpected abrupt changes in torque or deviations from the commanded torque. Inverters are designed to seamlessly transition the electric drive system to a safe state upon detection of a non-recoverable fault.

One critical fault is the loss of the HVDC and 12 V power inputs. A blown fuse can result in the loss of 12 V to the main contactors that feed HVDC from the high-voltage battery to the traction inverter, as well as loss of 12 V to the inverter itself. Maintaining control of the electric machine during these conditions is crucial from a functional safety standpoint.

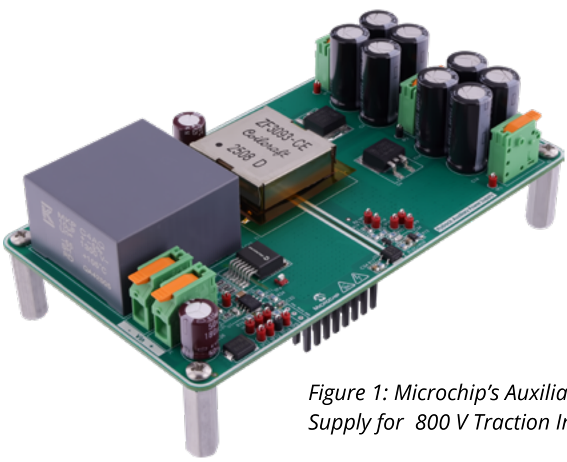

Figure 1: Microchip's Auxiliary Power Supply for 800 V Traction Inverters.

A common solution is to include a backup power supply in the inverter design that converts HVDC to a low-voltage supply, powering the inverter's control, sensing and gate drive circuits in the event of a loss of the 12 V input. This power supply is typically a flyback converter. In 800 V systems, silicon carbide (SiC) MOSFETs are used for their higher breakdown voltage rating compared to silicon MOSFETs. An 800 V system generally has a maximum continuous bus voltage in the 920-960 V range and a load dump voltage of 1000 V. Considering the reflected voltage and overshoot in a flyback converter, the voltage across the MOSFET's drain-to-source can easily exceed 1200 V.

Figure 1 illustrates Microchip's Auxiliary Power Supply for 800 V Traction Inverters, featuring an automotive-qualified mSiC™ MOSFET in a D2PAK-7L XL package with a 1400 V continuous and 1700 V repetitive voltage rating.

Looking deeper into the safety requirements, you will quickly determine that a typical 800 V flyback converter isn't sufficient in this application. To maintain operation in the event of a loss of 12 V to both the inverter and to the main contactors, the backup power supply requirements become more stringent to ensure safe vehicle operation.

Consider an electric machine. It operates as a motor when it converts electricity to mechanical energy and as a generator when it converts mechanical energy to electricity. Specifically, when the torque and angular velocity are in the same rotational direction, the electric machine functions as a motor delivering power to the mechanical system for vehicle propulsion. When the torque and angular velocity are in opposite directions, the electric machine functions as a generator. When the torque and angular velocity are of opposite rotational directions, the electric machine's voltage and current are of opposite polarity. During regenerative braking, the electric machine operates as a generator, with the AC current flowing into the inverter for rectification into DC current to charge the high-voltage battery.

Electric Drive System Safe States

At the start of a fault condition where the inverter is no longer connected to the high-voltage battery, its internal DC-link capacitor and the capacitance of other high-voltage electronics systems on the bus are initially charged to the high-voltage battery voltage. The inverter quickly detects the loss of power and transitions the electric drive system into a safe state. This involves shorting the electric machine's three-phase windings, commonly referred to as Active Short-Circuit (ASC) or "three-phase short," or maintaining an open-circuit, also referred to as "six-switch open." The safe state to transition to depends on a few factors, including the rotational speed of the electric machine and HVDC battery voltage.

During an open-circuit, the inverter monitors the electric machine's speed to estimate the back-electromotive force (BEMF), which is based on the electric machine's speed constant. The inverter's power switches remain in the off-state if the amplitude of the BEMF is lower than the HVDC battery voltage. This ensures the BEMF isn't rectified and used to charge the HVDC battery in an uncontrolled manner. With no current to charge or power the HVDC system, there is no electric power consumption from the electric machine and, more importantly, no fluctuations in torque that affect a driver's controllability of the vehicle.

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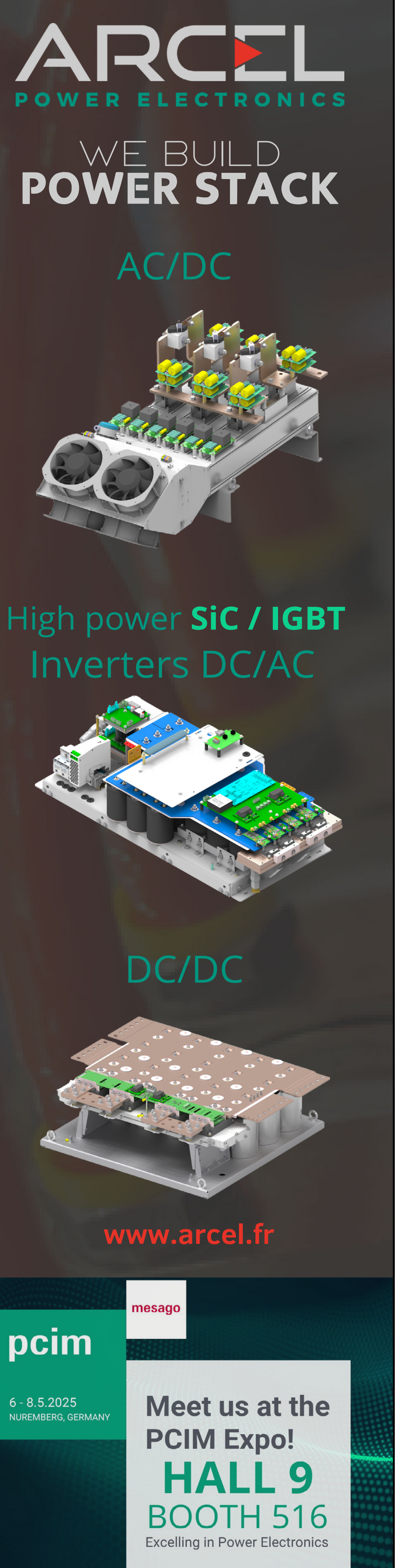

While in the open-circuit state, the HVDC bus voltage gradually decreases. If the electric machine speed increases causing an excessive BEMF, the inverter maintains ASC by driving the upper three, or the lower three, power semiconductor switches to the on-state, assuming a six-switch two-level inverter stage topology. The windings are shorted together during ASC to achieve ideally no electrical or mechanical power losses. In practice this is a stressful condition for both the inverter power devices and the electric machine. In this condition, since the windings are shorted together, the phase voltages are not rectified. Meanwhile, the HVDC bus voltage continues to decrease.

The duration of fault conditions varies from seconds to several minutes. It's imperative that the electric machine is maintained in the appropriate safe state, including during transient conditions requiring rapid transitions between the safe states. Suppose an electric machine spins at a low speed resulting in a low BEMF, the HVDC bus voltage will decrease to a low voltage, well below the input voltage range of a typical auxiliary power supply. With the lack of 12 V from the vehicle low-voltage system and HVDC supply, the inverter loses its ability to control its own power stage and the electric machine. During this scenario, a sudden increase in the electric machine speed results in a high BEMF that not only results in torque impacting the vehicle but also voltages that can potentially stress and damage the inverter active power devices and passive components. Consequently, the auxiliary power supply and control electronics design must have either a startup time faster than the electric machine's response time to speed changes or with a wide input voltage range to ensure it remains operational at extreme HVDC voltages. The latter is typically implemented in practice.

Auxiliary Power Supply Solution

The wide input voltage range is the key requirement of the auxiliary power supply in the traction inverter design for compliance with FuSa requirements. It is also the most challenging technical hurdle to overcome in the flyback converter's design. Microchip's Auxiliary Power Supply for 800 V Traction Inverters has a 45 W power rating and continuous operating voltage range of 40 V to 1000 V. The reference design enables customers to accelerate their traction inverter development, reducing time to market. Featuring dual outputs, the design provides a positive voltage supply to feed control, sensing and gate drive power circuits and a negative supply to power sensing circuits, such as a resolver driver for position sensing of the electric machine's rotor. The block diagram of the auxiliary power supply is shown in Figure 2.

Designing for the wide input voltage range presents challenges specifically to the transformer, snubber, control and stability designs. The reference design balances several competing design goals to achieve optimal performance. Important technical aspects addressed in the reference design relate to the transformer structure and construction, snubber circuit and controller. The design provides reliable controllability at both extremes of the input voltage range and ensures a stable output under fast, dynamic line and load conditions.

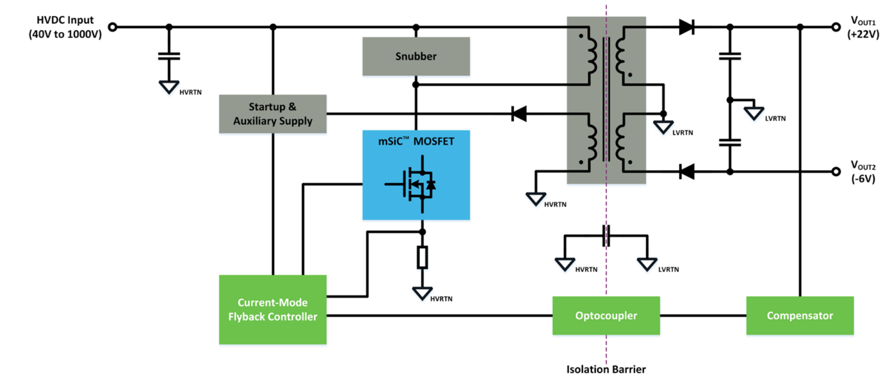

Figure 2: Block diagram of wide input voltage and dual output converter.

In conclusion, the design and implementation of a low-power auxiliary power supply within traction inverters are critical for ensuring the functional safety of electric vehicles. The use of flyback converters to convert a high-voltage DC input to low-voltage DC outputs provides a robust backup power solution during fault conditions. This redundancy is essential to maintain vehicle controllability and meet the stringent safety goals for compliance with ISO 26262 standards. The integration of SiC MOSFETs in the auxiliary power supply further enhances the system's capability to handle high voltages and ensures safe operation under various fault scenarios. By understanding the operating conditions of electric machines and the importance of maintaining a safe state during faults, engineers can design more reliable and safer auxiliary power supplies for traction inverters for electric vehicles.

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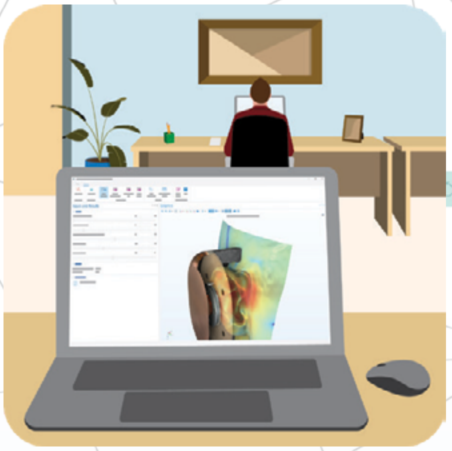

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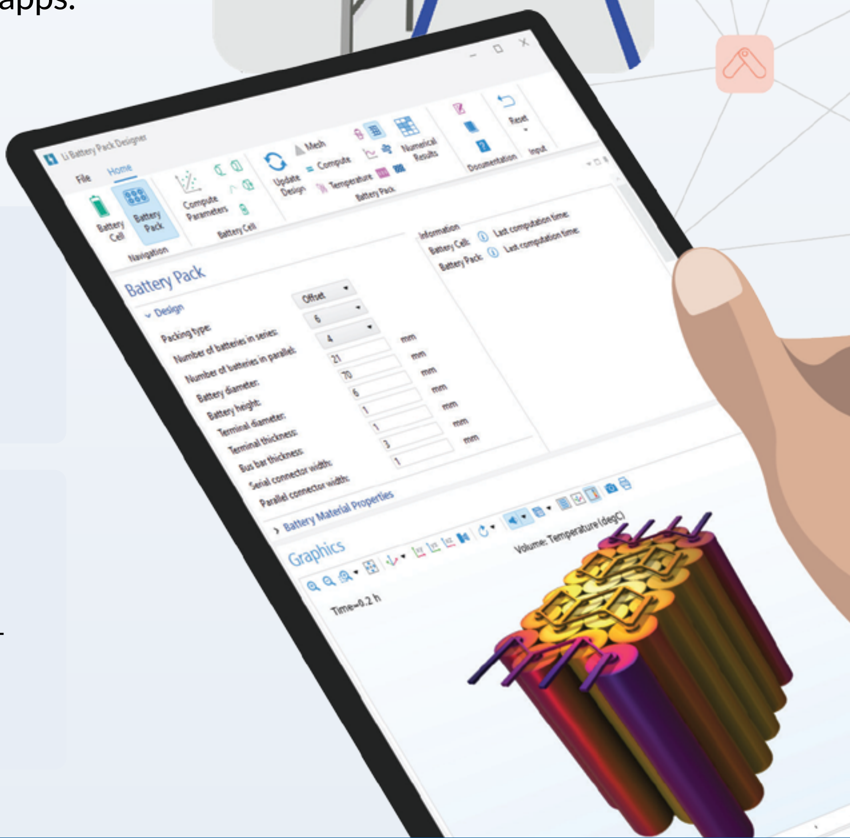

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Augmenting Car Sustainability with Flexible and Intelligent Power Control

Software-Defined Vehicles (SDVs) are transforming the automotive industry by enhancing flexibility, user experience, and sustainability. At the core of this transformation is the integration of electronic fuse control, which provides unmatched safety and efficiency in managing vehicle electrical systems.

By Giusy Gambino, Marketing Communication Specialist, Roberto Caputo, Application Manager, and Filippo Scrimizzi, Application Director, all STMicroelectronics

The automotive industry is shifting towards sustainability, driven by the innovative concept of Software-Defined Vehicles (SDVs). These vehicles leverage software integration and virtualization technologies to enhance functionality, connectivity, and autonomy. This innovation not only improves vehicle flexibility and user experience but also significantly contributes to sustainability efforts.

Traditional mechanical fuses are being replaced by electronic fuses, which offer precise and intelligent circuit management. They enable real-time monitoring of the vehicle's electrical system, providing rapid fault detection and response to electrical anomalies, thereby enhancing safety and reliability. Additionally, electronic fuses controlled through the Serial Peripheral Interface (SPI) seamlessly integrate with the vehicle's software, allowing for dynamic adjustments and remote diagnostics. This intelligent power control conserves energy and reduces waste, ensuring efficient vehicle operation.

Whereas hardware-driven I^2t (current squared through time) protection curves provide a limited optimization of the wire protection to the load profile, SPI-based products offer a revolutionary approach. The fully programmable solution boasts a cutting-edge function that can be effortlessly configured by setting just two parameters: nominal current and time. This groundbreaking design provides unparalleled adaptability and performance, making the solution not only more efficient but also exceptionally capable of meeting the diverse and dynamic electrical protection needs of modern vehicles.

Power Management in Automotive

A notable advancement in this domain is the development of STi^{2}Fuse intelligent electronic fuses fully programmable through an embedded SPI, which enables digital control and diagnostics.

This innovative capability offers significant advantages for power distribution and management in both conventional vehicles and innovative next-generation SDVs:

- Flexibility: Unlike competing electronic fuses that require physical modifications to change fuse curve levels, STi^{2}Fuse products allow for easy adjustments through software. This eliminates the need to modify components on the board.
- Ease of Use: Users can simply update the fuse settings via a graphical user interface (GUI), streamlining the process and reducing the time and effort required for adjustments.
- Precision: The proprietary I^2t function ensures that the fuse curve levels can be fine-tuned with high accuracy, providing optimal protection and wiring harness optimization.

The smart STi^{2}Fuse switches are key components in automotive zonal architectures, where each zone safely receives the appropriate power through a Power Rail Switch (PRS) rather than relying on a centralized domain-based system, as shown in Figure 1.

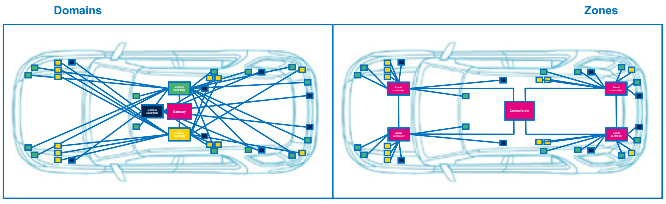

Figure 1: Automotive architectures (domain-based and zonal).

Each zone has its own control unit, simplifying wiring, reducing weight, and improving overall system efficiency, as illustrated in the block diagram for power distribution in Electric Vehicles (EVs) shown in Figure 2.

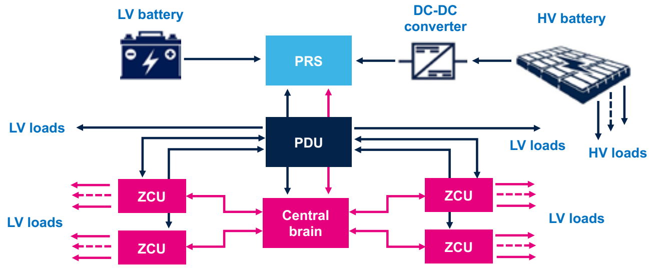

Figure 2: Block diagram for power distribution in EVs.

To withstand harsh current levels with high accuracy, reliability, safety, and resilience, PRS can be realized using smart STi^{2}Fuse controllers driving high-current power MOSFETs in a back-to-back (B2B) configuration. This setup manages lines bi-directionally, as shown in Figure 3.

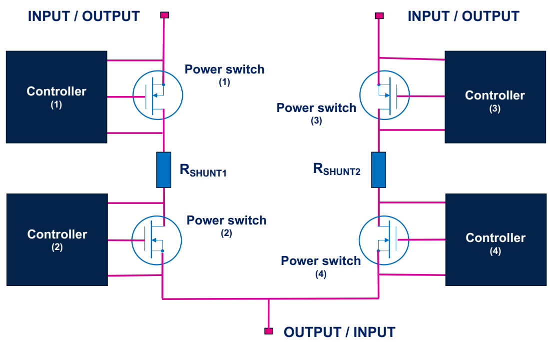

Figure 3: PRS block diagram in B2B configuration.

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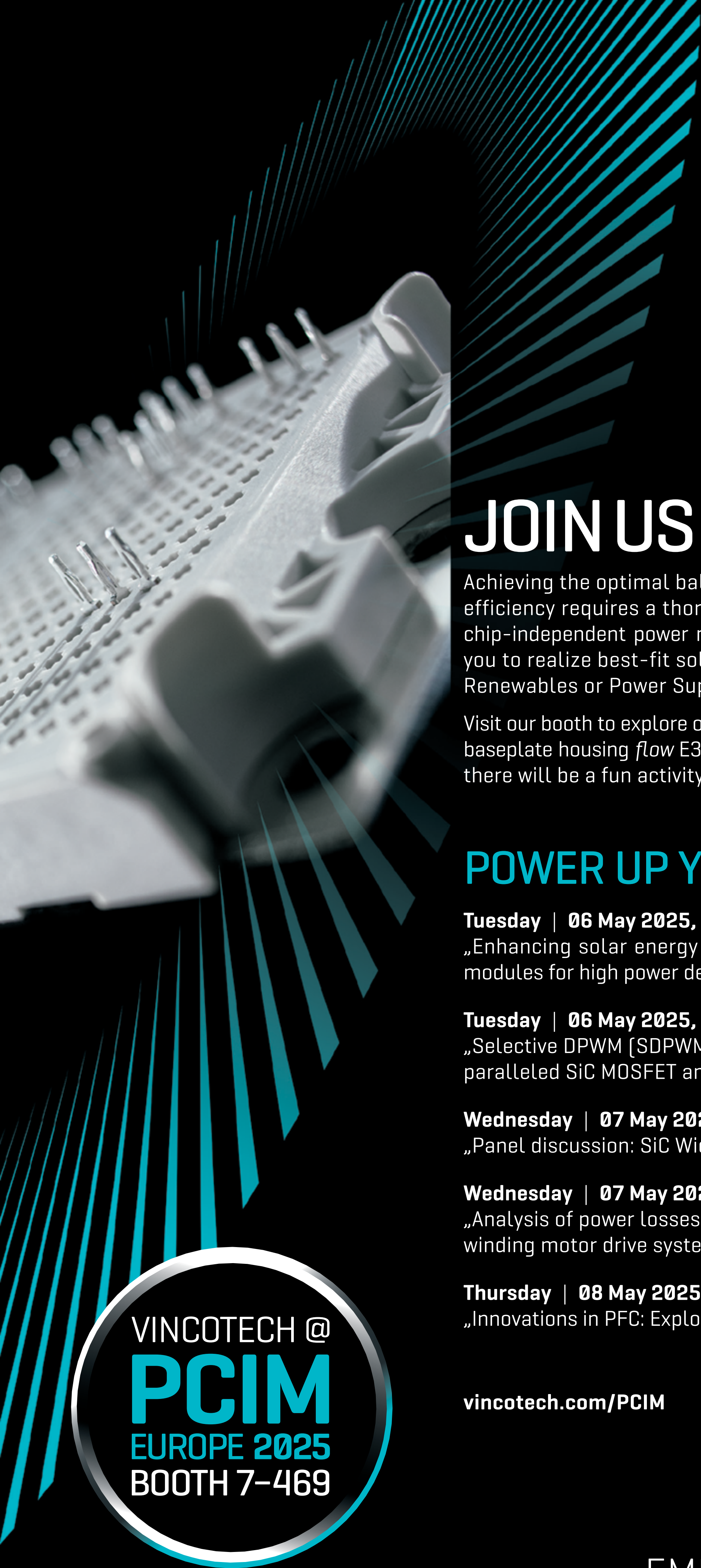

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Wednesday | 07 May 2025, 1:15 pm | Technology Stage
„Panel discussion: SiC Wide Bandgap: State of the Art"

Wednesday | 07 May 2025, 12:45 pm | PCIM Conference
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EMPOWERING YOUR IDEAS

Four single-channel STi^{2}Fuse controllers ensure safe power distribution, preventing overloading and potential damage to electrical components, thereby enhancing the reliability of the vehicle's electrical system.

Experimental Results

A comprehensive performance analysis of the controllers is presented based on measurements on a complete solution that integrates both hardware and software. The evaluation boards used for the driver and power section are depicted in the following figures (Figures 4 and 5).

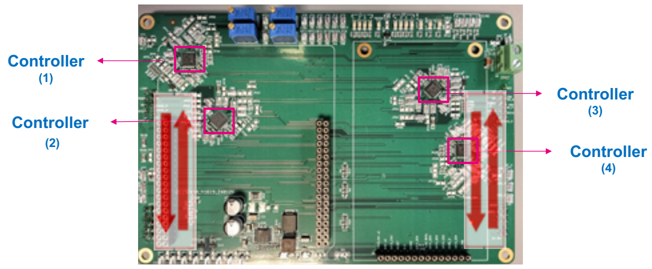


Figure 4: Evaluation board for the driver section.

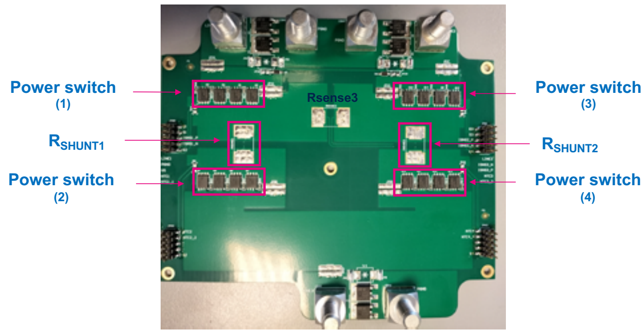
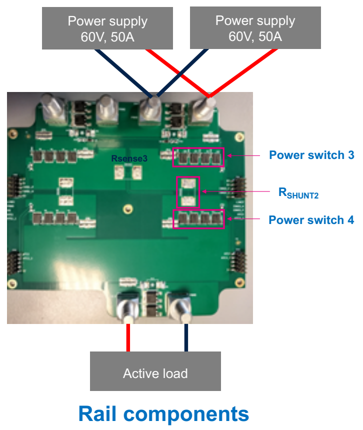


Figure 5: Evaluation board for the power section.

A thermal analysis has been performed on a single rail at the following conditions:

- V_{BAT} = 12 V
- I_{RAIL} = 100 A

where V_{BAT} is the battery voltage and I_{RAIL} the current flowing through the single rail.



The thermal maps for the rail components, specifically the power switches, shunt resistor, and connectors, are illustrated in Figure 6.

where:
2 indicates the R_{SHUNT2} resistor
3 the power switch 3
4 the power switch 4

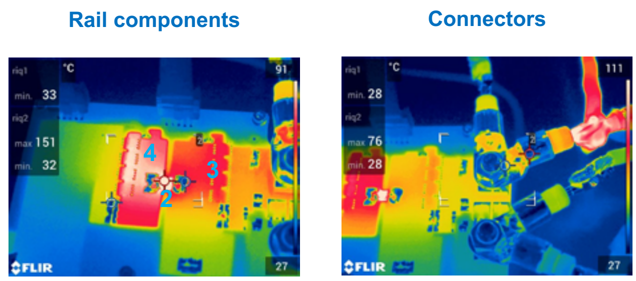


Figure 6: Thermal analysis of a single rail power stage.

Each power switch is composed of four power MOSFETs connected in parallel to manage the current. As a result, both power switches reach a temperature of approximately 85°C. This outcome highlights the effectiveness of the evaluation board in ensuring an equal distribution of the rail current through the two power switches.

The I2t function of the smart STi^{2}Fuse switches has been tested to determine the level of protection provided to circuit components and wiring, by considering the following testing circuit (Figure 7).

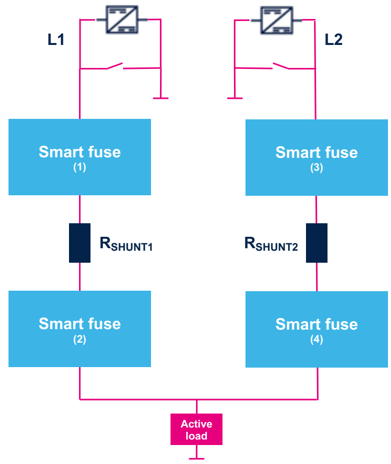


Figure 7: Testing circuit for the protection function.

If a short circuit condition occurs on both the L1 and L2 rail lines, the smart fuse devices will intervene to protect the load. The reaction time of these devices decreases as the overcurrent level increases. This response time is determined by the I²t curve configured within the smart fuses. The experimental data are reported in Table 1.

Load overcurrent	Reaction time
20 A	31.6 ms
30 A	8.16 ms
85 A	10 µs

Table 1: Experimental data for smart fuses reaction times.

The measured voltage and current waveforms that illustrate the behavior of the smart fuses in rail line L2 with a load overcurrent equal to 30 A are shown in Figure 8.

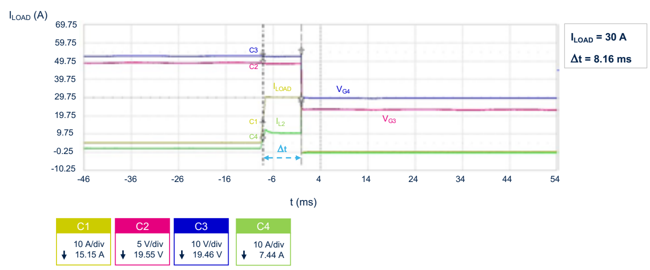


Figure 8: Measured waveforms with rail short circuit conditions.

Upon detecting a short circuit condition, smart fuse 4 triggers the power switch to latch off, causing the gate voltage (VG4) to drop to a low level. Consequently, the increased drain-source voltage (VDS3) of smart fuse 3 causes its gate voltage (VG3) to also drop to a low level. This action opens rail L2, resulting in the current in rail L2 dropping to zero. A similar behavior is observed in rail line L1. As a result, the load current is reduced to zero, effectively protecting the load. This entire sequence of events occurs within a few milliseconds.

Additional failure events can directly involve the circuit load. In such cases, if the current detected on both rails exceeds the software-defined short circuit threshold, both lines will be switched off, blocking the current flow thanks to the back-to-back body-drain diode of the two power switches.

If only one of the two rails is shorted, to fulfill the safety requirements of the connected load and simultaneously avoid the still operative DC-DC converter feeding the short circuit itself, the PRS detects the overcurrent on the involved rail, disconnecting it and allowing the permanent biasing condition for the critical safety load.

Conclusions

A comprehensive performance analysis has confirmed the effectiveness of the STi²Fuse switches in real-world scenarios. These intelligent electronic fuses revolutionize power management in automotive applications with their unmatched flexibility, precision, and rapid response. STi²Fuse switches are essential for enhancing the safety, reliability, and efficiency of modern vehicles. Their integration into automotive zonal architectures underscores their critical importance in advancing vehicle electrical systems.

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Optimal Efficiency Enabled by New Generation Super-Junction MOSFETs in Refrigerator Compressor Drives

Globally, about 220 million refrigerators and freezers are sold per year as of today, valuing at a market of around 75 billion US dollars in 2024. [1]This market is predicted to see a continuous CAGR growth of 6.27%, reaching around 120 billion US dollars by 2032. Two predominant Silicon based technologies are currently being used in the compressor drives of the fridge itself, the first one being the IGBT, and the second one being the High Voltage (HV) MOSFET. Out of the two, HV MOSFET's adoption is accelerating and there are two major trends contributing to it. The first trend is inverterization in the fridge's compressor systems, which enhances the efficiency, performance, and longevity of refrigerator compressors by utilizing inverter technology.

By Pengwei Sun, Principal Engineer, Product Definition and Application, and Huei-Tsuen Hsu, Senior Specialist, Product Management, both Infineon Technologies

Introduction

Traditional compressors operate at a fixed speed, constantly turning on and off to maintain the desired temperature. This on-off cycling can lead to energy wastage. In contrast, an inverter compressor adjusts its speed based on the cooling demand, running more consistently and at lower speeds when less cooling is needed, giving several advantages including energy savings, temperature stability, noise reduction and extended compressor life. This trend drives demand for performance optimized discrete devices, such as an HV MOSFET, as opposed to an IGBT. The second trend is more demanding regulations on system design and component selection. By 2026, China will implement a new energy efficiency standard - 20231710-Q-469 [2], which will push almost all refrigerators to optimize their design to fit this standard and increase invertersed weight for more efficiency. All-in-all, suppliers must look for more innovative ways to increase efficiency of the inverter stage, especially at light load operations. The new CoolMOS™ 8 at Infineon targets this modern challenge, balancing the cost competitiveness with high performance to fit the requirement for low energy consumption.

Refrigerator operations

During the lifetime of refrigerators, there are mainly three operational modes. The first one is pull down operation at 100% power. The fridge starts from ambient temperature, and the compressor runs at the maximum power to cool it down. It happens only a few times over the lifetime of the fridge, for example when the new fridge first gets plugged in or when it's moved to a new location. The second one is nominal load operation at around 50% power. The compressor runs at higher power to keep it cool when the fridge door is open and people store food inside or get food from the fridge. It really depends on the usage frequency of each individual household, for example the door is open about 10 times per day for 10s. The third one is light load operation at around 20% power. The compressor runs at low power to main the temperature when the door is closed. It counts for majority of the lifetime, around 95%. Therefore, the efficiency at light load is the most critical in terms of energy savings in fridge operations. In order to boost up energy efficiency and obtain higher energy star ratings, fridge manufacturers put more emphasis on improving the light load efficiency.

CoolMOS™ 8

Infineon's newest CoolMOS™ 8 (CM8) [3] at 600 V is leading the way in high voltage super-junction MOSFET technology, setting the standard for both technology and price performance. The series is equipped with an integrated fast body diode offering lower reverse recovery charge, making it suitable for hard-switching motor drives applications. The thermal resistance improvement with up to 50% made possible by .xT package interconnect technology, leads to better thermal performance compared to the previous generation of PFD7 series. It fulfills Class 2 level of ESD HBM classification, which is a must-have design requirement in home appliances.

Evaluation platform

In order to better evaluate the performances of different technologies in refrigerator compressor drives application, we use the following reference board from Infineon [4] in Figure 1. It's a dedicated single-layer PCB without any heatsink, targeted for 3-phase rotary fridge compressors. It operates with IMD111T[5], which is a smart driver with the microcontroller and the 3-phase gate driver inside. The devices under test are six discrete power switches, either IGBT or HV MOSFET.

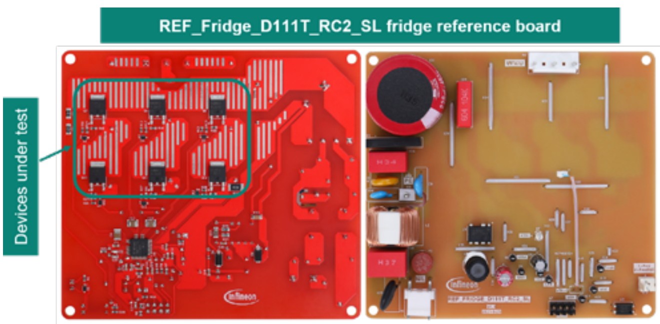

Figure 1: Fridge reference board

Figure 2 shows the test platform set-up. DC power supply at 300V is used for the input. Power meters are used to measure the input DC power, the output AC power and the auxiliary power respectively. A thermocouple is attached to case of the low side middle phase transistor device to monitor the case temperature. The efficiency of the devices under test can be expressed as η = AC power/ (DC power-Aux power) x100%.

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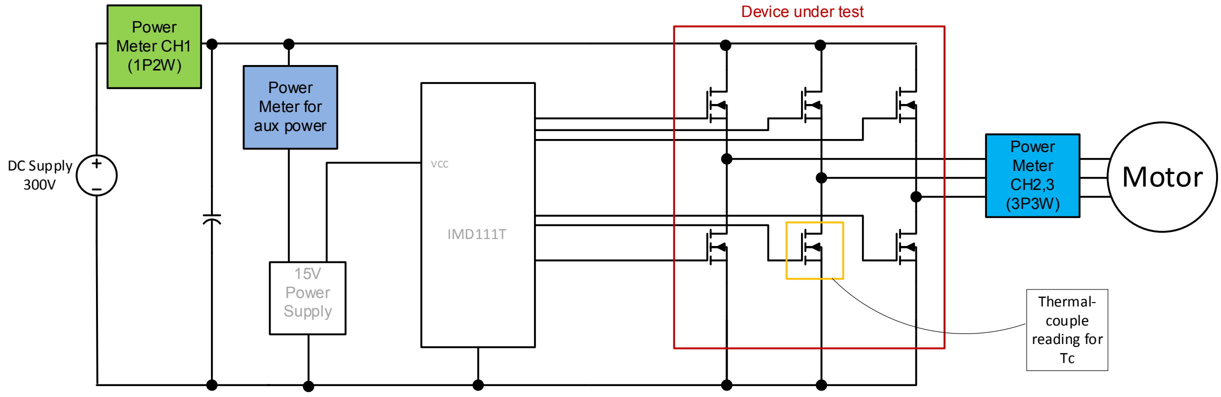

Figure 2: Test platform set-up

Efficiency measurement

Several device technologies are included in the evaluation, including 600 V/600 mΩ CM8 MOSFET, 600 V/600 mΩ PFD7 MOSFET, 600 V/6 A RCD2 IGBT from Infineon, and a competitor 600 V/600 mΩ MOSFET. All the devices share the same package, DPAK, which has been widely adopted in this application. The typical switching frequency of refrigerator drives is from 4 kHz to 6 kHz. Therefore, the 5 kHz 3-phase SVPWM scheme is used in the evaluation. The board is placed in an enclosure with maintaining an ambient temperature of 25°C. The power is tested from light load 30W up to full load 300W. The efficiency curves are plotted in Figure 3.

As can be seen from the measurement, MOSFET's efficiency is higher than IGBT across the entire load range, thereby offering better energy savings over all the refrigerator operation modes. Efficiency peaks at 100W, and CM8 has the highest peak efficiency at 98.5% among all the compared technologies. At light load 60W (20% load), CM8 efficiency is 98.4%, while RCD2 IGBT only has 97.2%, and CM8 is leading IGBT by 1.2%. At 10% load, the benefit of CM8 is even more obvious with 1.6% ahead of IGBT. At full load, CM8 offers 97.2%, which still leads IGBT by 1.2%.

Compared to the previous generation PFD7, CM8 sees efficiency improvement of 0.2% at 20% light load, and 0.6% at 100% full load. CM8 is leading the competition HV MOSFET across the entire load by 0.6% to 1%.

Figure 4 shows the case temperature measurement at different load conditions. As can be seen, it's a good reflection of efficiency measurement where CM8 has the coolest readout across the entire load range. This also then implies more reliable operation of CM8 over the lifetime of the fridge compared to all other technologies. Additional switching frequencies are tested at 3kHz and 10kHz to show the capability of CM8, and the efficiency curves are plotted in Figure 5. Basically, the frequency change has a more impact on the light load efficiencies where switching losses are more prominent. If the frequency change can be implemented in the light load, more efficiency improvement will be achieved.

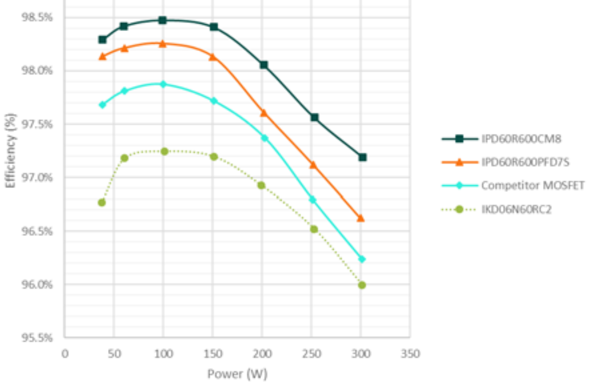

Figure 3: Efficiency measurement

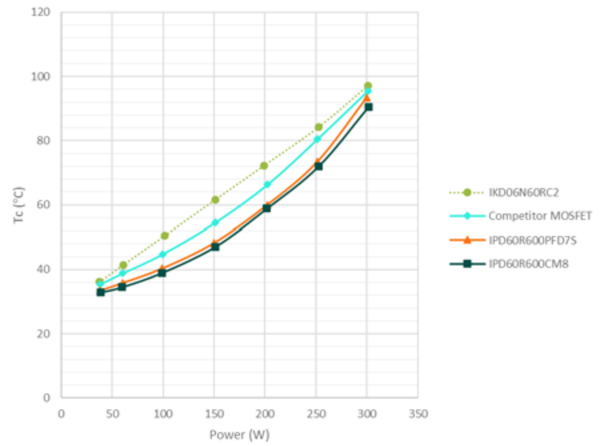

Figure 4: Case temperature measurement

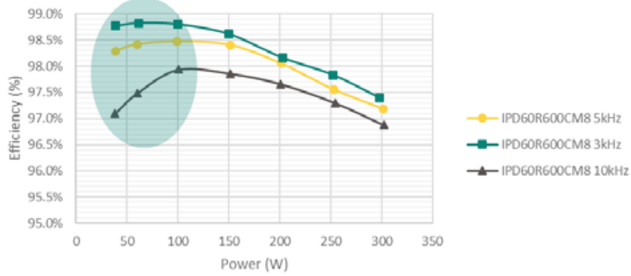

Figure 5: Efficiency measurement at different switching frequencies

Conclusion

In this article, several power device technologies have been studied and compared for efficiency in the refrigerator compressor drives application. Through these measurements, CM8 is proved to be the best option with the lowest losses across the entire load that translate into 1.2% to 1.6% efficiency improvement compared to IGBT solutions. With the adoption of CM8, the energy consumption of the fridge will be greatly reduced and requirement of higher energy star ratings shall be met.

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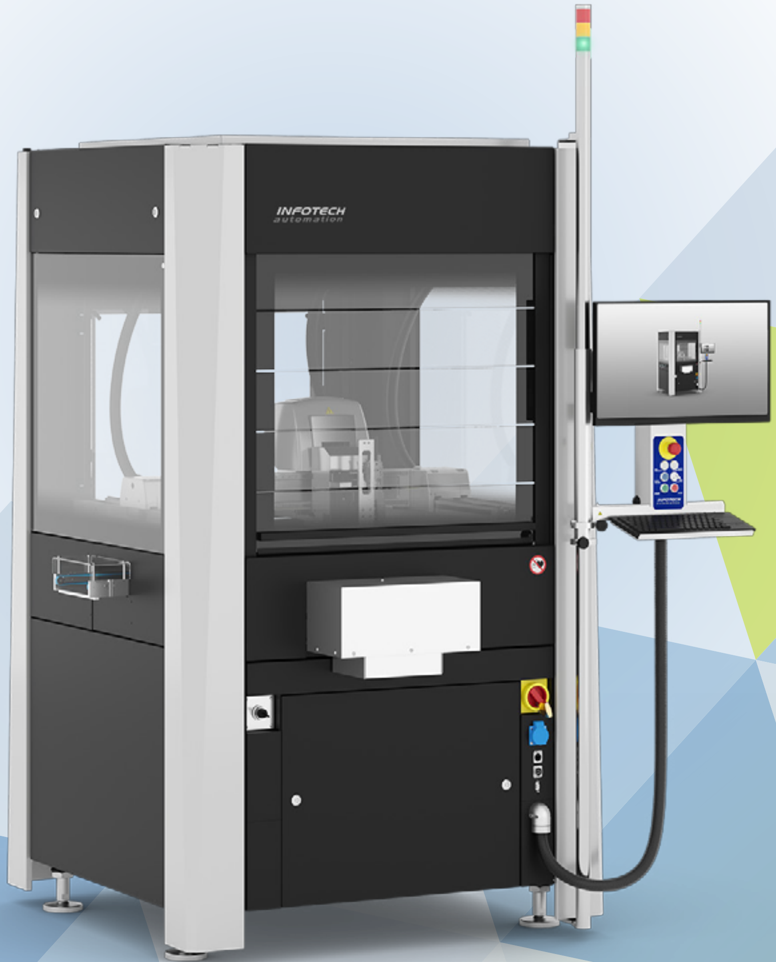

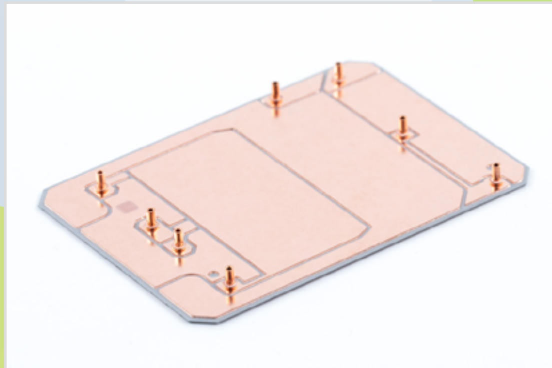

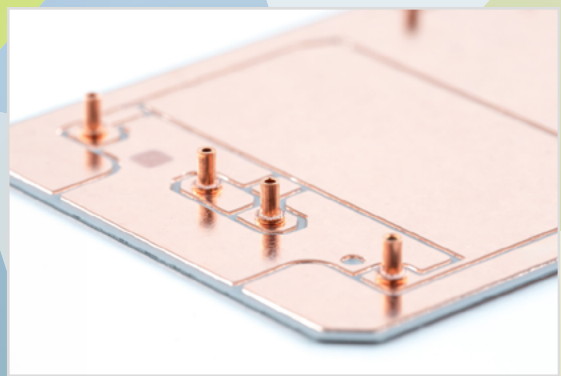

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Powering the SiC Revolution with Vertical Integration

By Ajay Poonjal Pai, Head of Innovation, Sanan Europe, and Thomas Lehmeier, Yan Zhou, Institute of Power Electronics, Friedrich-Alexander-Universität Erlangen-Nürnberg

SiC is Revolutionizing the Power Semiconductor Market

Silicon Carbide (SiC) has a 3x Bandgap compared to Silicon (Si) resulting in a nearly 10x higher critical electrical field. This enables SiC unipolar devices like Schottky diodes and Mosfets in the several kilovolt (kV) range, which is traditionally difficult in Si. Unipolar devices such as MOSFETs usually offer lower conduction (under partial load conditions) and switching losses making them attractive for many applications such as Photovoltaics (PV) and Automotive Traction Inverters. As a result, SiC based devices have already penetrated the market, with a market share that is expected to reach close to 10B$ at the end of the decade with a CAGR of over 30%, thereby revolutionizing the power semiconductor market.

Silicon Carbide is not Silicon!

However, the manufacturing of SiC is significantly different from Silicon. E.g., SiC monocrystal is usually grown by sublimation unlike Si which is usually grown from a melt. Furthermore, the processing of SiC wafers is more challenging owing to its higher hardness and brittle nature, compared to Si. Also, SiC usually involves higher processing temperatures. All these factors not only make the entire process significantly more expensive compared to Si, but also result in a higher defect density compared to Si. This is why a strong understanding of the complete process all the way from crystal growth to device fabrication and packaging is crucial for success in SiC.

Sanan Benefits from 20+ years of Compound Semiconductor Expertise

Sanan Semiconductor benefits from a strong knowhow of compound semiconductors, stemming from its 20+ years of expertise in semiconductors such as GaAs, GaN, InP, LN, LT etc., catering to markets such as optoelectronics, RF, optical devices and Power semiconductors, each of the semiconductors for which Sanan is today vertically integrated.

Figure 1: Sanan's Vertically Integrated State-of-the-art 150 and 200 mm SiC Mega Factory.

Vertically Integrated State-of-the-art 150 and 200 mm SiC Mega Factory

In 2020, Sanan established a state-of-the-art vertically integrated SiC mega factory (Figure 1) with a planned capacity of around half-a-million wafers annually. Built with an investment of over $2B, this fab caters to producing SiC, all the way from substrates to packaged products, in both 150 mm and 200 mm. This makes it possible to cater to a wide base of customers, at different stages in the value chain. As a result of vertical integration, Sanan maintains the complete supply chain thereby leveraging its capacity, cost and quality advantages.

200mm Substrates and Epi-wafers released for Mass Production

Sanan has developed the processes in-house to mass produce SiC powder, which is the raw material for substrate production, with a purity of 6N grade (99.9999%). This is crucial to producing SiC substrates with low defect densities, which is necessary to reach high levels of yield in device fabrication. 150 mm substrates have been in mass production since 2021, and Sanan leveraged this experience also to 200mm (see Figure 2), which have been released for mass production this year. SiC devices are usually fabricated on an epitaxial layer, which serves as the drift region, grown on the substrate. A good epitaxial process not only prevents new defects forming in the drift layer, but also stops any remaining killer defects present on the substrate from expanding into the drift region. Therefore, high quality epitaxy is crucial to fabricating devices in high volume at high quality. Epi-wafers have been released for mass production, in 150 mm as well as 200 mm.

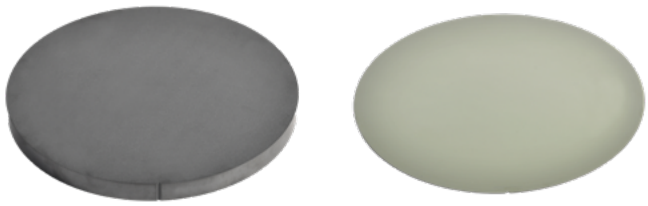

Figure 2: 200mm SiC Boule (left) and Substrate (right) released for mass production.

Over 200 Million SiC Devices Shipped for Various Applications

Three generations (G1, G2 and G3) of SiC schottky diodes have already been released to the market, in a wide portfolio ranging from 2-60A, in voltage classes from 650V-2kV in various standard packages, for industrial as well as for automotive markets. Different applications usually have different trade-offs. For example, outdoor applications such as solar usually need higher surge current capability. On the other hand, power supply applications need the lowest forward voltage. Keeping this in mind, two flavours of the G3 diode have been tailor-made to meet the above applications, namely the "higher-surge" version and the "Low Vf" version, in addition to the "General Purpose" version. A popular application example for SiC Schottky diodes is a classical boost Power Factor Correction (PFC) converter, where replacing the Si diode with a SiC schottky diode helps to cut down the reverse recovery losses in the diode and the turn-on losses in the active switch, thereby enhancing the system efficiency by 0.5 p.p (Figure 3). Moreover, both the diode and active switch operate at a significantly lower temperature [1].

Sanan has already released the Gen-1 SiC Mosfet based on the planar structure (Figure 4) targeting industrial and automotive applications. Subsequently, cell engineering of the above planar structure has lead to significant improvements in the Rds*A Figure-of-Merit (FOM) which is available as Gen-2 (released) and Gen-3 (to be released later in 2025). Current portfolio extends from Rdson classes

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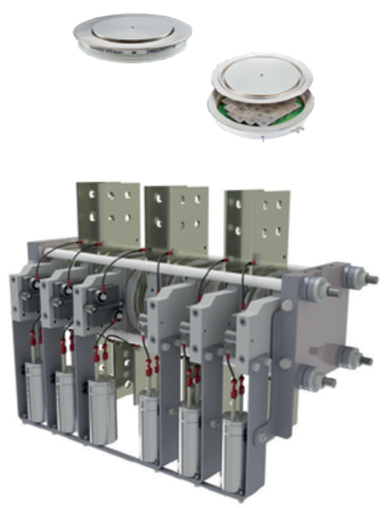

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of 10mΩ - 1000 mΩ, in voltage classes 650V, 750V, 1200V, 1700V and 2000V, industrial and automotive qualified devices, available as bare dies, standard discrete packages such as TO-247, D2PAK, top-side cooled, and customer specific modules [2]. Furthermore, a trench structure (in early development), and a super-junction Mosfet (in early concept development) are expected to significantly enhance the FOM of the SiC mosfets, bringing them closer to Si devices in terms of cost-performance.

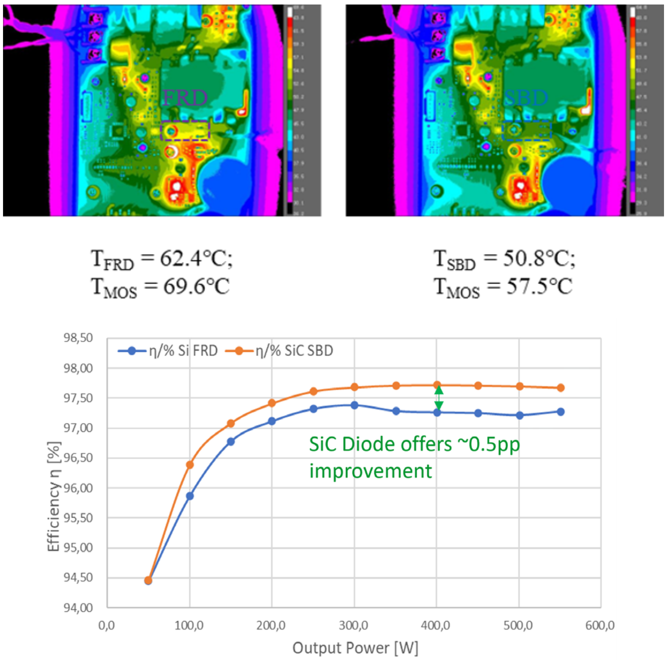

Figure 3: Replacing the Si diode in a Boost-PFC Converter with a SiC Schottky diode helps enhance system efficiency by 0.5 p.p (bottom) and the diode and active switch operate cooler (top: left Si, right SiC).

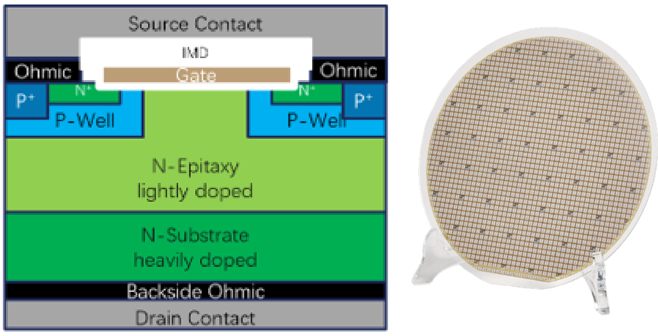

Figure 4: Automotive Qualified SiC Planar Mosfet Technology currently in Mass Production. Unit cell (left) and bare-die wafer (right).

Chip capabilities complemented by Packaging capabilities
To reap the superior performance of SiC devices, it is imperative to have enabling packaging technologies which allow, e.g., lower parasitic inductances, better cooling, better layout for good current sharing. Being a vertically integrated supplier, Sanan has in-house capabilities not only for many state-of-the art-packages, but also for customer-specific packages. This can enable customers to reach their required levels of performance at desired costs, thus bringing the benefits of vertical integration to help power the SiC revolution.

Sanan SiC Mosfets Demonstrate 99.6% Efficiency in a Soft-switching Inverter Topology
To demonstrate their performance in an application, Sanan SiC Mosfets were tested in an inverter application (Figure 5). The topology used in this case is the Single Shared Inductor Auxiliary Resonant Commutated Pole (S²I-ARCP) [3], which is a soft-switching topology. The main branch, which carries the load current, was populated with 1200V 16 mΩ SiC Mosfets in TO-247 package (SMS1200016M2) [4]. The auxiliary branch, which is responsible for the soft switching and which carries only a small fraction of the load current was populated with 1200V 20 mΩ SiC Mosfets (SMS1200020M2) [5] though even higher-Rdson devices would have sufficed. These devices have been optimized for soft switching, by enabling a higher switching speed. Figure 6 shows the measured efficiency at dc link voltage V_{dc}= 800 V, output voltage $V_{0,rms}$= 230 V, output frequency f_{el} = 50 Hz and switching frequency f_{sw} = 30 kHz, and it can be seen that the peak efficiency exceeds 99.6%, demonstrating the performance of the SiC Mosfets. Figure 7 compares the measured temperature in the case of hard switching and soft switching. It can be seen that the main switches (Pu1) operate significantly cooler in the case of soft switching. Of course, some of the losses are moved to the auxiliary switches (Pu2 and Pu3), but they are insignificant compared to the savings in the main switches.

NOTE: Further details on this topology and measurements will be presented in more details in a future article.

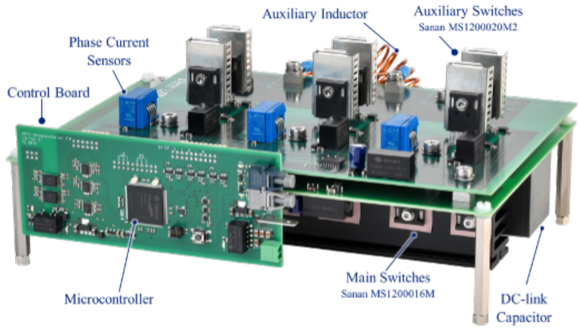

Figure 5: S²I-ARCP Soft-switching Inverter populated with SiC Mosfets from Sanan Semiconductor.

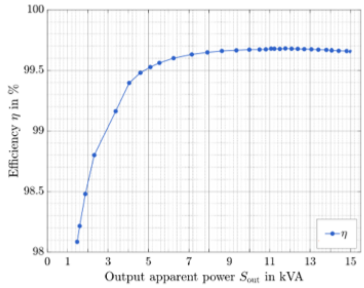

Figure 6: Measured Efficiency in the S²I-ARCP Soft-switching Inverter populated with SiC Mosfets from Sanan Semiconductor. V_{dc}= 800 V, $V_{0,rms}$= 230 V, f_{el} = 50 Hz, f_{sw} = 30 kHz.

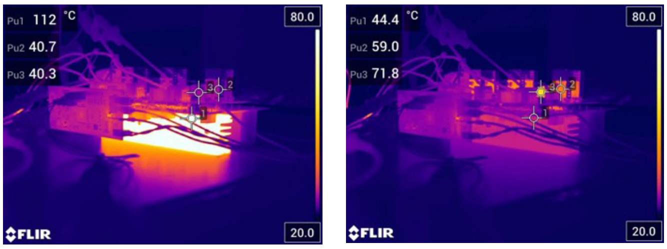

Figure 7: Measured Temperatures in the S²I-ARCP Soft-switching Inverter populated with SiC Mosfets from Sanan Semiconductor. V_{dc}= 800 V, $V_{0,rms}$= 230 V, f_{el} = 50 Hz, f_{sw} = 30 kHz. (Left: without soft-switching, right-with soft-switching).

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[1] "Silicon Carbide Schottky Barrier Diodes", Application Note, Sanan Semiconductors
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[3] T. Lehmeier, A. Amler, Y. Zhou, and M. März, "Three-Phase ARCP Inverter Using Soft-Switching With a Single Shared Inductor," IEEE Trans. Power Electron., vol. 39, no. 2, pp. 2505–2521, 2024.
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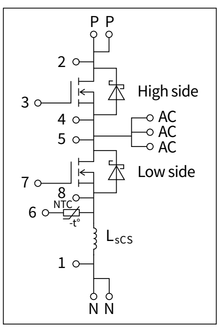
Package Highlights

- High reliability by using silver sintering technology
- Equipped with current sensing terminal & built in thermistor
- High channel temperature ($T_{ch,\,max}$ = 175°C)
- Low stray inductance
- Low thermal resistance

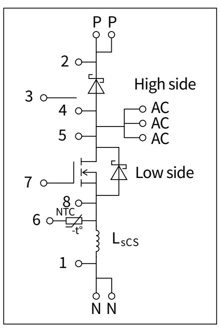
Featured Product

- 3300V 800A – MG800FXF2YMS3

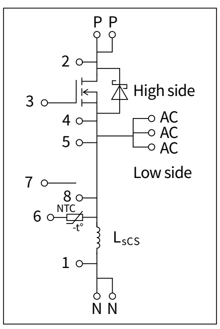
Internal circuit options



Half bridge



Chopper low



Chopper high

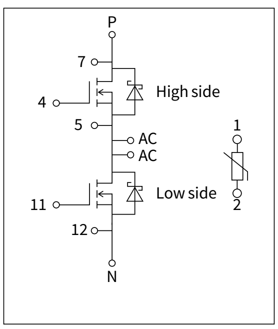
Package Highlights

- High mounting compatibility with Si IGBT module
- Lower loss characteristics than Si IGBT module
- High channel temperature ($T_{ch,\,max}$ = 150°C)
- Low stray inductance
- Low thermal resistance

Featured Products

- 1200V 400A – MG400Q2YMS3
  600A – MG600Q2YMS3
- 1700V 250A – MG250V2YMS3
  400A – MG400V2YMS3
- 2200V 250A – MG250YD2YMS3

Internal circuit option



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Super Clamp TVS – Solution with extremely low Clamping Ratio

Taiwan Semiconductor introduces, first of its kind, transient voltage suppressor (TVS) called Super Clamp TVS. Super Clamp TVS adopts snapback characteristics which is beneficial to extremely low clamping ratio between working voltage (V_{WM}) and clamping voltage (V_C). The low clamping ratio TVS can suppress high surge current to provide lower clamping voltage than conventional TVS and metal oxide varistor (MOV), which means designers could use lower working voltage components of capacitor, switching MOSFET, reverse polarity protection diodes, and regulators.

By Muhammad Ahad Rafiq, Senior Field Application Engineer, Taiwan Semiconductor Europe

Super Clamp TVS structure

Super Clamp TVS adopts BJT (Bipolar junction transistor) which is different from conventional TVS as shown in Figure 1. When breakdown voltage occurs for Super Clamp TVS, due to its instinctive snapback characteristics, it foldbacks and then breakdown happens again. This low clamp ratio provides lower V_C (clamping voltage) at high I_{PP} (peak impulse current), which means the discrete components, which come after the Super Clamp TVS, could sustain lower voltage stress and designer could use lower working voltage specification components like capacitor, MOSFET etc.

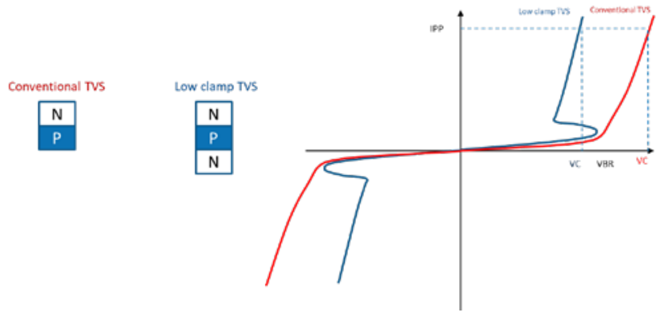

Figure 1: Conventional TVS and Super Clamp TVS structure, V_C – I_{PP} curve

TSC high power DO-218AB package Super Clamp TVS specification:

8/20us I-V curve comparison

Taking Super Clamp TVS LTD7S24CAH and conventional TVS TLD8S24AH to test 8/20us transient surge and recording V_C – I_{PP} waveform as shown in Figure 2. LTD7S24CAH curve shows snapback characteristics whose V_C clamping ratio is 1.63 (V_C/V_{WM}) and Rdny is 0.0058 ohm, which are lower than those of TLD8S24AH. TLD8S24AH curve shows exponential characteristics and whose VC clamping ratio is 3.78 (V_C/V_{WM}) and Rdny is 0.0224 ohm. Super Clamp TVS can suppress transient surge closer to V_{BR} than conventional TVS.

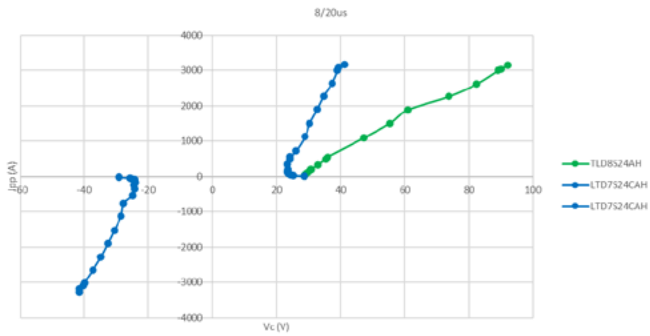

Figure 2: Super Clamp TVS LTD7S24CAH and conventional TVS TLD-8S24AH 8/20us I-V curve

ELECTRICAL SPECIFICATIONS (T_A = 25°C unless otherwise noted)

Part number	Device marking	Breakdown voltage V_{BR} at I_T (V) (Note 1)		Test current I_T (mA)	Working stand-off voltage V_{WM} (V)	Maximum blocking leakage current I_R at V_{WM} (µA) (Note 1)	Maximum blocking leakage current I_R at V_{WM} T_J =175°C (µA) (Note 1)	Maximum peak impulse current I_{PPM} (A) tp =10/1000 (µs)	Typical clamping voltage V_C at I_{PPM} (V)	Typical temp. coefficient of V_{BR} αT (%/°C) (Note 2)
		Min	Max							
LTD7S24CAH	LTD7S24	26.7	29.5	5	24	1	150	300	24	0.081

Table 1: Fan Single phase H-bridge BLDC motor usage component

Comparison

In order to understand Super Clamp TVS characteristics and advantages over conventional TVS, take DO-218AB package bi-directional Super Clamp TVS LTD7S24CAH of TaiwanSemi and DO-218AB package uni-directional conventional TVS TLD8S24AH of TaiwanSemi to do the comparison.

V_C tested by 8/20us I_{PP} comparison

Taking Super Clamp TVS LTD7S24CAH and conventional TVS TLD-8S24AH to test 8/20us transient surge. Applying 8/20us of I_{PP}=155A to these two TVS and recording V_C results as in Figure 3. LTD-7S24CAH VC (23.623V) is 76.56% of TLD8S24A V_C (30.853V).

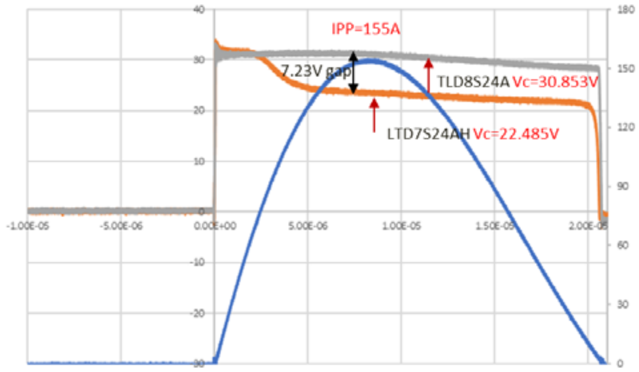

Figure 3: Super Clamp TVS LTD7S24CAH and conventional TVS TLD-8S24AH tested 8/20u I_{PP}=155A

10/1000us I-V curve comparison

Taking Super Clamp TVS LTD7S24CAH and conventional TVS TLD-8S24AH to test 10/1000us transient surge and recording V_C – I_{PP} waveform as shown in Figure 4. LTD7S24CAH curve shows snap-back characteristics whose VC clamping ratio is 1.049 (V_C/V_{WM}) and Rdny is 0.0075 ohm, which are lower than those of TLD8S24AH. TLD8S24AH curve shows exponential characteristics whose VC clamping ratio is 1.349 (V_C/V_{WM}) and Rdny is 0.0234 ohm. Super Clamp TVS can suppress transient surge closer to V_{BR} than conventional TVS.

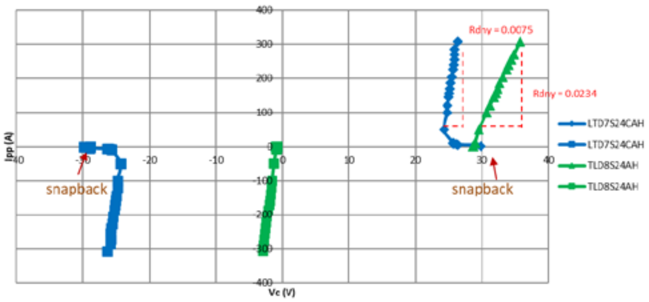

Figure 4: Super Clamp TVS LTD7S24CAH and conventional TVS TLD-8S24AH 10/1000us I-V curve

Device V_{BR} temperature deviation comparison

V_{BR} will be a focus point for a designer if TVS inadequately turns on when temperature is increasing. Taking Super Clamp TVS LTD-7S24CAH and conventional TVS TLD8S24AH to test V_{BR} in temperature range -55ºC to 175ºC as shown in Figure 8. For LTD7S24CA, when operating in temperature range -55ºC to 175ºC, V_{BR} deviation difference is 2.73V; For TLD8S24A, when operating in temperature range -55ºC to 175ºC, V_{BR} deviation difference is 5.58V. So, for LTD7S24CA V_{BR} difference of temperature deviation is more stable than TLD8S24A.

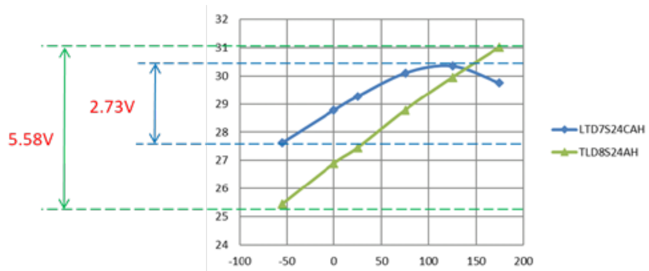

Figure 5: LTD7S24CAH V_{BR} temperature variation is lower than TLD-8S24AH

Potential application example– BLDC FAN Back-EMF threat

24V industry Fan uses Single phase H-bridge BLDC motor circuit as shown in Figure 6. The motor exhibits Back-EMF (Back Electromotive Force) when in operation. When current flows through motor, Back-EMF will flow to voltage source while motor decelerates or stops and it might damage front components like MOSFET.

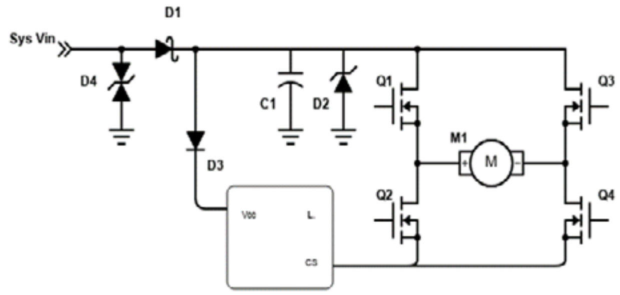

Figure 6: Single phase H-bridge BLDC motor circuit

Advantage

Normally the components selection for industry Fan Single phase H-bridge BLDC motor needs to consider Back-EMF robustness as shown in Table 2. 24V motor will have 60V Back-EMF threat and it will use TVS with VBR=28V to clamp this Back-EMF to 33V for protecting the 60V MOSFET. If it adopts Super Clamp TVS LTD7S24CAH, it could clamp Back-EMF to 25V. That brings benefits: 60V MOSFET may exchange to 40V MOSFET and 50V Capacitance may exchange to 35V Capacitance.

Supply voltage	reverse polarity diode	MOSFET	TVS	Back-EMF
12V	45V	30V	18V	18 - 24V
24V	60V	60V	26V/28V	33 - 60V
48V	120V	100V	78V	80V-100V

Table 2: Fan Single phase H-bridge BLDC motor usage component

Though it is completely dependent on end application, a general estimate for BOM cost reduction can be estimated from below table.

Traditional TVS	Snapback TVS as Replacement	Changes in BOM Cost
24V Old TVS	24V New TVS	~20% Up
60/80V N-Mosfet	40V N-Mosfet	~35% Down
50V/uF Capacitor	35V/uF Capacitor	~40% Down

Table 3: Fan Single phase H-bridge BLDC motor usage component

Conclusion

Super Clamp TVS adopts snapback technology and its low VC could help protect discrete components sustain lower voltage stress, based on application design, compared to conventional TVS. That helps downsizing components rating and eventually BOM cost reduction.

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Market leader for more than 30 years for HVDC rated IGBTs

For more than 30 years, Hitachi Energy has consistently maintained market leadership in IGBT devices, particularly for High-Voltage Direct Current (HVDC) and power quality (StatCom) applications. IGBT modules are crucial in these applications, which are highly efficient solutions for transmitting large amounts of electricity over long distances, and for integrating renewable energy sources [1].

By Evgeny Tsyplakov, Product Manager, Hitachi Energy

Initial success in high voltage IGBTs

In its early years ASEA (now Hitachi Energy) made impressive progress in thyristor technology for what it called HVDC Classic applications. Between 1960 and 1980, the maximum blocking voltage and the maximum power handling per device increased approximately linearly in time from virtually zero before 1960 to 6,000 V and 600 kW, respectively, by 1980. In the late 1980s it became clear that MOS-controlled power semiconductor devices could potentially reach power levels required for HVDC applications. It was then that research started on the MCT (MOS-Controlled Thyristor). To achieve the power levels, a few IGBT cells needed to be controlled.

It came as a big surprise during development of the MCT, when it was discovered that the 4.5 kV IGBT cells experienced less power loss, which encouraged the initiation of a program to develop high voltage IGBTs. Success came swiftly and, in 1992, the world's first sample of a 4.5 kV, 600 A IGBT module was introduced [2].

In 1994, ABB Power Systems (now Hitachi Energy) started the development of HVDC Light® technology. This was intended for DC transmission in a power range up to 100 MW, now extended to GW(s). The first commercial HVDC Light link on Gotland in1999 was to support the integration of renewable wind power into a weak island grid. The project was a showcase for how HVDC Light can support grid resilience through active and reactive power control with excellent dynamic performance. Compared with today's standards, the power level was a modest 55 MW at 80 kV.

Next generation StakPak: a star is born

To meet the increasing demand, Hitachi Energy launched a new range of high efficiency, low-loss modules ranging from 2500 A to 5000 A in 2024, with potential to extend to 6250 A (figure 2). The new, optimized chip is designed for lower on-state losses, which ultimately translates to a higher current capability than previous generation(s). Further, Hitachi Energy optimized its IGBT chip for lower collector-emitter leakage, which enables devices to operate at a higher temperature, purely because of chip-level thermal runaway considerations. [3]

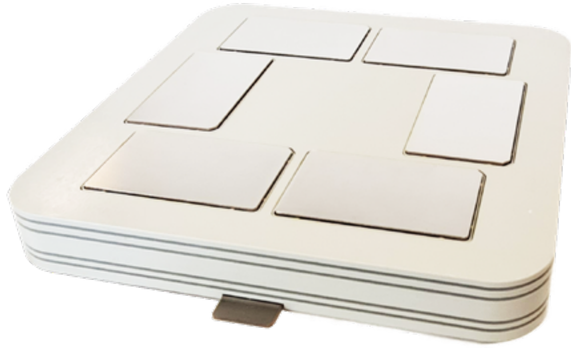

Figure 2: StakPak 5000 A_MR2

These IGBT devices are assembled into IGBT modules in the StakPak press-pack package, which is optimized for stack assembly with modular flexible current ratings. The StakPak design ensures uniform pressure in the contact to each individual chip, plus uniform current sharing, and is capable of bypassing the current load in the unlikely event of device failure (intrinsic and extrinsic) for a short period until the permanent bypass is activated.

Impressive power capabilities

The improved IGBT StakPak module contains 6 submodules and is rated for 4500V / 5000A (833 A per submodule). Devices show low V_{cesat}, which is attributed to optimization of IGBT-chip design, focusing specifically on HVDC applications, that lowers the on-state losses. The new generation of IGBT chip shows V_{cesat} of about 2.85 V at 150 °C. Lower on-state losses also imply improved current capability, thus making this module suitable for high current (>= 5 kA) applications.

Figure 1: To serve the demand, a range of press-pack modules were developed starting with 700 A 2500 V (Gotland-Link) (left), extended then to 2000 A, 3000 A, and 4500 V (fright).

The I_{ces}, characteristics of IGBT show around 50% lower current leakage compared to the previous design. This is due to the implementation of an advanced backside process for reduced collector leakage that doesn't compromise on-state losses, something that would be expected from conventional design approaches. Lower collector-emitter leakage is expected to re-

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sult in improved temperature capability (>125 °C). Measurements have confirmed stable blocking operation without any thermal runaway related failures when measured up to 150 °C.

These devices not only exhibit lower V_{cesat}, but also lie on a superior technology trade-off curve. With 600 mV lower V_{cesat} than previous designs, they have similar turn-off switching losses. The higher channel density design used for new designs also affects the turn-on losses *E*on of the new chip generation, reducing *E*on close to 40% compared to previous designs.

With our design and process improvements, IGBT-only StakPak modules deliver an impressive reverse bias safe operating area (RBSOA) capability in excess of 2x Inom where the DC-link voltage V_{CC} = 3.6 kV, at T_{vj}=150 °C.

At a given stray inductance of L_{σ}=160 nH, these devices can be safely operated without the risk of reaching critical over-voltage. Another well-known threat to device safety is dynamic avalanche that can occur in high-voltage-high-current IGBTs, limiting RBSOA capability, particularly at high temperatures. The gate drive limits the effects of dynamic avalanche, while ensuring device switch off with reduced losses.[3] [4]

This technology also shows an impressive short-circuit safe operating area (SCSOA), as well as a capability to withstand short-circuit pulses greater than 18 μs with V_{CC} =3.6 kV and V_{GE} =15 V.

StakPak & FRD: State of the Art technology for demanding applications

A high current rating, high reliability, and good cooling capabilities are common requirements for demanding applications, with important additional features being Short Circuit Failure Mode (SCFM), explosion resistance, and easy clamping for stack assembly and maintenance. StakPak designs incorporate all these features and use state-of-the-art technologies in materials engineering and manufacturing, resulting in an ideal semiconductor solution for the ever-widening Modular Multilevel Converter (MMC) topology designed for HVDC applications. In a parallel effort, Hitachi Energy also developed a range of discrete fast-recovery diodes (FRDs) with current ratings to provide free-wheeling function for StakPak modules. [5]

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[3] E. Tsyplakov et al., New generation high power semiconductors for 8GW VSC-HVDC applications, PCIM Asia 2023

[4] Jeremy Jones et al., Next generation 4.5 kV IGBT StakPak module and FRD for 8GW HVDC application, , PCIM Asia 2024

[5] www.hitachienergy.com/products-and-solutions/semiconductors/diodes

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Direct Determination of Traction Inverter High-Frequency Power Losses with Innovative Power Analysis Technology

Despite current challenges for vehicle manufacturers and suppliers, the long-term outlook for electromobility remains positive, driven by stricter CO_2 fleet targets and the expansion of charging infrastructure. In particular, the advancement of traction inverters contributes to optimized power density, cost efficiency, and environmental sustainability. Targeted and separated analysis of power losses, in particular those arising from the high-frequency switching processes of the inverter's power semiconductors, provides significantly more valuable clarity for drivetrain manufacturers to assess and stimulate optimization potential. Only suitable and application-oriented power analysis technology effectively provides these added values and helps engineers reaching the next level of marketability."

By Patrick Fuchs, Head of Business Development at ZES ZIMMER Electronic Systems

Significant advances in research and development of semiconductor and materials science led to increased market viability and attractiveness of electromobility and its technology. This has continuously resulted in highest EV drivetrain efficiencies and correspondingly high vehicle ranges. In particular, components as traction inverter and electric motor must perform together optimally. Only this enables maximum conversion efficiency and optimal driving dynamics. Manufacturers and system integrators of electric vehicle drivetrains face the challenge of optimizing the control of power semiconductors for the traction inverters' conversion process, tailored to the individual electric motor and the driving operating point. The aim is to ensure a consistently optimal energy balance across the driving profile. This with minimal impact on the mechanics (driving dynamics and acoustics). Additionally, this should occur bidirectionally in both ways of the energy flow (recuperation during the braking process).

Challenge for manufacturers and system integrators:

- High driving dynamics (controlled torque)
- High efficiency (bidirectional) (reflects range)
- Optimal acoustics (positive subjective noise rating)
- Low impact on mechanics (vibration)

However, the conversion process of a traction inverter is associated with various power loss mechanisms, in particular those that arise from the high-frequency (HF) switching processes of the power semiconductors. These losses are caused by control methods based on pulse width modulation (PWM). Resulting switching processes impose harmonics and high-frequency voltage and current components on the drive system, which do not contribute directly to generating turning momentum (torque), but cause power losses and affect the vehicle's electromagnetic environment. Some of these losses and loss mechanisms are listed below:

Typical losses and loss mechanisms due to HF components:

- Winding copper losses and iron core losses of the motor
- Leakage currents and associated insulation damage in the motor
- Switching losses and heat losses in the semiconductors in the inverter

In order to meet the above challenges for the drive system, the following solutions for optimization are available:

Solution for manufacturers and system integrators:

- Efficient control method of the traction inverter (vector control, space vector modulation)
- Variable switching frequency (depending on the operating point)
- Adaptive adjustment of the edge steepness (du/dt) of the PWM voltage

The question that arises here is: How can the effect of the above measures on the drive system's optimized efficiency be verified? With this article we will clarify this question and describe in particular the procedure for directly determining the inverter-related high-frequency power losses of an EV electric drivetrain using the ZES ZIMMER LMG671 power analyzer.

Integrating the power analyzer into the measurement setup

A complete efficiency measurement on the electric drive train is usually performed by measuring the electrical power between the respective main components: high-voltage battery (HV battery), traction inverter and electric motor. A typical connection of the LMG671 power analyzer in the current paths of the measurement setup is shown in Figure 1. The individual stages of the power measurement follow according to this connection shown.

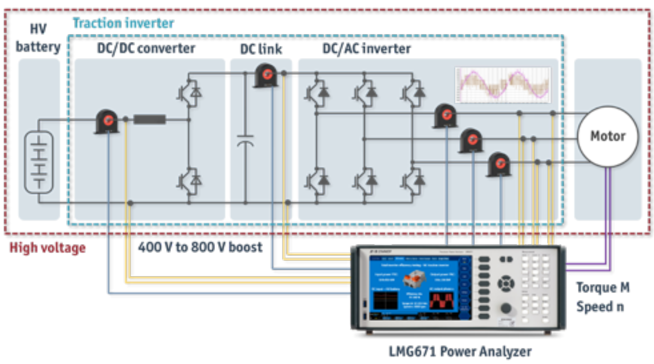

Figure 1: Wiring of the LMG671 power analyzer to the electric drivetrain test setup

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San'an

The measurement of currents in their signal form, frequency and phase, both on the DC and AC side of the inverter, requires high accuracy, linearity and stability. Current sensors with minimal phase errors are essential, particularly at the inverter output and fundamental frequencies of up to 1000 Hz. Precision current transducers, such as of ZES ZIMMER's PCT series, should be used here, which are also supplied directly from, and automatically scaled by the LMG671 using its unique Plug'n'Measure feature.

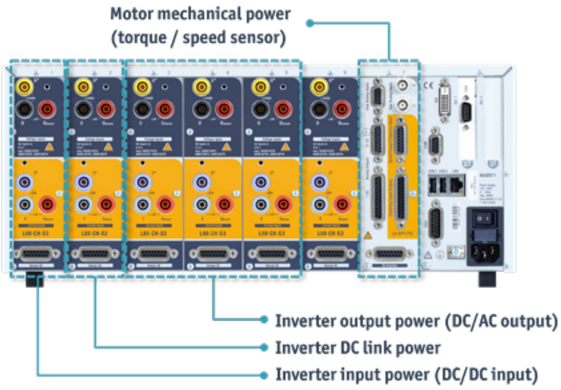

Figure 2: Wiring and grouping of the LMG671 measuring channels

DualPath measuring channel architecture enabling power spectrum separation

Signature for the LMG600 power analyzer series is its powerful GROUP menu, as shown in Figure 3, in which the targeted application-specific parameterization of the power analyzer for the processing of the measurement signals happens. As a result, plausible and precise measurements can be carried out. In particular, the parameter "Processing" is of high significance in this matter, since the LMG600 series' DualPath technology in the corresponding mode, enables the separation of the fundamental, narrowband and wideband power as intended in this application.

Figure 3: LMG671 GROUP menu for parameterizing the signal processing

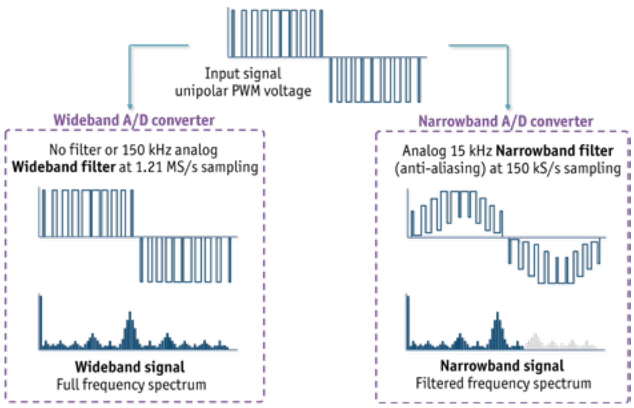

Figure 4: Schematic representation of the LMG600 series DualPath signal processing

This can be achieved by individually adjusting the narrowband and wideband path's low-pass filter cut-off frequency. DualPath parametrization summarized:

- **Signal processing:** defining the two-path signal processing using DualPath
- **Signal filters:** with DualPath processing, the filters for the narrowband and wideband path can be individually adjusted

DualPath describes the simultaneous sampling (two A/D converter principle) and processing of the measurement signal as a narrowband and wideband spectrum, both in the current and voltage path of a measurement channel, see Figure 4.

The pulse-width modulated voltage signal, in Figure 4 the output voltage of the inverter which has already been converted from delta to star voltage, is now further processed using DualPath in two bandwidths to calculate the measured values, here the narrowband and wideband signal. The LMG671 also provides the exclusive fundamental frequency values by integrated Fast Fourier Transformation as an additional 3rd bandwidth. The same DualPath processing occurs simultaneously for the current signal. This ultimately results in equivalent bandwidths for the power signal. The resulting trio of bandwidths provides the following power spectra at the inverter output for further detailed analysis and measured value processing:

- **Full power spectrum** up to the 150 kHz cut-off frequency of the wideband filter or unfiltered (utilizing the 10 MHz analog bandwidth of the S-channel)
- **Aliasing-free power spectrum** up to the 15 kHz cut-off frequency of the narrowband filter
- **Fundamental power** from the Fast Fourier Transformation applied to the aliasing-free power signal of the narrowband path

Analysis of inverter-related high-frequency power losses

Once the DualPath processing has been parameterized, the power analyzer's integrated script editor enables the HF power respectively the HF power loss component of the traction inverter to be determined using mathematical calculations. The difference between the measured wideband and fundamental power is typically calculated as in the following formula, whereby this is based on the active power component:

$$P_{hf} \cong P_{wide} - P_{fund}$$

high-frequency power wideband power fundamental power

This formula is finally written and installed in the power analyzer's script editor, see Figure 5. Here, the script is basically written in 3 sections to define, assign and calculate values, as finally the HF power:

- **Definition of variables – the "def" function:** script variables are defined with e.g. S.I. units

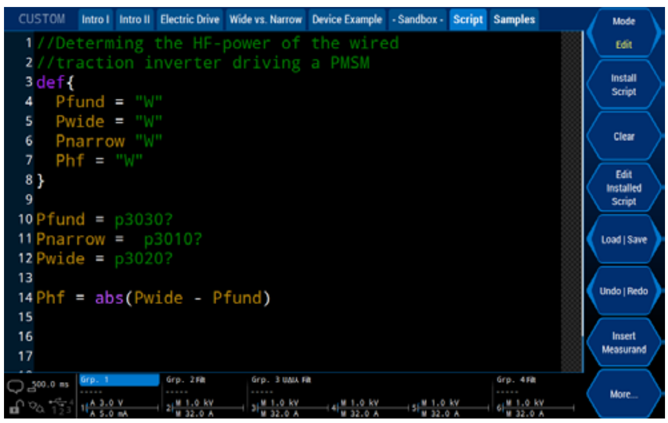

Figure 5: LMG671 script editor for calculating high-frequency power losses at the converter output


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- **Assignment of measured values:** script variables are assigned to measured values
- **Calculating HF power:** applying mathematical operations for calculations

Finally, in the application scenario on an EV drivetrain, all three electric powers can be measured and evaluated in a time-efficient and highly accurate manner for specific operating points, i.e. at constant speed and different torques, and even for bidirectional operation, i.e. acceleration operation and regenerative braking operation (recuperation via back EMF), see Diagram 1. By having the measurement supplemented with additional torque, speed and eventually mechanical power measurement, the high-frequency power (losses) can likewise be calculated with below following formula from the motor's power losses, as additionally visualized in Diagram 2:

$$P_{hf} \cong P_{lm\_wide} - P_{lm\_fund}$$

high-frequency powerlosses wideband motor power losses motor fundamental power losses

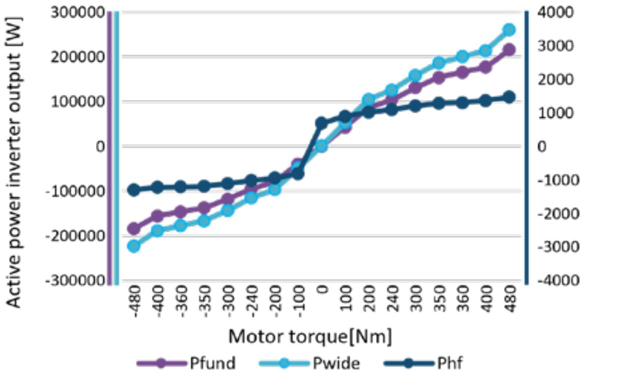

Diagram 1: Active inverter output power at 4000 rpm, bidirectional traction inverter on synchronous machine

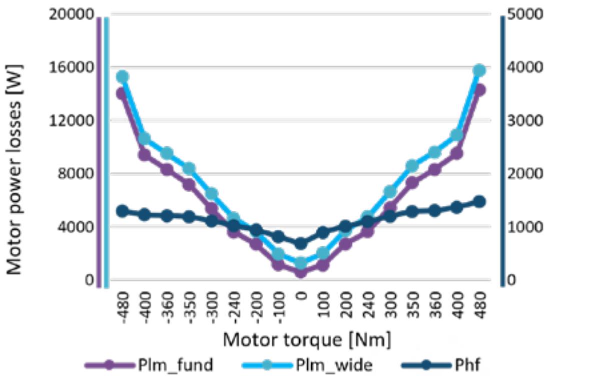

Diagram 2: Motor power losses at 4000 rpm, bidirectional traction inverter on synchronous machine

For the application itself, the LMG671 also offers the specific creation and display of a measurement menu customized to its requirements, which allows the direct reading and cross-checking of the measured values, the calculated values, and signal waveforms during testing at the operating point reached. This is shown as an example in Figure 6. Scope signals can also be substituted or supplemented by plot diagrams, in order to observe the thermal settling of the test object for the operating point to be verified.

The big picture: efficiency analysis of the entire drivetrain
The separation of the wideband power spectrum for separate analysis of the fundamental and HF power is part of a comprehensive efficiency measurement on an electric drivetrain. The LMG671 is optimally developed for this application.

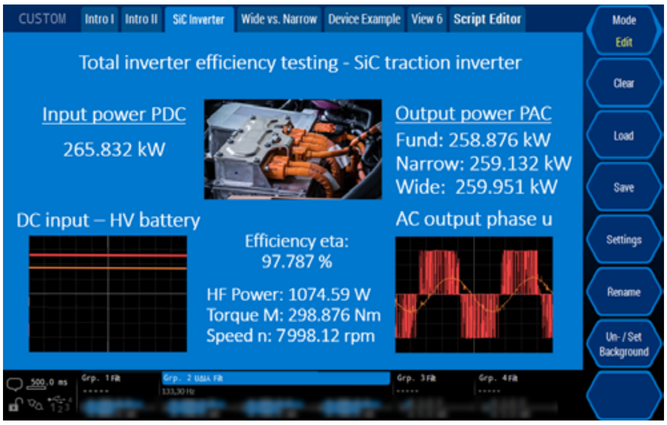

Figure 6: LMG671 CUSTOM menu for the power efficiency testing application of a SiC traction inverter

The measurement is supplemented by the acquisition of either analog or frequency signals (encoder or resolver signals) from torque and speed sensors via the power analyzer's process signal interface (PSI) – the user receives a direct measurement of the torque, the speed and, as a result, the mechanical power of the motor. Measuring on a synchronous motor (e.g. permanent magnet synchronous motor), the LMG671 also facilitates the measurement of the Id, Iq and I0 current components for the verification of the field-oriented control. When connecting according to Figure 1 and Figure 2, it furthermore ensures a complete measurement of the power conversion efficiency with the highest accuracy and reliability. For an optimized display of the results, the LMG600 series graphical user interface (GUI) enables to quickly create an application-specific measurement menu as illustrated in Figure 6. It provides all the important data at a glance. Performing efficiency measurements with dependencies of the speed and torque, as a first step at constant

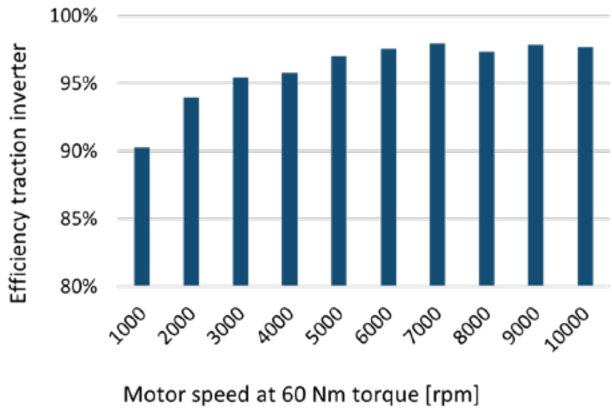

Diagram 3: Efficiency of the traction converter at variable speed and constant torque

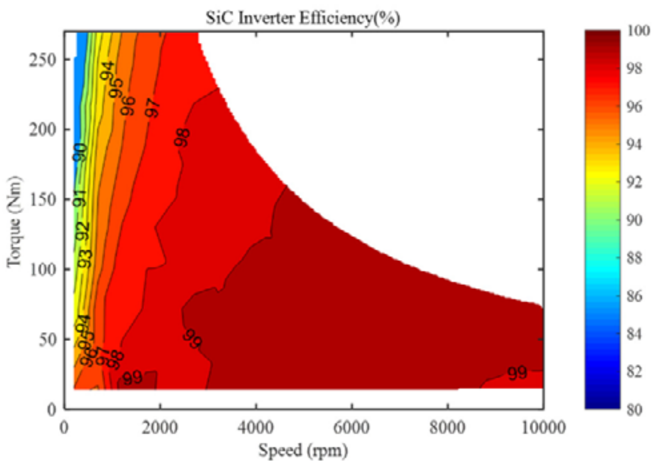

Figure 7: Efficiency map of a SiC inverter, (Su, et al., 2022)

torque, the efficiency curve in Diagram 3 can be obtained. With further iterative torque-speed combination measurements, one gets the so-called efficiency map for certain operating quadrants, as shown in Figure 7 for the first quadrant (forward acceleration/ driving).

Recognizing the clues: inverter input and output waveform analysis

At times, the devil is in the details but a further closer analysis, based on raw data of the measured signals and beyond the numerical analysis of the electrical power and efficiency, can shed some light on the matter. With the dedicated signal analysis software LMG600 SampleVision, the samples of the signals measured can be streamed at up to the maximum power analyzer's sampling rate of 1.21 MS/s to enable post-processing evaluation options of the recorded waveforms, such as:

- Recording and qualitative evaluation of the inverter signals
- Qualitative investigation of atypical or unwanted signal peaks

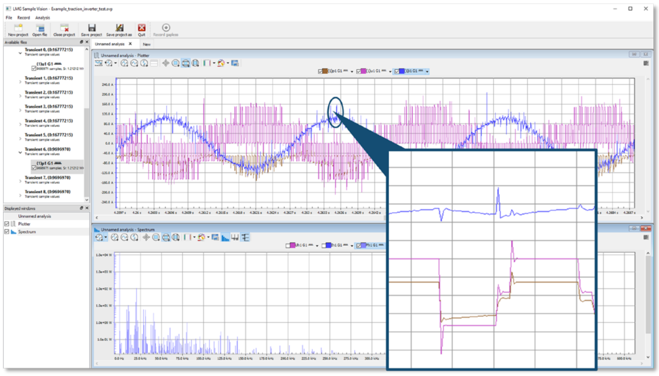

Figure 8: Analysis of the inverter signals with the LMG600 SampleVision waveform analysis software

- Investigation of the frequency spectrum up to 600 kHz for a specified time interval

This evaluation options pave the way for optimization potential of the switching behavior, such as:

- **Adjustment of the switching time:** soft switching
- **Snubber circuits:** implementing RLC circuits in the commutation path to compensate or smooth the transient peaks
- **Adjustment of the gate resistor:** increase/decrease resistance value at the switch-on and switch-off time (e.g. at SiC-MOSFETs)

Conclusion

The precise determination of high-frequency power losses in traction inverters is crucial for optimizing efficiency, driving dynamics, and overall system reliability in electric vehicles. By leveraging advanced power analysis technologies like the LMG671 precision power analyzer, manufacturers can directly measure and separate fundamental and high-frequency power losses, enabling targeted optimization of inverter control strategies. The application of the power analyzer's specific DualPath processing allows for detailed spectrum analysis, improving insights into loss mechanisms and their impact on drivetrain performance. This approach supports the development of more efficient and durable EV drivetrains, ensuring a balanced trade-off between range, performance, and mechanical integrity. Ultimately, precise and sophisticated power loss analysis provides a solid foundation for engineering advancements and enhanced marketability of electromobility solutions.

References

Su, H., Zhang, L., Meng, D., Li, Y., Han, N., & Xia, Y. (2022, September 24). Modeling and Evaluation of SiC Inverters for EV Applications. Retrieved from MDPI: https://www.mdpi.com/1996-1073/15/19/7025

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Bi-Directional GaN Switches: Power Conversion with Single- Stage BDS Converters

A single-stage with bi-directional GaN eliminates the PFC stage and the DC-link capacitors while enabling ultra-high frequencies. What are the implications and benefits?

By Llew Vaughan-Edmunds, Senior Director of Product Management & Marketing, Navitas

Over 70 % of today's high-voltage power converters use a 'two-stage' silicon topology. For example, a typical AC/DC EV On-Board Charger (OBC) implements an initial power-factor-correction (PFC) stage and a follow-on DC/DC stage, which is buffered with bulky 'DC-link' capacitors. The problem with this topology is that the resulting systems are large, lossy, complex and expensive. This article looks at a new class of power converter that enables single-stage conversion and allows bi-directional power to move back and forth between storage and the grid as required.

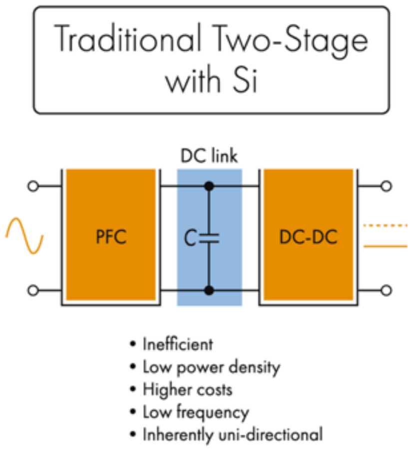

Figure 1: Over 70 % of today's high-voltage power converters use a two-stage topology, with a PFC stage followed by a DC/DC stage to deliver the desired voltage.

A short history of bi-directional power converters

An ideal switch is bi-directional, able to block voltage in both directions AND handle current in both directions. It would offer minimal conduction and dynamic losses, dissipate heat effectively, and have a high-power density. In the nearly 80 years since the creation of the bipolar transistor (1947), there have been many developments in power semiconductors that have moved the industry closer to this ideal.

The thyristor (1957) was capable of handling voltage in both directions, but not current. The triac (1958) could handle both current and voltage, but was very slow and operated at just 50 or 60 Hz, matching the AC line. The MOSFET (1959) could operate at tens of kilohertz, even 100 kHz. A bi-directional MOSFET was subsequent created, but this was low power and had limited applications. The silicon IGBT (1980) followed and offered much higher power, but bi-directional functionality remained a challenge, with the IGBT able to handle either current OR voltage, but not both in a single device.

The introduction of wide bandgap semiconductors enabled significant gains in power technology, significantly improving power density; but again, these initial devices lacked bi-directional capability. The use of gallium nitride (GaN) took things further, providing higher switching frequencies and high power, with integrated control and protection on the same chip. However, it still wasn't bi-directional.

In March, however, Navitas launched the industry's first bi-directional 650 V GaN power IC, enabling the transition of power conversion from a two-stage, to single-stage topologies. Navitas's NV6427 and NV6428 are bi-directional GaN power ICs that deliver at 650 V_{SS} continuous with an $R_{SS(ON)typ}$. of 50 mΩ (I_{SS} of 49 A) and $R_{SS(ON)typ}$. of 100 mΩ (I_{SS} of 25 A). They have zero reverse-recovery charge and operate at up to 2 MHz. They are housed in a TOLT-16L thermally-enhanced top-cooled package.

Bi-directional GaN power switch

The advent of bi-directional GaN power switch consolidates the two stages into a single, high-speed, high-efficiency stage, and in the process, eliminating the bulky capacitors and input inductors. It is able to handle current and voltage in both directions and switch at very high frequency which means that it is well-suited for single-stage converters.

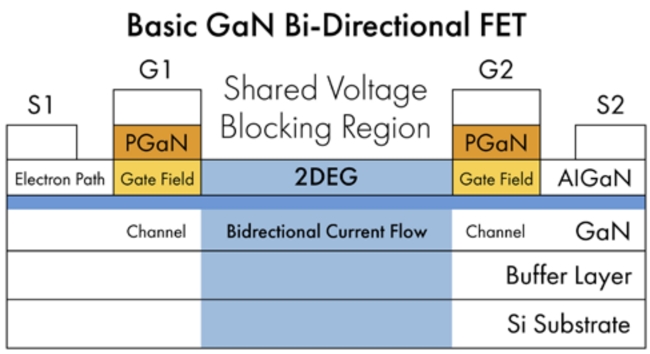

Figure 2: Bi-directional GaN switches use a GaN/AlGaN structure on silicon substrate to create a two-dimensional electron gas (2DEG) conducting channel with two power terminals and two gates.

The bi-directional GaN must handle voltage in both directions and therefore requires separate gates to control current flow depending on polarity. To achieve this, a GaN/AlGaN epi-stack is grown on a silicon substrate to form a 2DEG conducting channel. The processed device structure features two power terminals and two gates. Implementing this structure alone would have performance issues as the silicon substrate is not associated with the source terminals and therefore floats, leading to a substrate potential build-up and reducing the 2DEG concentration due to this 'back-gating' effect.

Navitas was the first to develop and release an active-substrate-clamp to autonomously drive the silicon substrate to the source with the lowest potential. This has the resulting benefit of enabling the BDS (Bi-Directional Switch) to operate stably with no shifting in resistance and to run 15 °C cooler in many applications than alternative unclamped solutions. This improvement can be seen in figure 4, with current (green triangle wave), and voltage across the switch: clamped (pink curve) and unclamped (white curve). Here we see proper clamping removes any increases, improving efficiency and enabling a smoother operation.

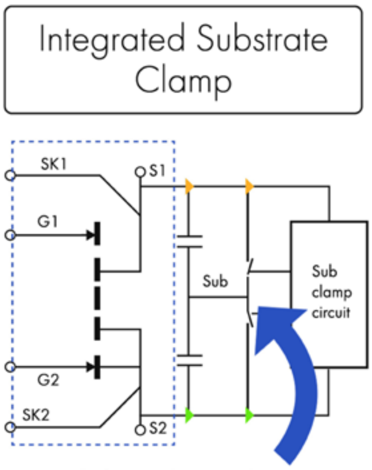

Figure 3: The devices automatically detect and connect alternative sources to substrate.

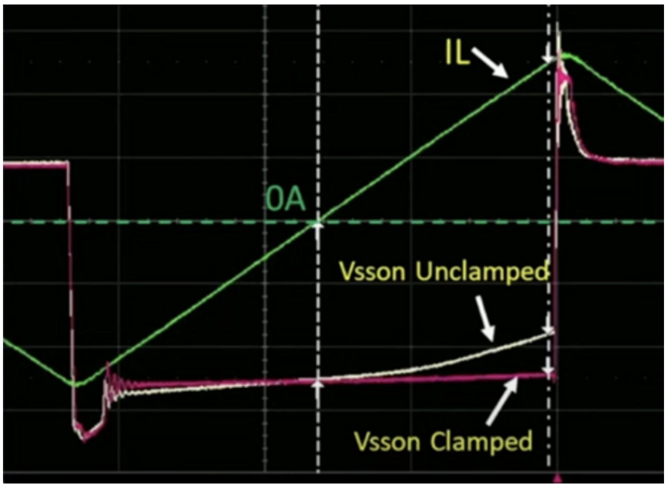

Figure 4: Clamped (pink) / unclamped (white) voltage and current (green) across the switch – with clamped voltage not displaying an efficiency-reducing voltage spike.

It should also be noted that bi-directional GaN also requires a dedicated driver to control its two gates, which must be capable of handling high transient conditions, very high voltage isolation, and ensure exceptional signal integrity. In this case, the device is able to operate at over 5 kV and handles extreme transients up to 200 V/ns.

Therefore, to complement the bi-directional GaN, the IsoFast™ driver has been developed as a high-speed isolated GaN driver, specifically tailored for this switch, operating at over 1 MHz and handling 5 kV while maintaining high-speed signals with integrity switch, operating at over 1 MHz and handling 5 kV while maintaining high-speed signals with integrity. Additionally, no negative drive is required to turn-off the device, reducing cost and complexity.

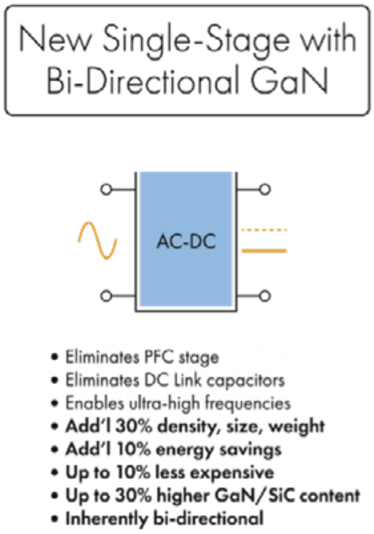

Figure 5: The new single-stage with bi-directional GaN eliminates the PFC stage and the DC-link capacitors while it enables ultra-high frequencies. This means additional 30 % in terms of densitity, size and weight, complemented by 10 % energy savings and up to 10 % of price savings for the system solution.

Benefits of the single-stage topology

As we said at the start, the overwhelming majority of power converters use a two-stage topology, which is slower as well as being less efficient, and results in bulky power converters with losses that are far from ideal. As an industry, we've made great advances, especially with the introduction of silicon carbide (SiC) and GaN to improve these two-stage converters and improved efficiency, power density and switching speed. But we're approaching the limits of this topology, even with wide bandgap materials.

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The creation of single-stage BDS converters not only eliminates the PFC stage, but with it, the electrolytic capacitors and DC link capacitors. Furthermore, the topology is inherently soft switching, making it possible to exploit the high-frequency advantage while also significantly shrinking passive components. As a result, this delivers a 30 % improvement in power density, a 10 % improvement in energy savings, and a 10 % cost reduction. Arguably, more important, however, is the ability to deliver the bi-directional energy flow, which is crucial for allowing renewables, the AC power grid, energy storage (including electric vehicle on-board chargers) to efficiently exchange power.

Real-world example: solar microinverter

Moving away from theoretical values, let's look at a traditional 400 W solar microinverter with a two-stage topology, which transfers from the solar panel to storage or the grid. This uses a DC/DC step-up transformer, followed by a 400 V_{DC} bus, which then converts 400 V_{DC} to AC in order to feed the grid. As we can see in figure 6 and 7, this design requires magnetic components, plus bulk capacitors, and multiple switching components.

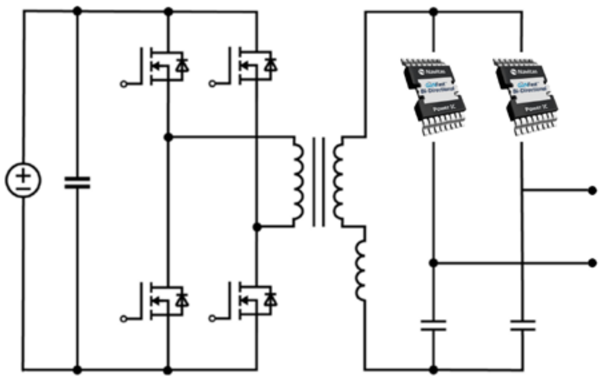

Figure 6: 500 W solar microinverter in a cyclo-converter-based topology.

Figure 7 shows a single-stage BDS that is being implemented by a leading solar microinverter manufacturer. For this, the design delivers a more powerful design (500 W) in a significantly smaller form factor, eliminating one magnetic component, and reducing the component count. This topology increases system efficiencies from 96 % to 97.5 % and reduces generation costs by 30 %, from \$0.10/W to \$0.07/W.

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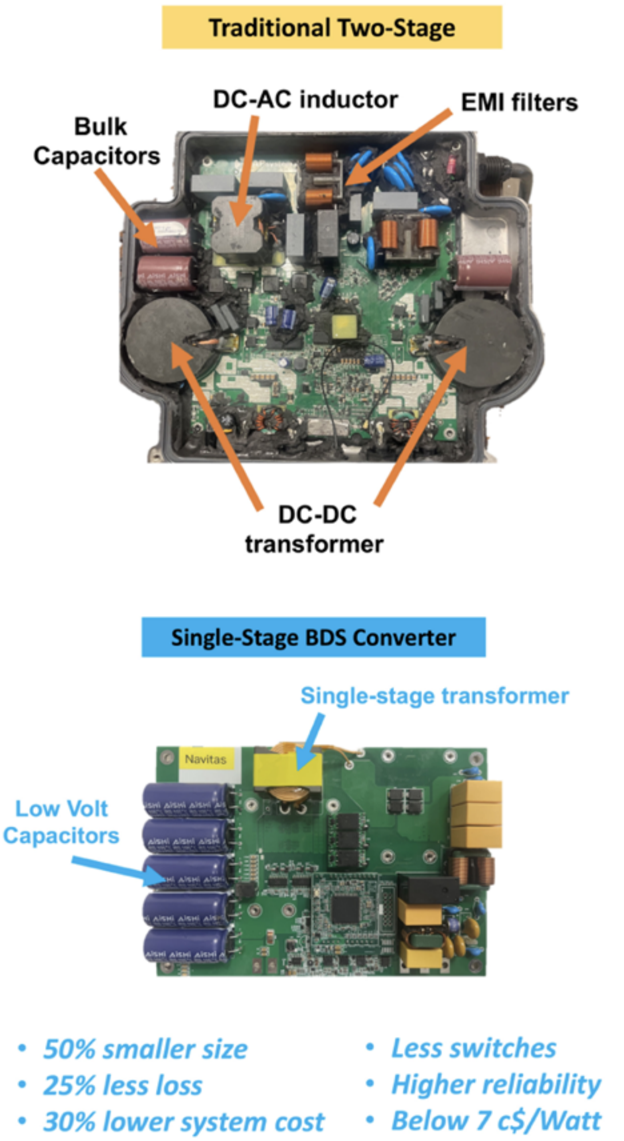

Figure 7: The 500 W solar microinverter in a cyclo-converter-based topology (circuit diagram in figure 6), with traditional 400 W 2-stage solution (top) and single-stage BDS converter solution showing reduction in size, component count, and complexity (bottom).

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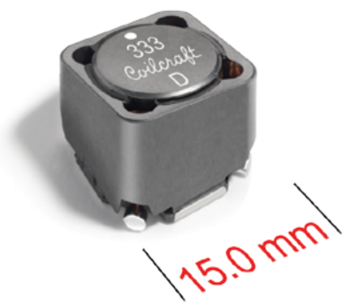

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Driving Innovation in Power-Supply designs with integrated TOLL-packaged GaN Devices

Today's power-supply designs require high efficiency and power density. As a result, designers are using gallium nitride (GaN) devices across various power-conversion topologies. GaN can enable high-frequency switching, which reduces the size of passives and therefore increases the density. GaN also lowers switching, gate-drive and reverse-recovery losses compared to technologies such as silicon and silicon carbide (SiC), which increases the power design efficiency.

By Srijan Ashok, Product Marketing Manager for GaN, Texas Instruments

GaN can enable high-frequency switching, which reduces the size of passives and therefore increases the density. GaN also lowers switching, gate-drive and reverse-recovery losses compared to technologies such as silicon and silicon carbide (SiC), which increases the power design efficiency.

You can use 650V GaN FETs for the AC/DC-to-DC/DC conversion, or 100V or 200V GaN FETs for DC/DC conversion to implement the power supplies.

If you work on cutting-edge products, it is also important to choose devices with an industry-standard footprint in order to streamline the supply chain for procurement teams. For this reason, in the 650V space, the transformer outline leadless (TOLL) package is gaining popularity in high-power-supply designs.

Apart from choosing industry-standard devices, integrated devices such as TI's LMG3650R035 GaN field-effect transistor (FET) can play a major role in creating designs with high density and reliable operation across various power topologies. This device has an integrated gate driver, and protection circuitry such as overcurrent protection, overtemperature protection and short-circuit protection. The integration of protection circuitry helps reduce external components to implement these features. The device can also support multiple power topologies in the high-voltage space, including totem-pole power factor correction (PFC), inductor capacitor, phase-shifted full bridge and dual active bridge.

Integrating the gate driver helps you create a simple, high-density and clean layout with significantly reduced parasitic coupling, as illustrated in Figure 1. Integration becomes especially important in high-switching- frequency power conversion because circuit parasitic coupling in the gate loop causes an increase in gate noise and overlap losses. By using integrated power stages, the parasitic coupling becomes negligible and simplifies layouts.

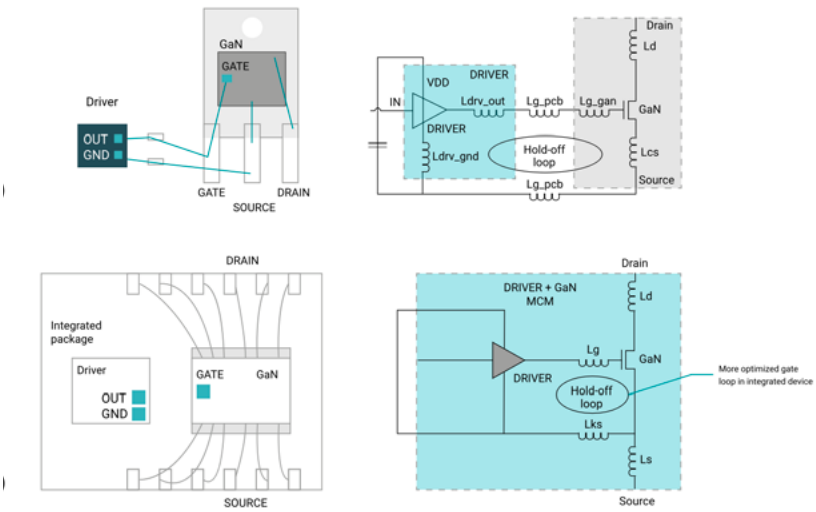

Figure 1: Circuit parasitics integrated GaN power stage vs. discrete GaN

Application areas of the TI high voltage TOLL devices

Let's review several major application areas for TI's TOLL devices where you can leverage the integrated protection features, integrated zero-voltage detection (which reduces third-quadrant losses), and the reduced overlap switching losses caused by negligible parasitic coupling.

PSUs for data center and telecommunication power

As demand for data centers and hyperscale computing increases, the need to create highly efficient, power- dense power-supply units (PSUs) will grow exponentially. Even as the telecommunications space moves from 4G to 5G – and now 6G – the power requirements of the equipment keep increasing, but the form factor remains the same.

This scenario becomes a potent use case for integrated 650V TOLL devices, which primarily convert AC power into a DC bus through the PFC and DC/DC stage, as shown in Figure 2. Our GaN devices in the TOLL package can achieve greater than 99% efficiency in the PFC stage and greater than 98% efficiency in the DC/DC stage across the topologies I mentioned earlier.

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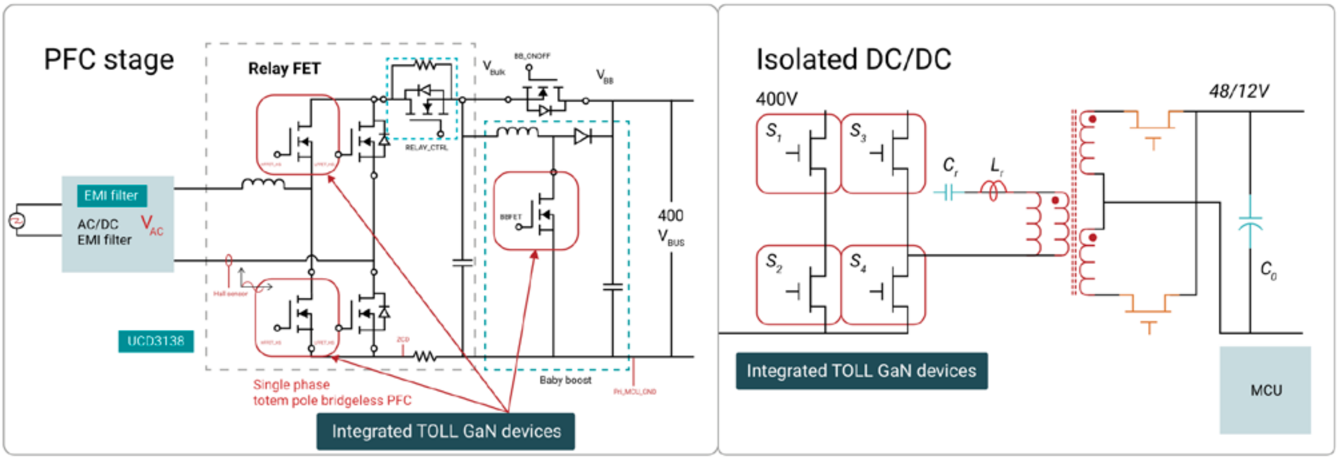

Figure 2: PSU block diagram

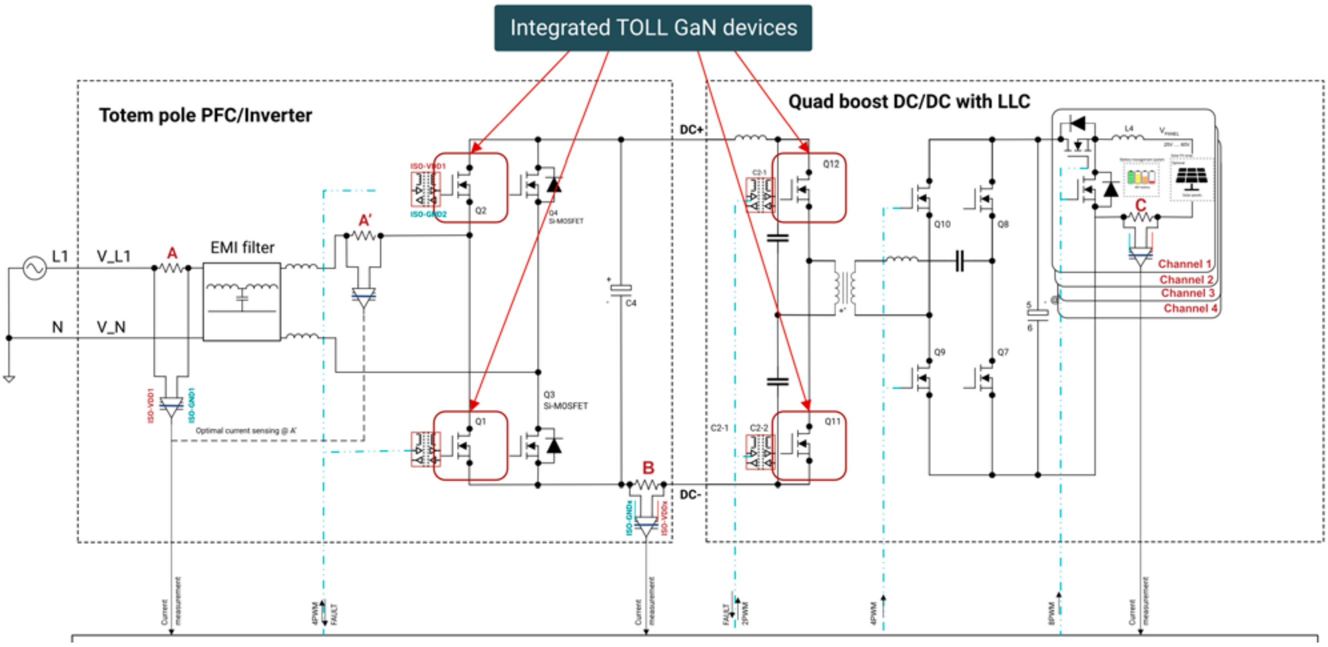

Figure 3: Microinverter block diagram

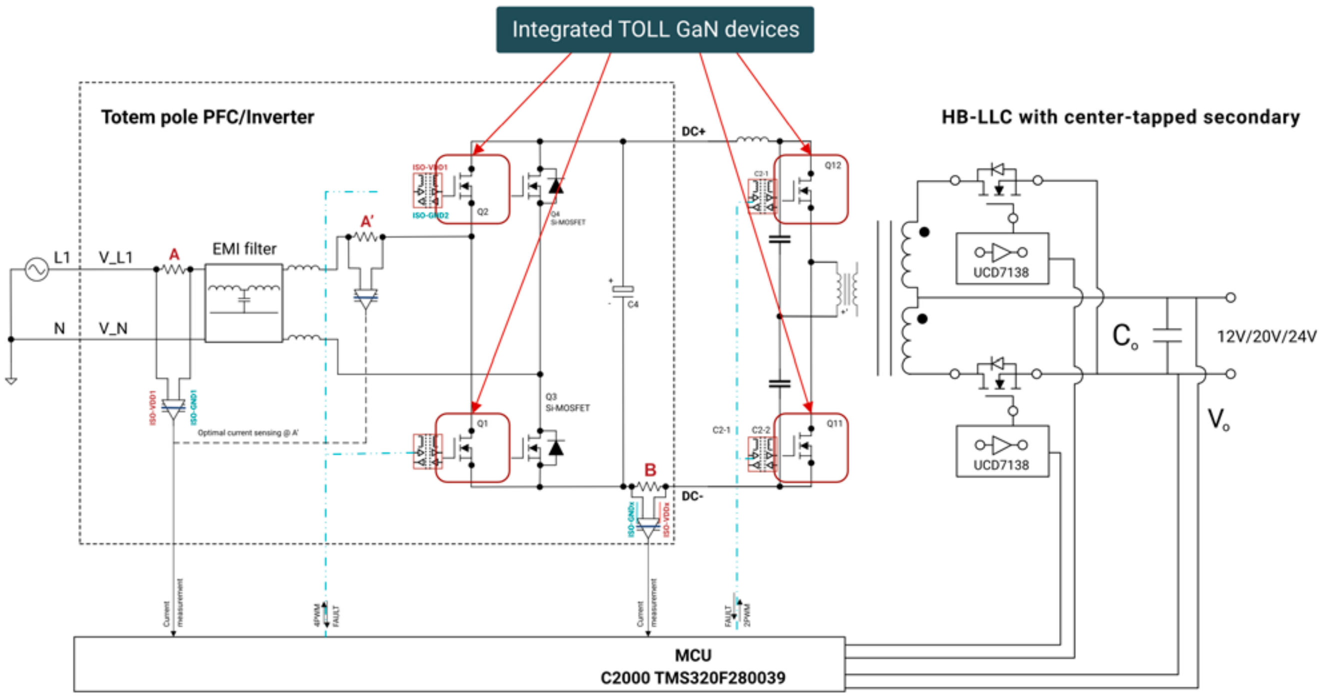

Figure 4: Onboard chargers

Solar microinverters

Solar energy as a power source is on the rise. As shown in Figure 3, both the bidirectional DC/DC and the PFC and inverter stage can use an integrated GaN TOLL device to convert the solar panel voltage to AC power. As clean energy requirements scale rapidly, it's important to deliver high efficiency and high power with a small footprint using industry-standard devices.

A TOLL GaN device can add value with an industry-standard footprint and integrated features. These devices can help you scale to different power levels and with different topologies using different drain-to-source on- resistances while not struggling with layout, since most sensing and optimization features are integrated in the power stage.

TV power supplies

There is sizeable growth potential in the large-screen (>40 inch) television market, as well as a trend toward lighter and thinner screens for aesthetic reasons. Because the power requirements increase with larger screens but the size is thinner, it's important to make televisions more power efficient. AC/DC conversion can use the TOLL devices in the PFC and DC/DC stage.

Integrated TOLL GaN devices enable you to keep the size of the passives the same and keep the external circuitry to a minimum with simple routing to deliver thinner printed circuit boards. The design will also be more efficient, while sticking to an industry-standard footprint.

2W, 3W and 4W onboard chargers

Vehicle electrification is always in the news as the world strives toward reducing tail-pipe emissions. Easy access to on-the-go charging necessitates electric vehicle onboard chargers (OBCs). Because its location in an electric vehicle is in the chassis, an OBC should be power dense and efficient in order to occupy minimal space and reduce losses, as there is no active cooling to dissipate losses.

Figure 4 shows a typical OBC block diagram. An integrated TOLL GaN device can help both the PFC and DC/DC stage by optimizing design size through integration and a higher switching frequency and reduce losses (gate drive and switching losses) for more effective heat dissipation. With TOLL GaN devices, at the device level all protections are enabled as well, which will help with the resiliency of the OBC design while keeping an industry-standard footprint.

Conclusion

One of the biggest design challenges that a power designer of the future will face is to deliver ever increasing power levels at the lowest possible losses with a high-density design. An integrated TOLL GaN device helps here by combining integrated GaN with an industry standard footprint and eliminates the hassle of extra circuitry and complicated PCB layouts. This helps in making the design less cumbersome. Additionally, this will also enhance designs in other end equipment spaces such as motor drives, industrial power supplies and appliance power who also value simple, high-density designs.

With the GaN FET technology making leaps, we will keep investing and improving the figure of merit of the TOLL devices in the future, aiding the designers endeavor to deliver even higher power in the same space.

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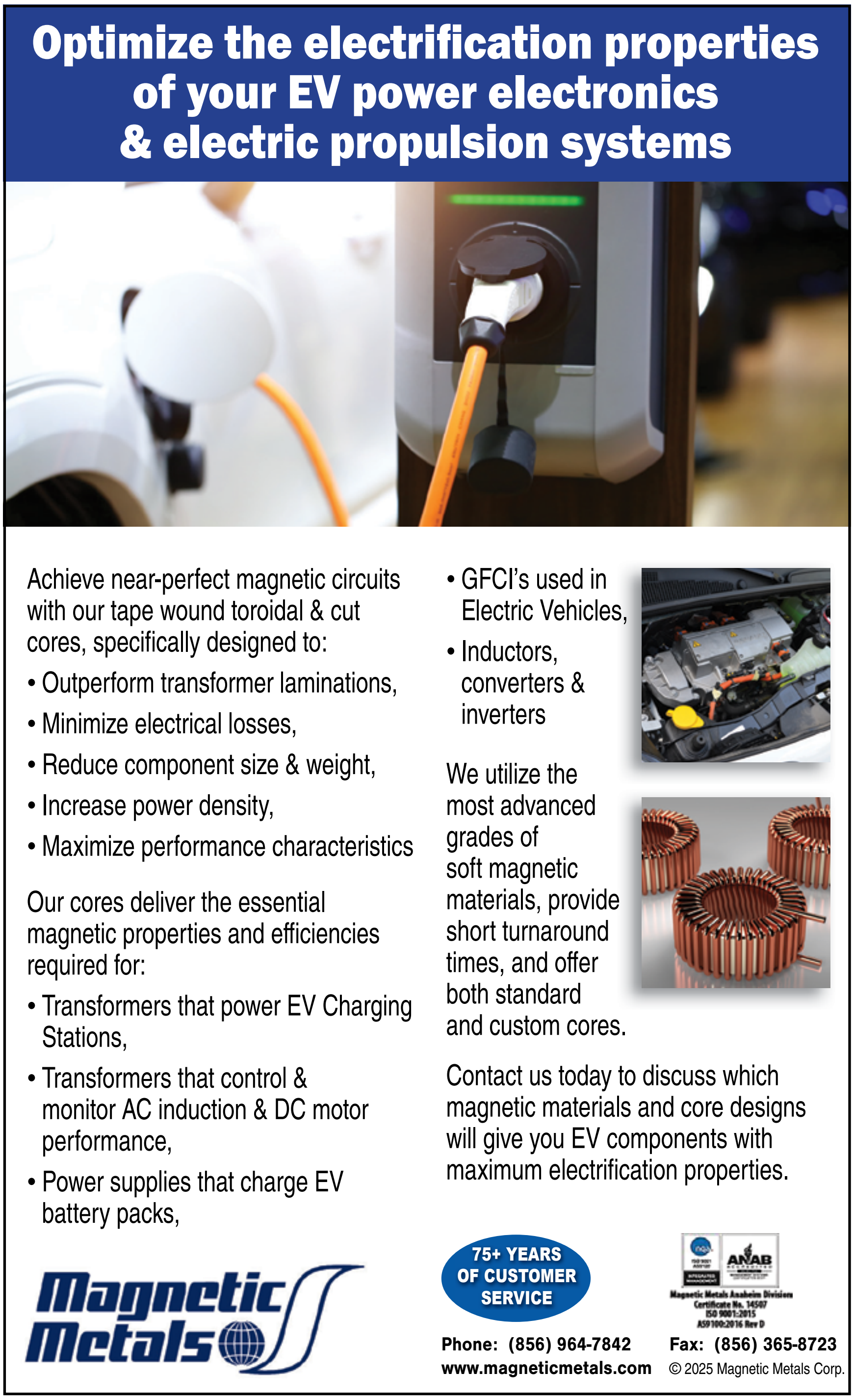


Enabling Smarter DC Link Discharge in EV Traction Inverters

Discharging high-voltage DC link capacitors in automotive inverters typically requires bulky, costly external components impacting significantly the bill of materials (BOM) cost (estimated $4–$6 per inverter), consuming valuable PCB space, and complicating the design—particularly in compact and cost-sensitive EV powertrain applications. NXP's GD3162 gate driver introduces a highly integrated solution, reshaping how system designers approach discharge strategy by embedding it directly into the gate driver IC—enabling leaner designs, reducing BOM, and paving the way for advanced diagnostic and control strategies.

By Bétina Bebey, High-Voltage Gate Drivers Product Marketer, NXP Semiconductors

DC Link Discharge Challenges in Inverter

High-voltage DC links are central to a wide range of power electronic systems in electric and hybrid vehicles—including inverters relying on large capacitors (e.g 1mF) to stabilize the voltage, reduce ripple, and support efficient control and operation. However, in the event of a malfunction or emergency—such as a crash or unexpected shutdown—the energy stored in these capacitors must be safely discharged to prevent human electrocution during car maintenance and in repair scenarios or first responders in crash. In this context, the automotive standard LV123 defines strict requirements for DC link discharge. It mandates that the voltage on the DC link (up to e.g 950V) must be reduced to a safe level (typically below 50 V) within defined time limits: using passive discharge within 2 minutes and active discharge within 2 seconds.

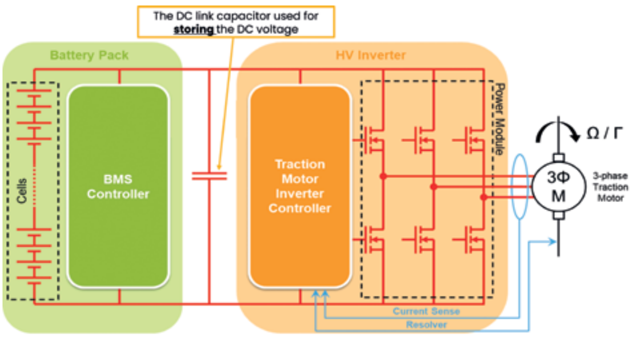


Figure 1: High-Voltage EV Powertrain Architecture

Conventional active discharge systems often utilize resistive elements or PTC devices, either switched or thermally triggered, to dissipate the energy. These solutions, while effective, come with several drawbacks. For instance, PTC-based systems might need significant cool-down time (often 2 to 10 minutes) before they can be safely reactivated, limiting their suitability for repetitive or fast-acting events. Additionally, resistors designed for continuous operation must be dimensioned for worst-case conditions—adding cost complexity, and space challenges.

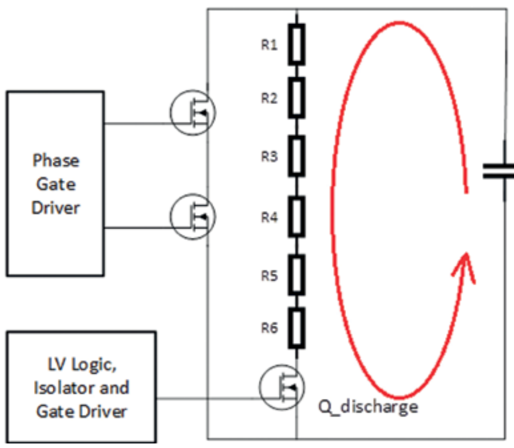


Figure 2: Conventional active HV bus discharge methods

Integrated Discharge: A New Paradigm for Inverter Design

The GD3162 represents a shift in power electronics system design to address active discharge. Rather than externalizing the discharge function, NXP has integrated it within the gate driver, leveraging the existing power transistors of the inverter itself. This system-level approach eliminates the need for external components dedicated solely to discharge, reducing BOM while freeing up space for other critical components.

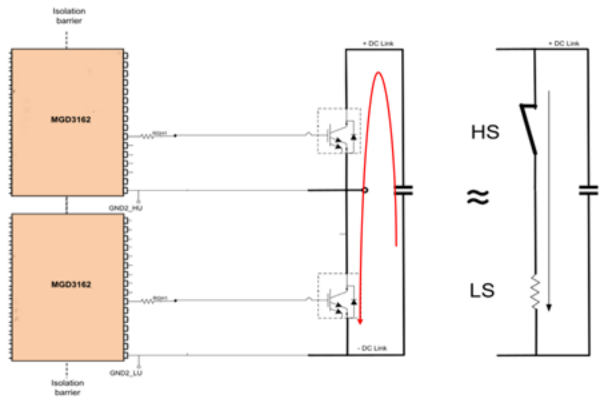


Figure 3: GD3162 DC Link Discharge operation

The graph below illustrates the controlled discharge of a 950V, 635uF DC link capacitor using a SiC power module and the GD3162 gate driver.

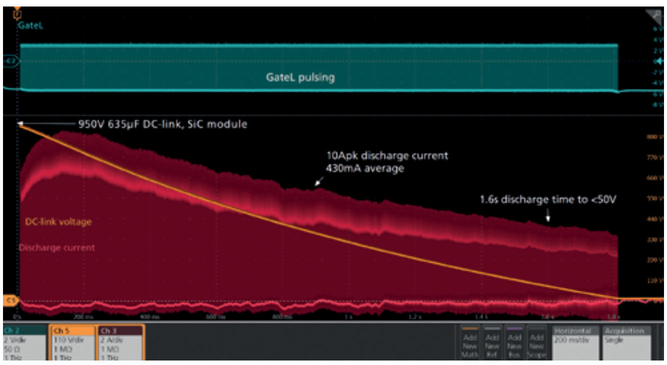


Figure 4: Demonstration of active DC Link Discharge using GD3162 Gate Driver

The integrated discharge function is more than a cost-saving measure—it's a platform enabler. With fewer components, designers can build more compact inverters, simplify system layout, and reduce failure points. The embedded intelligence also enables tighter coordination between safety functions, protection mechanisms, and diagnostics, which is crucial in automotive environments where functional safety and reliability are paramount.

System Benefits and Integration Considerations

From a system integrator's perspective, adopting a gate driver with built-in discharge control brings numerous advantages. First, the simplified bill of materials reduces sourcing complexity and overall production cost. Second in addition, the GD3162's design flexibility accommodates various system topologies. Whether used in SiC or IGBT-based platforms, the discharge function seamlessly integrates with the power stage. It also aligns with functional safety requirements, supporting ASIL levels through redundant monitoring, fail-safe modes, and self-diagnostic routines. This helps reduce the validation burden during automotive qualification and supports robust system-level FMEA.

Wolfspeed Collaboration: Validating Long-Term Reliability

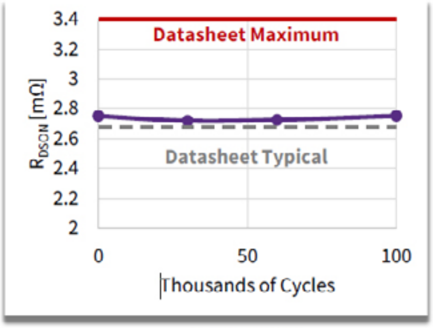
To validate the power module lifetime impact of the GD3162 DC link discharge feature, NXP collaborated with Wolfspeed to evaluate the effects of repeated discharge on Wolfspeed's EAB450M12XM3 SiC MOSFET power module. This test involved over 100,000 high-stress discharge cycles using a single phase setup under 800V and 400µF DC link conditions.

Despite the aggressive testing conditions—repeated discharge stress on the same die—Wolfspeed observed no measurable degradation in the SiC power module as illustrated on figure 5. These preliminary findings are encouraging and illustrate how a properly integrated discharge strategy can meet demanding automotive reliability standards without compromising performance.

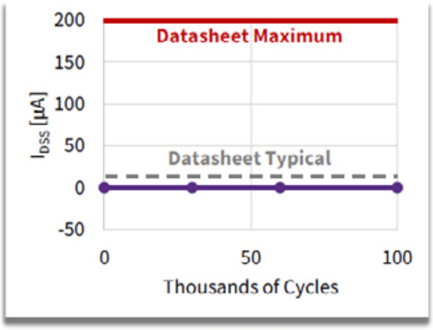
Conclusion: Integration as a Competitive Advantage

The GD3162 offers a compelling new approach for designers of EV inverters, where every component must contribute to compactness, reliability, and cost efficiency. By embedding DC link discharge functionality into the gate driver, NXP not only streamlines system design but also provides pathways for enhanced diagnostics and improved safety compliance. More information on GD3162.com

This is more than a component innovation—it's a shift in how power systems can be architected for the EV era. As OEMs seek to differentiate on performance, reliability, and cost, intelligent integration at the semiconductor level will increasingly define the frontier of power electronics design.



Conditions:
I_D = 450 A
T_{vj} = 25 °C



Conditions:
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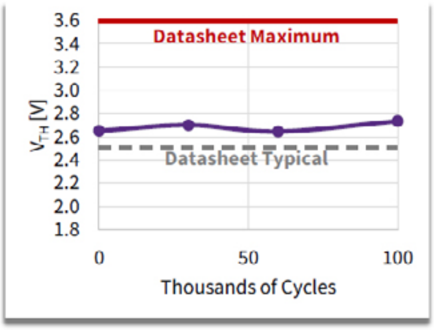
T_{vj} = 25 °C



Conditions:
I_D = 450 A
T_{vj} = 25 °C

Figure 5: Wolfspeed's EAB450M12XM3 SiC MOSFET parameters shift per discharge cycle at 25 °C

To experience this innovation in action, visit NXP at PCIM Europe, Booth 5-430. Explore the live demonstration of the GD3162's DC Link discharge feature and discover how NXP is enabling smarter, safer and more efficient EV systems through its latest portfolio of high voltage solutions.

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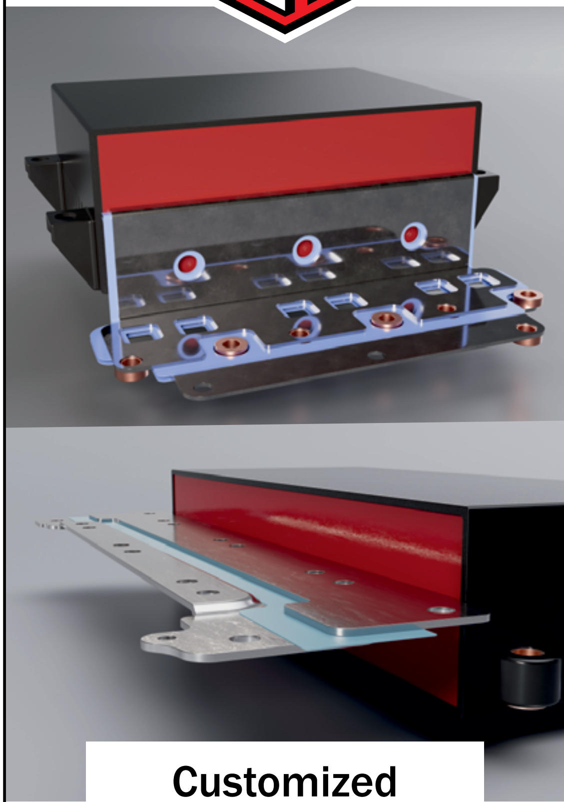

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Optimizing Efficiency: Exploring an Active Clamp Forward Converter's Secondary Rectified Circuit Design and Duty Cycle Role

The active clamp forward converter is a recognized high efficiency power topology utilizing P-channel MOS for clamping. This design allows for feedback of stored inductance energy to the grid, enhancing overall converter efficiency. To further improve efficiency, a secondary circuit featuring a MOSFET-based self-rectified circuit is incorporated. This article delves into the design challenges of the secondary rectified circuit, highlighting the role of duty cycle optimization. It's important to note that this is just one facet of the broader power technology employed in the active clamp forward converter.

By GuangQi Hou, Staff Engineer, Central Applications, Analog Devices

In an active clamp forward converter (ACFC), the duty cycle is a critical parameter for output voltage and efficiency. Typically, the maximum duty cycle of a forward converter is limited to 50%. With the active clamp technique, it allows the duty cycle to exceed the traditional 50%. There are many articles that have documented the relationship between the maximum duty cycle and ACFC topology, but not many have discussed how to design the minimum duty cycle.

One isolated ACFC power supply is introduced in this article as an example to explain how the minimum duty cycle impacts the design. It is intended for converting 24 V_{AC} or 48 V_{DC} to 60 V_{DC} with a delivery capacity of 1.5 A. Its isolation feature makes it suitable for powering industrial applications in the field. The ACFC topology contributes to achieving a peak efficiency of up to 91%. The design requests are shown in Table 1.

Parameters	Symbol	Min	Max
Input Voltage	V_{INDC}	27.8 V_{DC} (≈ 24 × 85% × √2-1)	60 V_{DC}
	V_{INAC}	20.4 V_{AC} (≈ 24 × 85%)	41.8 V_{AC}
Switching Frequency		350 kHz	
Peak Frequency	η	Higher than 88%	
Duty Cycle	D	0.22	0.46
Output Voltage	V_{OUT}	14.85	15.15
Output Voltage Ripple	ΔV_{OUT}	300 mV	
Output Current	I_{OUT}	0 A	1.5 A
Output Power	P_{OUT}	22.5 W	

Table 1: Design Requests

Analog Devices' MAX17598 serves as an active clamp current mode PWM controller, encompassing all control circuits necessary for designing an isolated forward converter power supply. This article delves into the considerations and evaluation results for the secondary self-rectified circuit design.

Design Consideration on the Secondary Self-Rectified Circuit

The ACFC could supply a higher efficiency by using a self-rectified circuit. Figure 1 shows a typical schematic of a MOSFET-based self-rectified circuit. Compared to a traditional diode rectified circuit, the MOSFET has lower ON resistance. This could lead to increased efficiency, especially in the case of low voltage but high current output.

Gate 1 is linked to the gate of N2 (shown in Figure 1), and Gate 2 is linked to the gate of N1. Gate 1 and Gate 2 are synchronized with the switching cycle. When Gate 1 outputs high, Gate 2 outputs low, and vice versa. The full circuit can be found in Figure 3.

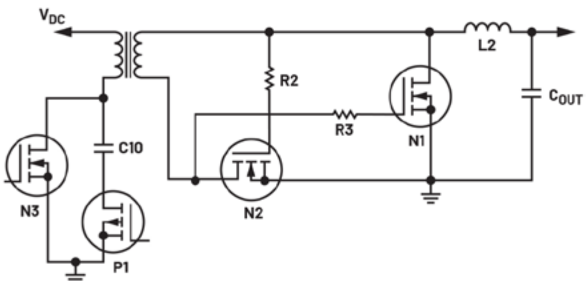


Figure 1: General output self-rectified circuit.

However, it is unsuitable when the output voltage is close to or over the MOSFET gate voltage operation range. An additional circuit can be designed to generate the gate driving voltage of these MOSFETs. Figure 2 shows the details of the circuit. G1 and G2 are connected to the auxiliary winding of the transformer.

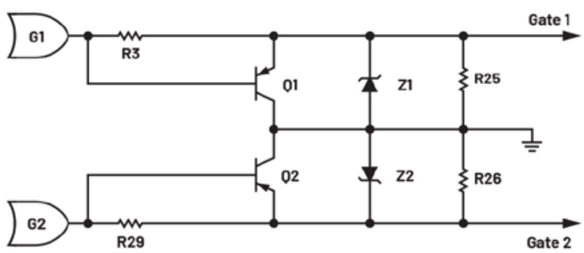


Figure 2: Gate driving circuit from the auxiliary winding transformer.

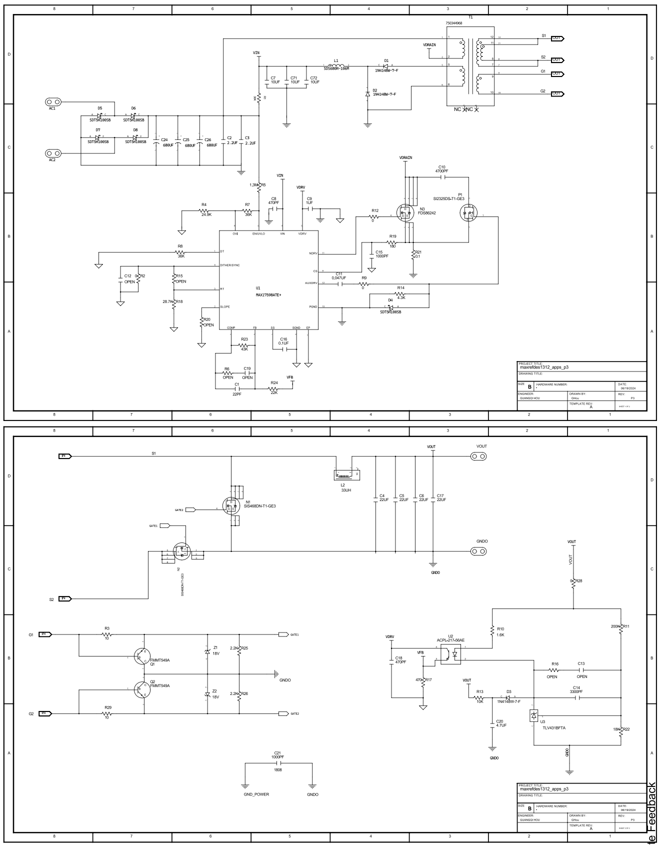


Figure 3: Example circuit used in performance test.

This loop must ensure the output is in the operation range for MOSFET V_{GS}. Equation 1 shows the relationship between the gate driving voltage and the turns ratio.

$$K_{GATE} = \frac{N_G}{N_P} = \frac{V_{GATE\_MAX}}{V_{DC\_MAX}} \tag{1}$$

K_{GATE} is the transformer ratio. N_G is the turns of the transformer winding. N_P is the turns of the transformer primary winding. V_{GATE_MAX} is the maximum voltage of the MOSFET gate driving voltage. V_{DC_MAX} is the maximum voltage of the DC input voltage.

When the main switch at the primary loop is ON, the voltage applied to the transformer is positive, which is the V_{DC}. The output of Gate 1 is high and Gate 2 is GND accordingly. It is related to the turns ratio and the DC input voltage.

$$V_{GATE1} \approx \frac{N_G}{N_P} \times V_{DCINPUT} \tag{2}$$

When the main MOSFET is OFF, the clamp circuit will limit the drain voltage to be V_{CLAMP}. Because V_{CLAMP} is higher than V_{DC}, the output of Gate 1 is GND and Gate 2 is high.

$$V_{CLAMP} \approx V_{DCINPUT} \times \frac{1}{1 - D_{ON}} \tag{3}$$

The voltage for Gate 2 is related to the turns ratio and the gap between V_{CLAMP} and $V_{DCINPUT}$

$$\begin{aligned} V_{GATE2} &\approx \frac{N_G}{N_P} \times (V_{CLAMP} - V_{DCINPUT}) \\ &= \frac{N_G}{N_P} \times V_{DCINPUT} \times \left(\frac{D_{ON}}{1 - D_{ON}}\right) \end{aligned} \tag{4}$$

Since the duty cycle changes with the input voltage, it is essential to ensure the gates' driving voltage can drive the MOSFET with the full V_{IN} range. Especially, when the maximum DC input and minimum ON rate is applied, the gate driving voltage will reach the minimum value.

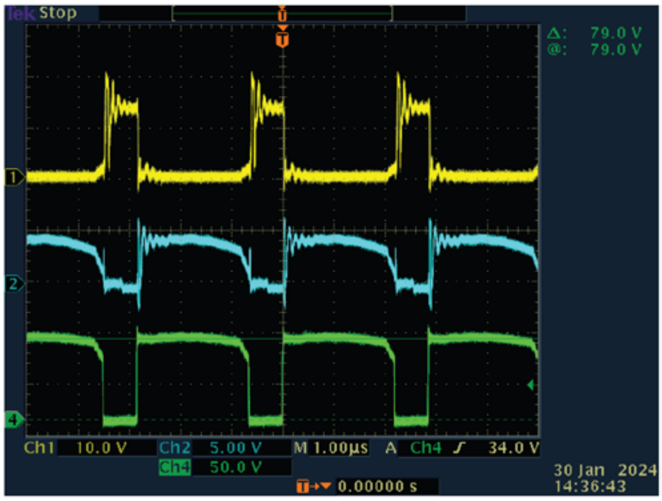
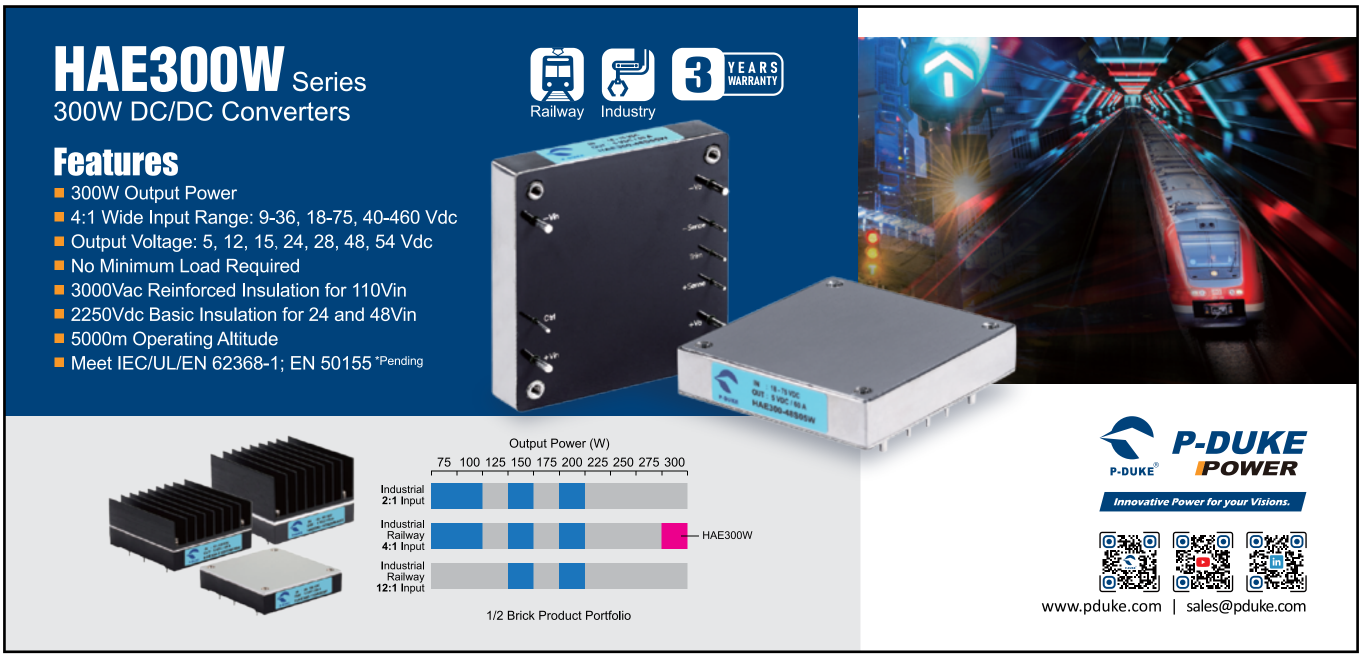


Figure 4: Gate 1 and Gate 2 voltage and MOSFET drain voltage (V_{IN} = 60 V).



In the design example, the lowest Gate 2 voltage can be calculated as shown in Equation 5. When the input DC voltage reaches the maximum value, the voltage on Gate 2 is only 4.23 V.

$$V_{GATE2} = 0.25 \times 60 \times \frac{0.22}{1-0.22} \approx 4.23\ V \qquad (5)$$

If this voltage is lower than the V_{GS} ON threshold, the MOSFET of the secondary rectified circuit will not work accurately. This could lead to an issue in which the power supply cannot start up without any load when the input voltage is close to the maximum value. In the example circuit, the V_{GS} threshold voltage is 3 V, which is less than the minimum V_{GATE2} calculated.

Figure 4 shows the measurement result on the example circuit. CH1 shows the voltage of Gate 1. CH2 shows the voltage of Gate 2. CH4 shows the source-drain voltage of the N-MOS at the primary side.

Performance of Example Circuit

To verify the accuracy of our calculations for the gate drive circuit, we conducted performance tests on the example circuit. Figure 5 shows the input and output voltage with different load currents of 0 A, 0.5 A, 1 A, and 1.5 A.

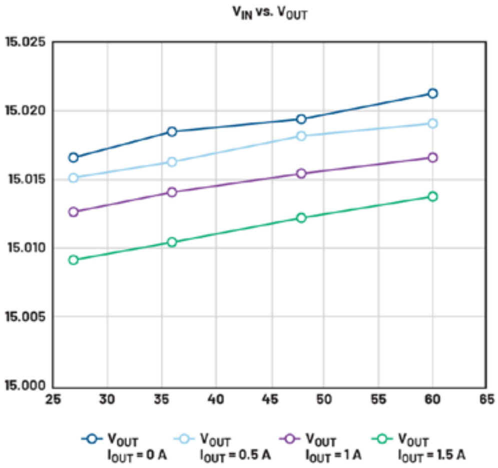


Figure 5: Input and output voltage in different loads.

Figure 6 shows how the output voltage level changes with a different output current. Different lines show the different input voltage.

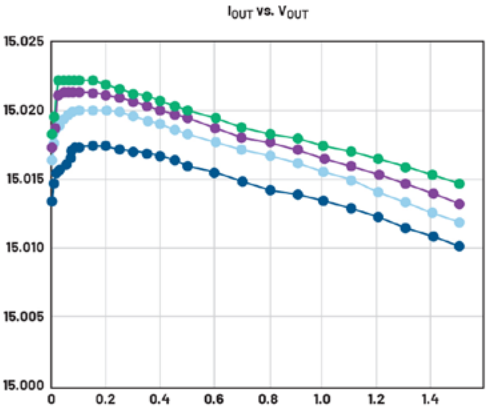


Figure 6: Output current and output voltage.

Figure 7 shows the peak efficiency by different input voltages and loads. The peak efficiency reached 91% when the input is 36 V with 1.5 A output.

The Bode plot shows the loop stability at the working condition of peak efficiency, which is $V_{DCINPUT}$ = 36 V, I_{OUTPUT} = 1.5 A.

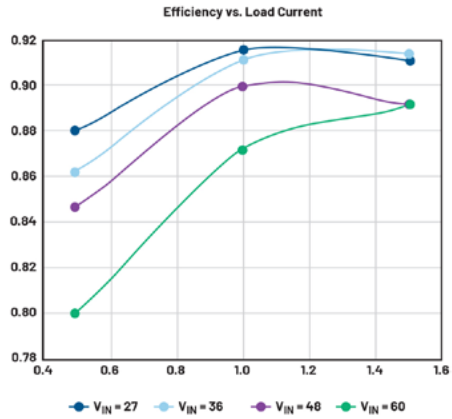


Figure 7: Peak efficiency.

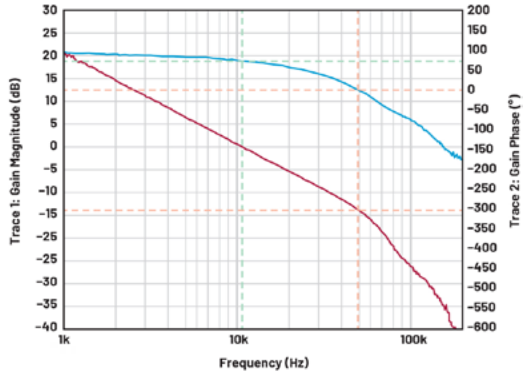


Figure 8: Bode plot.

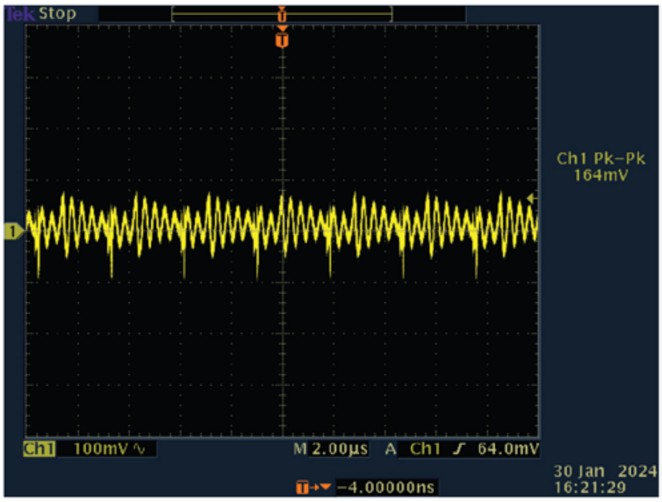


Figure 9: Output peak-to-peak voltage without load.

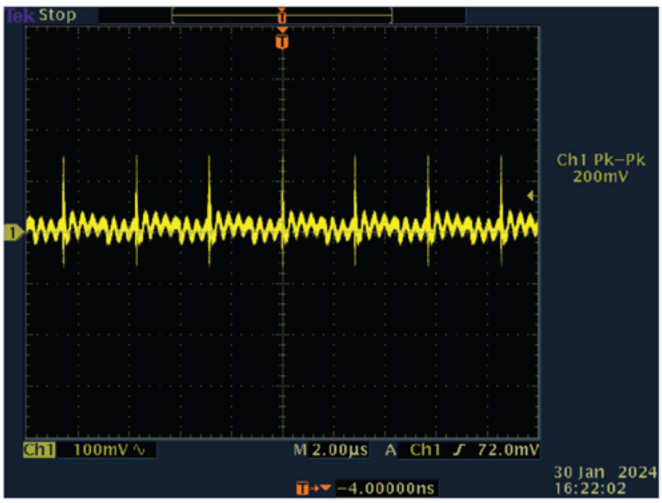


Figure 10: Output peak-to-peak voltage with full load 1.5 A.

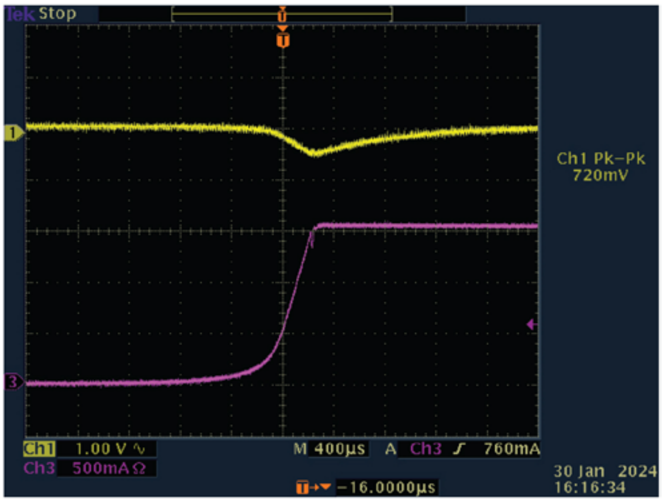


Figure 11: Transient response (0 A to 1.5 A).

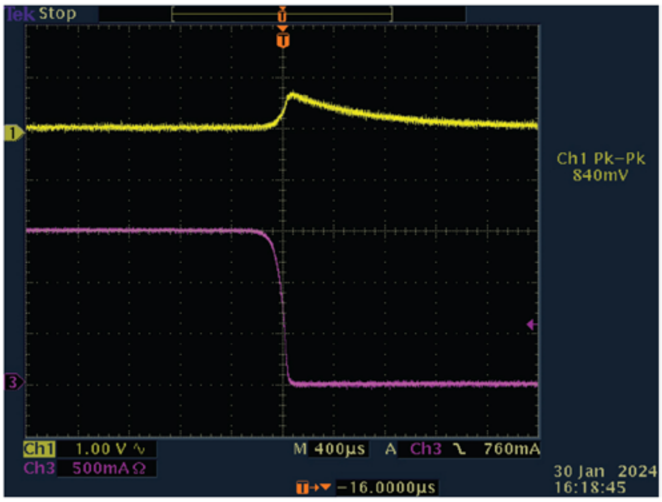


Figure 12:Transient response (1.5 A to 0 A).

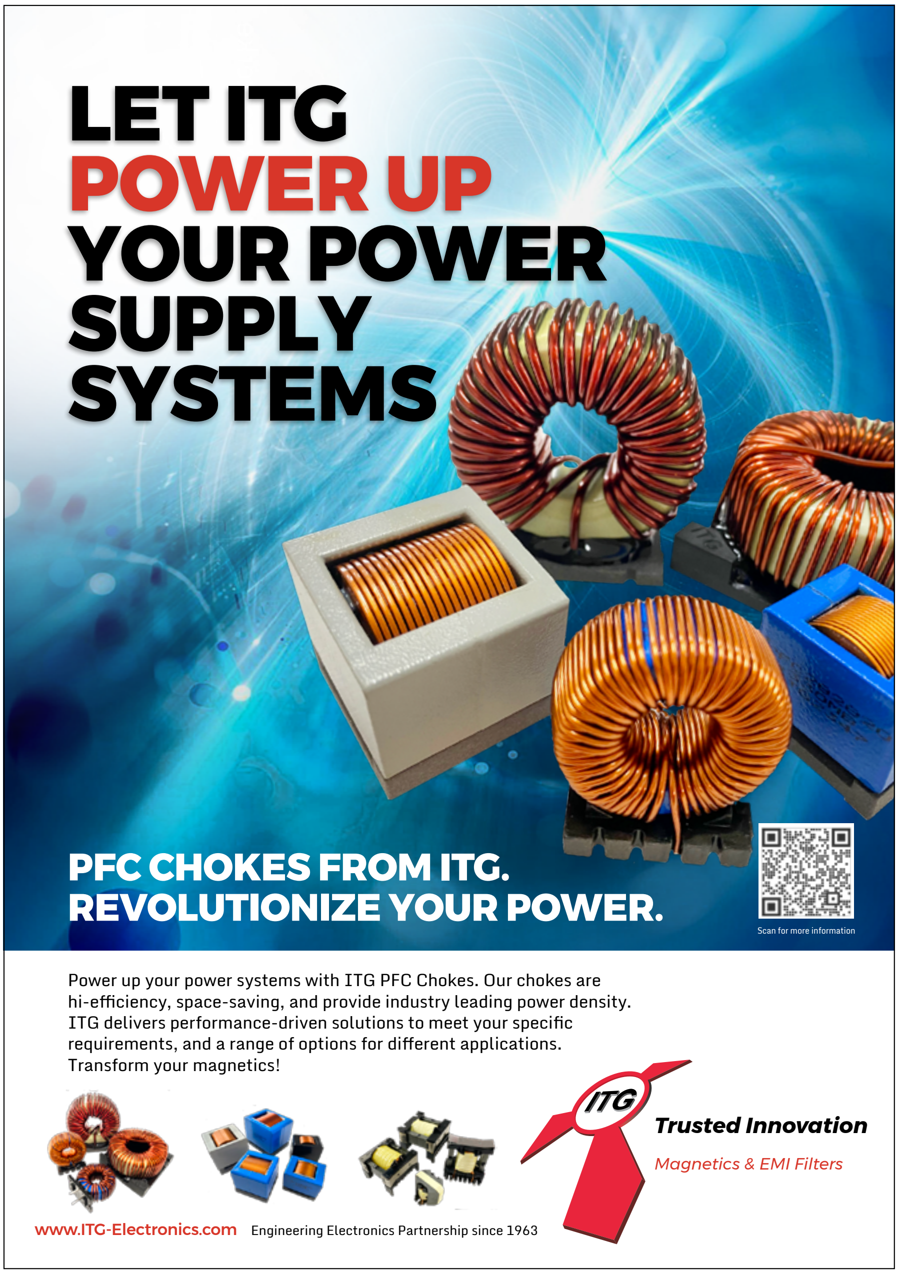
Figure 8 shows the loop response.

Figures 9 and 10 show the output peak-to-peak voltage. Figure 9 is without load current, and Figure 10 is the result with full load.

Figures 11 and 12 show the load transient response. Figure 11 shows the load changed from zero to full. Figure 12 shows the load changed from full to zero. CH1 measured the output voltage (AC-coupled). CH2 measured the output load current.

Conclusion
In conclusion, the study on ACFCs has revealed significant insights into their performance and efficiency. By examining the secondary rectified circuit design and the impact of the duty cycle, it has been demonstrated the limits of minimum duty cycle when an additional auxiliary gate drive circuit is requested. Furthermore, the ACFC with its unique ability to recycle energy stands out as a promising solution for high efficiency power supply systems. Through this article, it is evident that there is an optimal range for duty cycle. Not only the maximum duty cycle but also the minimum is important for MOSFET-based rectified circuits. Incorporating the findings from this study into the design and implementation of ACFCs could lead to avoiding problems during the design phase.

About the Author
GuangQi Hou received his B.E. degree in electronics and electrical Engineering from Keio University, Japan in 2008. He joined Analog Devices in February 2021. He is working in the China Technical Support Team and focusing on products related to fuel gauge, power management, industrial interface, motor, and motion control.



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11th ECPE SiC & GaN User Forum

Potential of Wide Bandgap Semiconductors in Power Electronic Applications

The biannual ECPE Wide Bandgap User Forum is dedicated to report state of the art and prospects of silicon carbide (SiC) and gallium nitride (GaN) devices in power electronic systemsm and to foster an exchange between system, circuit and device designers.

By Prof. Dr. - Ing. Andreas Lindemann, Technical Chairman of the ECPE SiC & GaN User Forum

SiC Schottky diodes and transistors — mostly MOSFETs — as well as GaN HEMTs are already well established in various applications. The programme of this year's event concentrated on actual questions related to their usage in circuits and systems and provided an outlook on prospective new devices. Some main findings are summarised in the following:

State of the Art and Trends

The first major topic relates to circuits and control: While power electronics conventionally has been based on silicon (Si) devices, wide bandgap devices have partially replaced them where appropriate and also helped to open up new applications. In some cases however the most efficient solution may neither rely solely on Si nor solely on SiC switches but on a combination of both, offering many degrees of freedom regarding circuit design and control. The new monolithic bidirectional GaN switch set another example where devices permit to improve circuit design and the resulting operational behaviour as has been illustrated amongst others with several power supply topologies. In many cases when designing such circuits, suitably adapted integrated drivers can be used which facilitates the control of the transistors. Further progress in circuit and system design can be expected from future devices: Those may e. g. be based on new production methods or new designs which allow for higher blocking voltages than 650V currently achieved by commercial GaN devices. Another interesting approach has been illustrated by the implementation of lateral GaN multichannel devices with further reduced on-state resistance and additional microchannel liquid cooling to improve the thermal management as illustrated in the figure. Structures like charge-compensated MOSFETs or IGBTs might also be adopted to SiC. Last but not least other ultra-wide bandgap materials are under consideration: Exemplarily research on devices based on aluminium nitride (AlN) or gallium oxide (Ga_2O_3) has been presented including application-related measurements of early Ga_2O_3 diode samples.

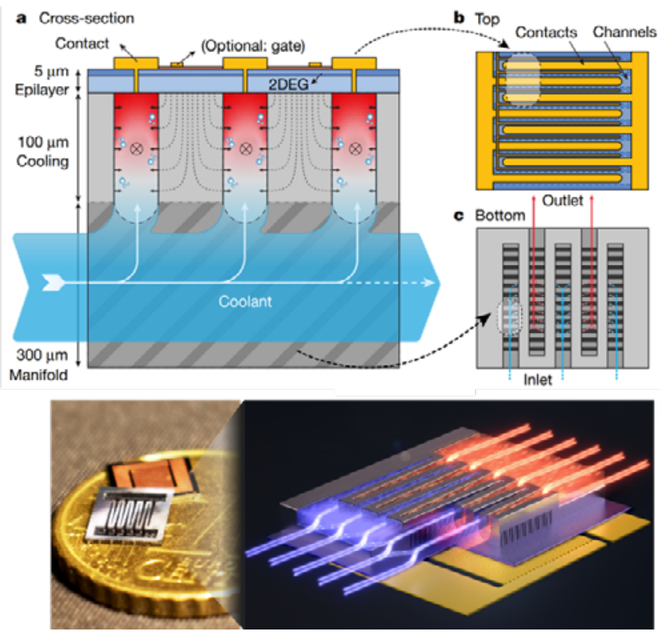

Figure 1: Monolithically-integrated microchannel manifold converts the silicon from a carrier wafer into an efficient heat sink for a GaN HEMT; figure courtesy by Prof. Elison Matioli, Ph.D., Ecole Polytechnique F´ed´erale de Lausanne (EPFL).

The operational behaviour of the fast-switching wide bandgap devices as well as their robustness and reliability are partially determined by the package. To overcome the limitations of conventional modules a fully copper based assembly of SiC chips has been demonstrated. Besides, chips with copper metallisation are of interest for embedding which allows for compact, low-inductance power sections when the thermal path has been thoroughly designed. Applications usually require a certain level of robustness, such as short-circuit withstand capability which depends on the technology of the transistors as has been investigated and explained with respect to SiC MOSFETs. Further, an application-related qualification is required. Consequently the guideline AQG 324 will in future consider wide bandgap devices more in detail regarding dynamic testing. The assessment of the reliability of SiC and GaN devices in transportation systems referenced a particularly demanding application.

This leads to the exemplary applications of wide bandgap devices which have been presented — i. e., railway traction outside of electrified lines, heavy duty electric road vehicles and the required charging infrastructure with a nominal power in the Megawatt range, which was finally complemented by the consideration of aircraft propulsion where the converter may be operated under cryogenic conditions. Inverters for photovoltaics have early adopted wide bandgap devices, allowing amongst others for high efficiency which has been followed up by an update about current trends.

Conclusion and Outlook

The findings as briefly summarised above illustrate the fast development of wide bandgap power semiconductors and their successful use in industry, driven by their advantages in key applications and the exploration of new areas. Engineers in research and development of devices, components, circuits and power electronic systems have undoubtedly achieved impressive results. Research and development in power electronics are ongoing. The European Center for Power Electronics (ECPE) is a stakeholder in this area, bringing together industrial partners and research institutions. After the broad interest of international participants in this year, ECPE will anounce the next SiC & GaN User Forum in 2027. There will be the occasion to report the progress achieved since today and pave the way to proceed even further.

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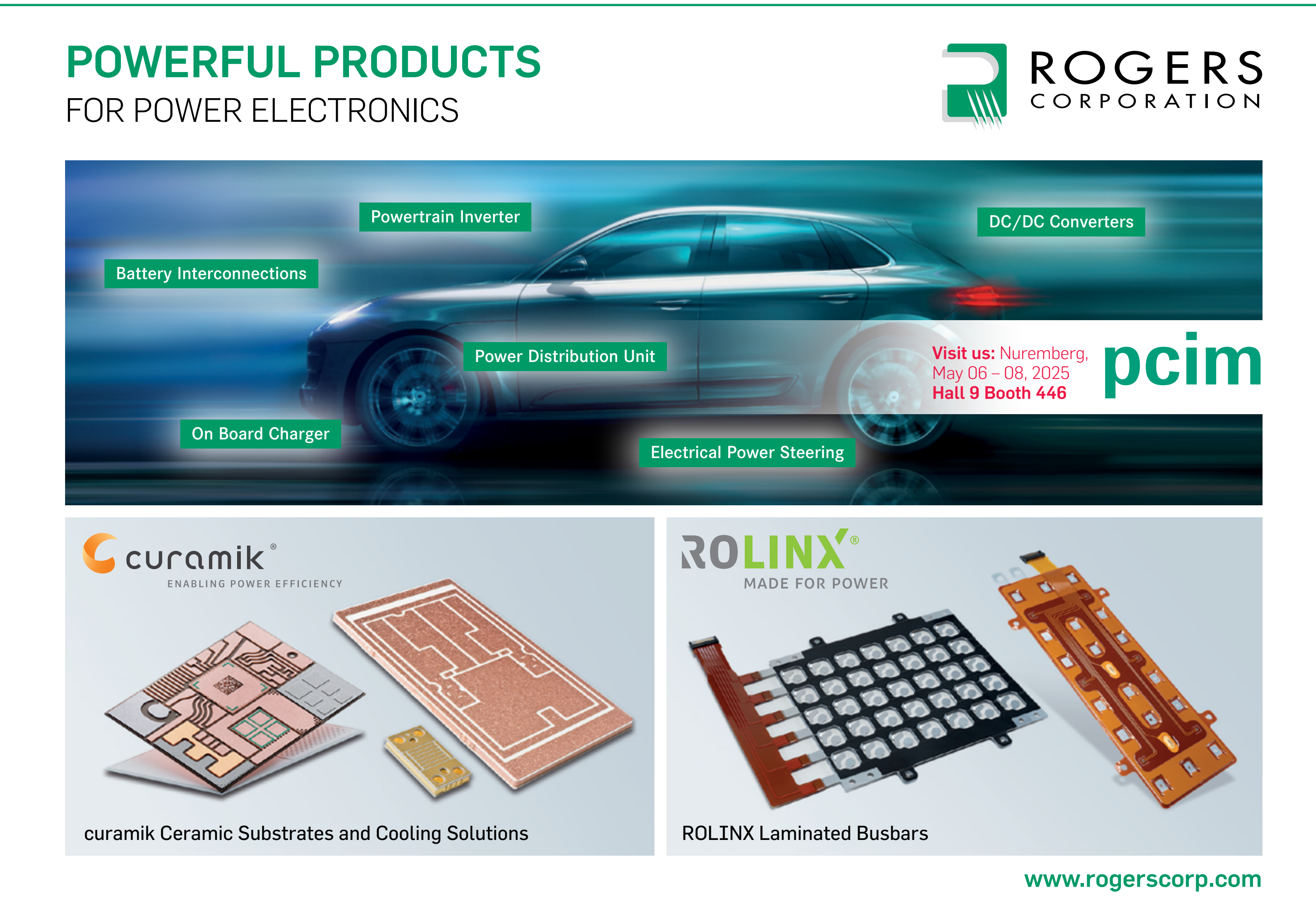
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Taiwan was Frontrunner of International Exhibitors at Embedded World

As the largest international exhibitor at embedded world 2025, which took place in Nuremberg in March, Taiwan was represented by more than 140 companies, offering pioneering solutions and demonstrating their role at the forefront of the global electronics and computing industry. Central element of this presence was the Taiwan Excellence Pavilion, where leading Taiwanese companies presented their innovations.

By Roland R. Ackermann, Correspondent Editor, Bodo´s Power Systems

On the opening day, innovations in the areas of edge AI, embedded computing and AI storage solutions were presented in the pavilion. "AI applications are the driving force behind progress – they are not only changing how we live and work, but also how we tackle future challenges", said Peggy Lin, Deputy Executive Director of the Taiwan External Trade Development Council (TAITRA). "Taiwan and Germany share a deep passion for precision engineering, high-quality manufacturing and cutting-edge research," added Prof. Dr Jhy-Wey Shieh, representative of the Taipei Representative Office in the Federal Republic of Germany, in his address at the opening press conference. "'The innovative AI-powered solutions from Taiwan are setting the course for new collaborations and business opportunities in Germany and the entire European market."

The participation was organised by International Trade Administration (TITA), an agency of the Ministry of Economic Affairs of Taiwan, responsible for planning trade policy, international cooperation and economic agreements. It promotes trade, develops the MICE (meetings, incentives, conferences and exhibitions) industry and manages regulatory trade issues. The agency plays a crucial role in eliminating trade barriers, analysing market data and resolving trade disputes.

Taiwan External Trade Development Council (TAITRA) is Taiwan's leading non-profit, semi-governmental trade promotion organisation, established in 1970. With the support of the government, industry associations and trade organisations, TAITRA operates a global trade network with over 1,200 specialists at its headquarters in Taipei and 60 branches worldwide. In cooperation with the Taiwan Trade Center (TTC) and the Taipei World Trade Center (TWTC), TAITRA promotes international trade through strategic measures.

The Taiwan Excellence Pavilion at EW2025 showcased Taiwan's best innovations, presenting 17 companies and 50 selected products that demonstrated the country's global competitiveness in smart technologies. The pavilion served as a one-stop shop offering customers innovative and reliable solutions. A directory of all Taiwanese exhibitors at the show was also provided there.

One of the exhibitors in the power area was EDAC Power Electronics, a prominent Taiwanese manufacturer specializing in standard and custom-made switching power supplies. Recent innovations on show were e.g. a 140W USB-C Medical/ITE GaN PD charger that combines high efficiency with a compact design (EUM114A Series) or a Medical GaN Desktop power supply (EM1331 Series) designed to provide reliable and efficient power for medical devices.

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Operational Amplifiers join Existing Radiation Tolerant Product Offerings

Apex Microtechnology is excited to expand its radiation-tolerant (RT) product portfolio with the introduction of three devices: the PA12R, PA02R, and PA74R. Building on the success of their initial rad tolerant product launch, which included the PA07R and PA08R amplifiers, Apex is further enhancing their commitment to providing solutions for the space industry and applications in radiation-prone environments. Designed with stringent SWaP requirements in mind, these devices offer high performance and reliability with minimal lead times, meeting the growing demand for robust analog components in space missions.

PA12R: Class A/B Radiation Tolerant Power Amplifier
The PA12R is a 10A, 90V high voltage, very high output current operational amplifier designed to drive resistive, inductive and capacitive loads. This hybrid integrated circuit utilizes thick film (cermet) resistors, ceramic capacitors and semiconductor chips to maximize reliability, minimize size and give top performance.

PA74R: Radiation Tolerant Dual Power Amplifier
The PA74R is a dual power operational amplifier featuring 2.5A x 2 of continuous output current on 5V to 40V single supplies. The product design for the PA74R utilizes both monolithic and hybrid technologies by placing two ICs in an electrically isolated, hermetically sealed, 8-pin TO-3 metal package.

PA02R: Radiation Tolerant Power Amplifier with Fast Settling Time
The PA02R is a 5A, 38V power operational amplifier with a very high 350kHz power bandwidth designed to drive resistive, inductive and capacitive loads such as motor, valve and actuator controls. The PA02R provides a complementary "collector output" stage that can swing close to the supply rails and is protected against inductive kickback.

www.apexanalog.com

Advert

Module with Double the Heat Dissipation Performance for EV Buses, Electric Ships, and Stationary Applications

Toshiba Electronics Europe announced that Toshiba Corporation has launched a SCiB™ module, a lithium-ion battery designed for use in EV buses, electric ships, and stationary applications. The product features an aluminium baseplate that dissipates approximately twice the heat of current modules.

The use of lithium-ion batteries is increasing and diversifying, and there is a growing demand for batteries that can support constant rapid charging and discharging in applications as diverse as electric buses and power load levelling in stationary applications. However, constant input and output at high power levels in a short time period generates life-shortening heat within the batteries. The challenges for battery developers are to manage heat dissipation and maintain battery life while realising high power input and output in a short time.

Toshiba's SCiB™ rechargeable batteries have a lithium titanate negative electrode that realises safe operation, a long life, low-temperature performance, fast charging, high input and output, and a high effective state of charge (SOC). They are widely used in hybrid vehicles and industrial applications, including electric buses, cranes, trains, and automated guided vehicles in logistics centres. In addition to battery packs and cells, Toshiba also offers battery modules that can be connected in series or in parallel connections to meet required voltages and capacities.

www.toshiba.semicon-storage.com

Power Adapter uses GaN Technology to deliver 360W output Charging

TT Electronics announces the launch of the TEAD360 series of 360W AC power adapters. Weighing just 950g (2.09lb) and measuring 170mm (6.69") x84mm (3.31") x 31.5mm (1.24") (LxWxH), the adapters deliver 360W of continuous power with an efficiency of up to 95%. Accepting a nominal input range of 90 to 264VAC, the adapters deliver a wide range of output voltages, from 12 to 56VDC, meeting the needs of various high-power demand applications, including industrial equipment, security systems, digital signage and audio-visual equipment.

Offered in either Class I or Class II (double-insulated, no ground connection required) configurations, the series complies with various global standards to protect against electric shock. The adapters are available with IEC 320 C14, C6, C18, or C8 inlets to accommodate different AC power cords. As standard, the DC output features the popular 6-pin Molex mini-fit connector; however, other connectors are available upon request.

All models meet the highest DOE Level VI efficiency requirements for global use, with no-load power consumption below 0.5W. In addition, the active PFC function ensures maximum power efficiency, even under full-load conditions. Standard protection features cover short-circuit, overvoltage, overcurrent, and overtemperature conditions.

"Bringing together the efficiency of GaN and our robust power supply design capabilities, the TEAD360 is a powerful, compact, and extremely efficient solution that meets the needs of today's high-demand electronics," says Dr Adam Royles, Global Product Development Director at TT Electronics.

www.ttelectronics.com

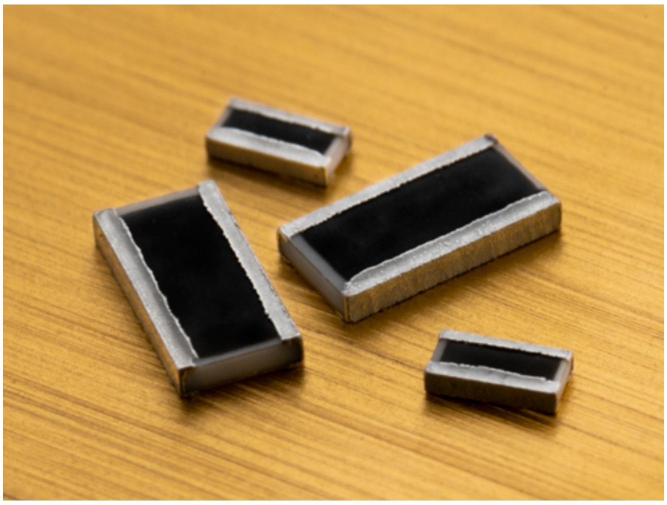
High Power, Wide Termination, Metal Thin Film Chip Resistors

KOA Speer Electronics latest offering is the high power-precision WN73H series metal thin film chip resistor, designed to meet the demanding requirements of high heat and high moisture applications. These reverse geometry resistors pack power ratings of 0.3W in a 0306 package and 1W in a 0612. Resistance values range from 10Ω ~ 100kΩ, with high precision resistance tolerances as low as ±0.1% and a high performance T.C.R. down to ±10ppm/°C.

The WN73H offers excellent heat tolerance with an operational temperature range of -55°C ~ +155°C and a rated ambient temperature of 85°C. It also has excellent moisture resistance in qualification testing at 85°C and 85% relative humidity for 1,000 hours.

This series of high precision resistors are ideal for applications that demand high reliability such as automotive, medical, and industrial applications. The WN73H resistors are useful for Electronic Control Units (ECUs) such as inverters and 48V mild hybrid systems.

www.koaspeer.com



Silicon Carbide-Based Intelligent Power Modules for Inverter Motor Drives

onsemi introduced the first generation of its 1200V silicon carbide (SiC) metal oxide semiconductor field-effect transistor (MOSFET) based SPM 31 intelligent power modules (IPMs). onsemi EliteSiC

SPM 31 IPMs deliver higher energy efficiency and power density in a smaller form factor compared to using Field Stop 7 IGBT technology, resulting in lower total system cost. Their improved thermal performance, reduced power losses and ability to support fast switching speeds make these IPMs ideally suited for three-phase inverter drive applications such as electronically commutated (EC) fans in AI data centers, heat pumps, commercial HVAC systems, servo motors, robotics, variable frequency drives (VFDs), and industrial pumps and fans. The EliteSiC SPM 31 IPMs offer several current ratings from 40A to 70A. Complemented by onsemi's IGBT SPM 31 IPM portfolio, covering low currents from 15A to 35A, onsemi now provides the industry's broadest range of scalable and flexible integrated power module solutions in a small package.

www.onsemi.com

Current Sensors and Fan Driver ICs for automotive and industrial Applications

Allegro MicroSystems announced three solutions designed to enhance motor control and thermal management performance in e-mobility and industrial automation applications. These solutions, the ACS37035 and ACS37630 current sensors, and the A89347 automotive-grade fan driver IC, provide advanced capabilities for a wide range of applications.

ACS37035 Current Sensor

Allegro's ACS37035 current sensor boasts a 1 MHz bandwidth and 0.45 µs typical response time, enabling precise measurement of high-frequency currents in fast control loops. Its differential sensing capability, combined with a Common-Mode Rejection Ratio (CMRR) of 4 mA/Gauss, provides high immunity to external magnetic fields, ensuring accurate measurements even in noisy environments.

ACS37630 Current Sensor

Designed for U-core current sensing applications like xEV traction inverter and battery management systems, the ACS37630 offers high bandwidth (up to 250 kHz) and a fast analog output with a 1.6 µs typical response time. Its vertical Hall technology enables sensing parallel to the package surface, ideal for system integration with U-core magnets.

A89347 Fan Driver IC

Allegro's A89347 is an automotive-grade, sensorless sinusoidal three-phase BLDC driver for EV seat- and battery-cooling fans. It offers integrated closed-loop speed control, minimizing vibration and audible noise. Additionally, a customizable speed curve, configured via EEPROM, allows for tailored performance in various fan applications. The A89347 features slew rate control, lock detection, and a low-power standby mode with a current consumption of just 10 µA.

www.allegromicro.com

Advert

MOSFET for Supercapacitors Rated at 3V or Higher

Advanced Linear Devices announced its latest addition to its Supercapacitor Auto-Balancing (SAB™) MOSFET family. This dual MOSFET provides auto-balancing capabilities and power management for supercapacitors ranging from 2.8V to 3.3V. The ALD910030 uses virtually no power for cell balancing and prevents most catastrophic failures. The chip enhances performance across various sectors, including utility boxes, backup power systems, industrial applications, uninterruptable power supplies, renewable energy and consumer electronics.

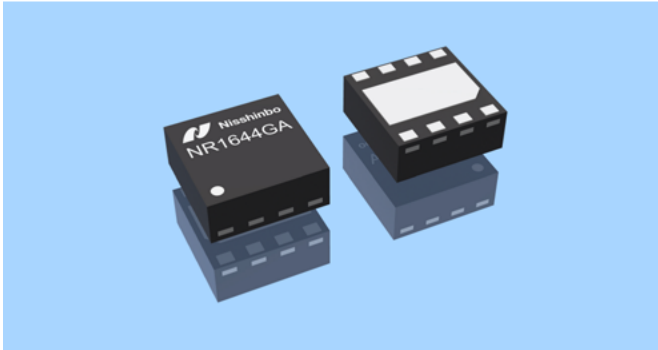
Traditionally, widely used supercapacitors had a voltage rating of 2.7V to 3.0V. However, 3.3V supercapacitors are increasing the demand for advanced voltage and leakage current balancing schemes. ALD's SAB™ MOSFET addresses this need by precisely and effectively balancing series-connected supercapacitors. By dissipating near-zero leakage currents, this chip practically eliminates excessive power usage, making it an energy-efficient solution for a wide range of applications. Each part is precision factory-trimmed according to individual voltage specifications.

Supercapacitors are commonly connected in series to reach targeted voltage levels. For instance, four 3.3V-rated supercaps can be stacked for applications that need a standard 12V direct current supply voltage. This configuration will produce 13.2V, satisfying the requirements of a 12V power supply while allowing for potential fluctuations.

With its electrical characteristics, the ALD910030 ensures precise monitoring and control of voltage and leakage current for each supercapacitor in a series-connected stack. The chip exponentially adjusts drain currents to effectively balance voltages, safeguarding against voltage runaway power fluctuations. The MOSFET operates within a temperature range from -40°C to +85°C.

www.aldinc.com

2 A / 0.4 V High-Performance LDO Regulator with Low Noise and High Ripple Rejection



Nisshinbo Micro Devices releases the NR1644, a low-noise, high-ripple rejection, and low-dropout (LDO) voltage regulator. Designed to deliver superior power regulation with efficiency and precision, a key solution for applications requiring stable, low-noise power supply.

The NR1644 is a 2 A output voltage regulator with a minimum output voltage as low as 0.4 V. It incorporates advanced features such as a high ripple rejection ratio of 110 dB at 1 kHz and ultra-low output noise voltage of just 5µVrms. It makes it an ideal solution for power-sensitive applications, including CMOS image sensors, RF communication devices, high-precision ADC/DACs, and SoC/FPGA power supplies.

A special feature is its automatic mode selection feature, the NR1644 dynamically switches between fast response mode and low-power consumption mode based on the application's output current requirements. The main benefit is that the enlarged current consumption in fast -mode only occurs when needed. This ensures optimal performance while maintaining power efficiency, when required, a dedicated fixed fast-mode version is also available. What makes the NR1644 also unique is its separated input terminal for the regulator driver and internal control circuitry. It results in a Bias pin to connect a supply voltage for the internal error amplifier, reference voltage circuit, and gate control voltage for the N-channel driver, the other VIN pin connects the N-channel driver. This innovative design allows the LDO to regulate very low input and output voltages, even beyond limitations for typical P-Channel driver LDOs.

www.nisshinbo-microdevices.co.jp

Automotive Grade Chip Inductor Series Designed for High Frequency Applications

Bourns announced its CW2012A series automotive grade, AEC-Q200 compliant chip inductors. The chip inductor series features a high Q value, high self-resonant frequency and low DCR in a compact footprint. Designed as an energy-efficient solution for an increasing number of high frequency applications, Bourns CW2012A Series chip inductors are particularly well-suited for signal filtering in radio transmitters, RF amplifiers, tuning applications and automotive advanced driver-assistance systems (ADAS) and high-frequency power supplies.

These chip inductors are wirewound constructed on a ceramic core, and offer features that help reduce power dissipation and enhance circuit efficiency and functionality. With high Q values up to 80 and inductances from 2 to 1000 nanohenry (nH), Bourns chip inductors have a DCR from 30 to 2600 milliohms, up to 800 mA maximum rated current and have an operating temperature range from -55 to +125 °C.

www.bourns.com

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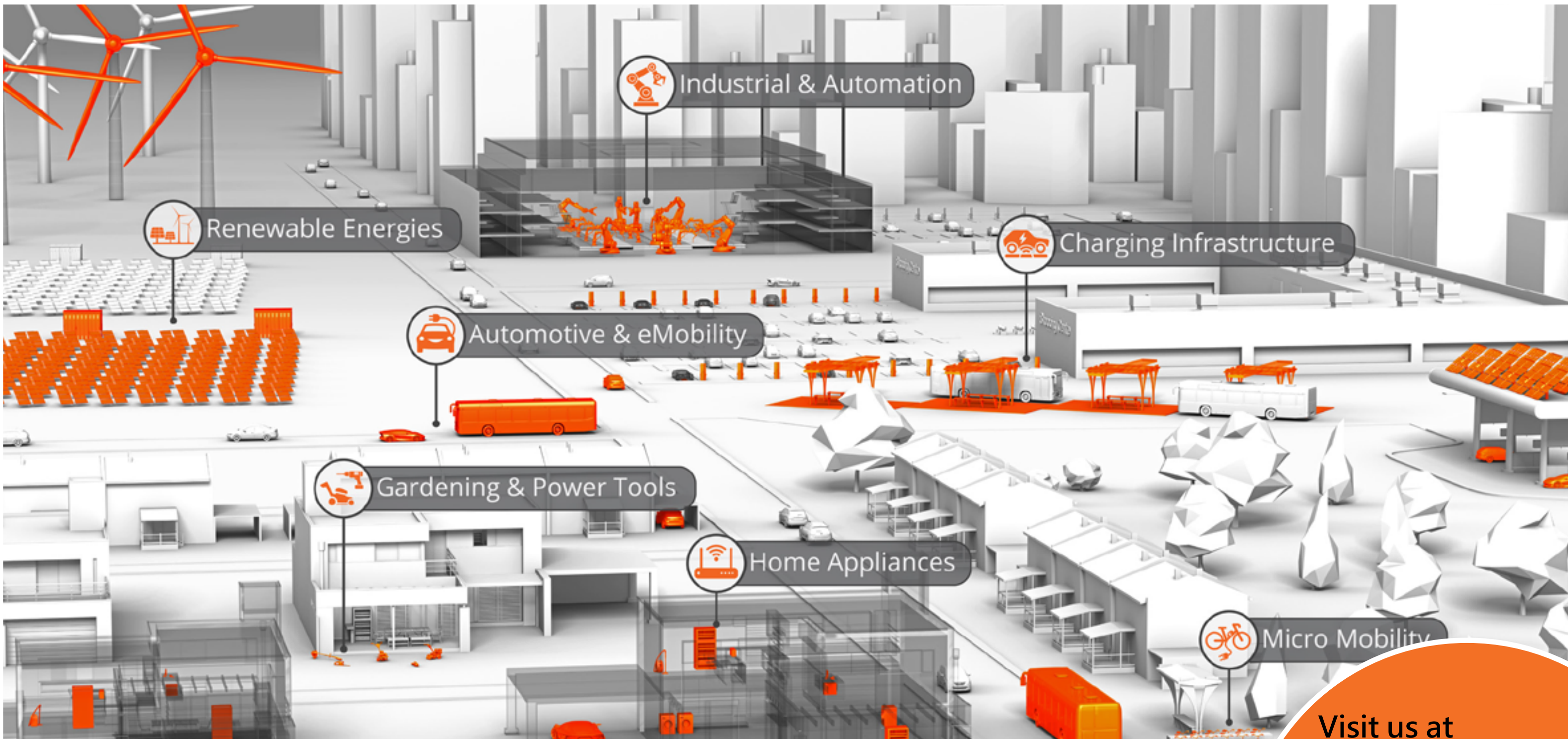

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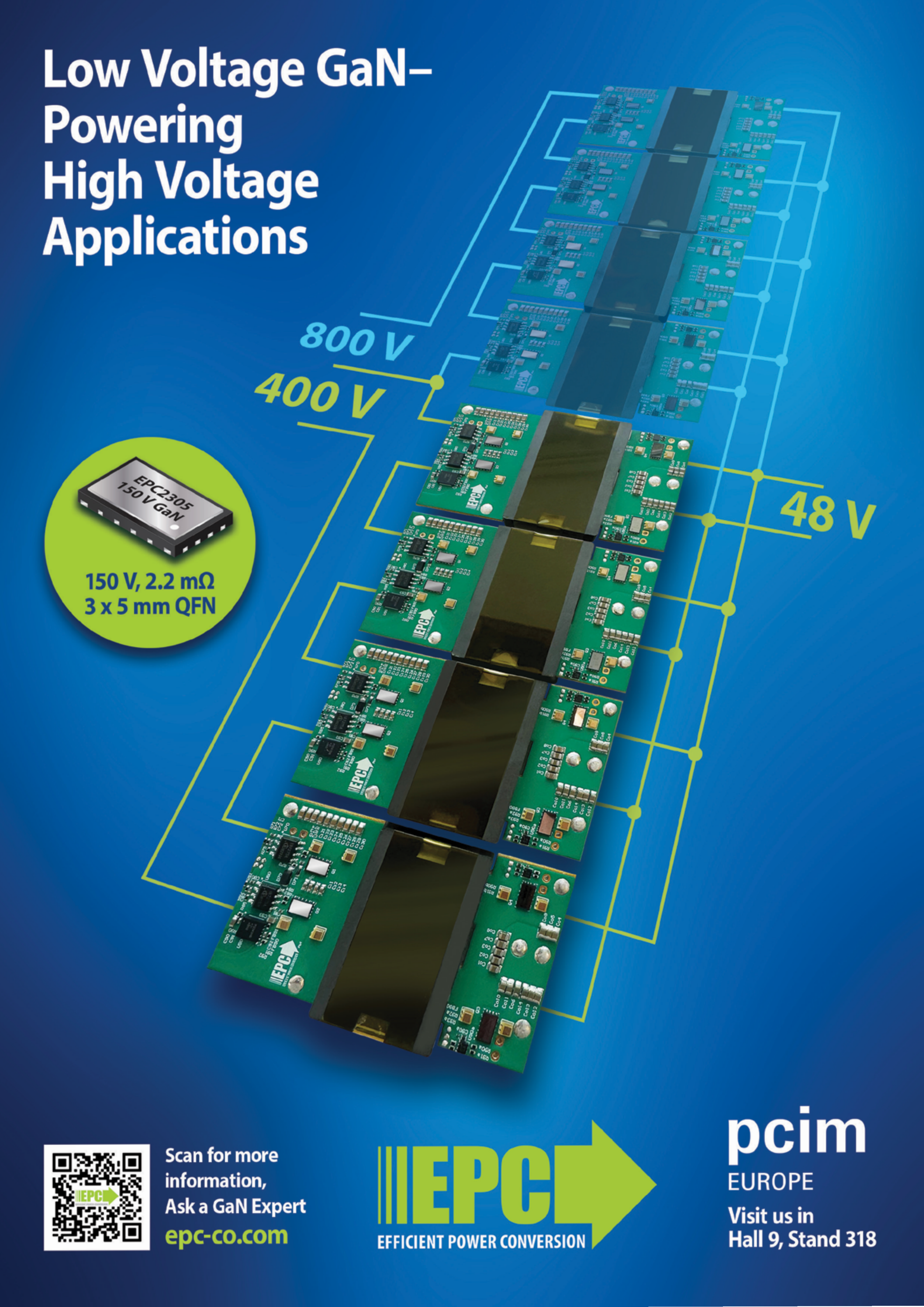
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