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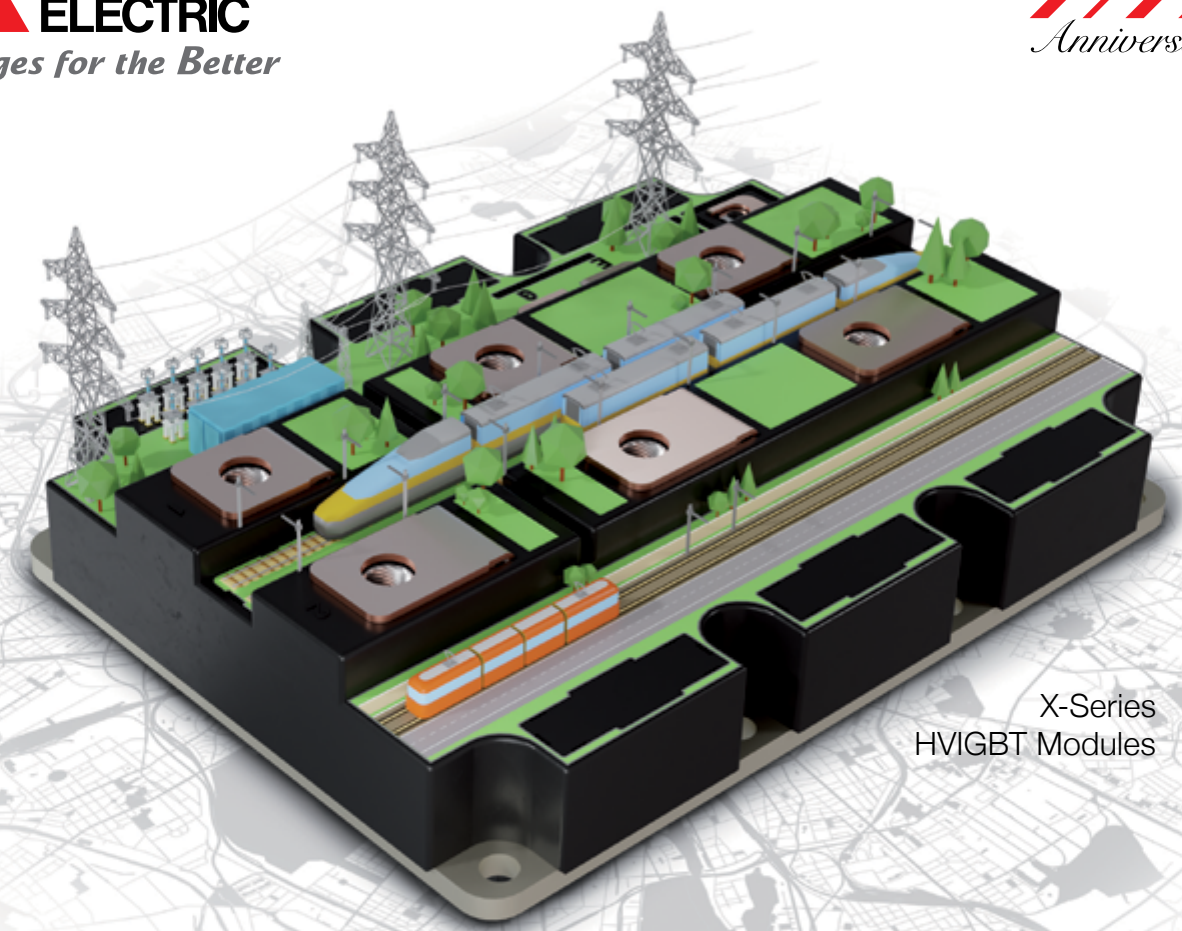
Bodo´s Power Systems®

Electronics in Motion and Conversion

September 2021



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Dramatic Findings

The Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change, in August released its latest report on climate change. The experts' findings are worrying. The changes since the last report in 2014 are significant and the consequences are visible to everyone. The floods in Central Europe, the heat wave in the Northwest of the American continent and the fires in Southeastern Europe, to name just a few. It is frustrating to see that these scientific findings are still being ignored or even doubted in some places. Some of the experts are of the opinion that we can no longer stop climate change at all, but only mitigate it. Which is bad news!

A reduction in man-made CO2 emissions can certainly lead to this needed mitigation. During his VIP interview in this issue, Bodo discusses with Alex Lidow, CEO, Efficient Power Conversion (EPC), the efficiency of electric drives and the possibilities offered by gallium nitride. This is particularly interesting in the increasingly widespread 48 and 96V application areas where there is great potential. My beloved e-bike immediately comes to mind.

100-year birthdays are truly not an everyday occurrence, even for companies. The founder of Mitsubishi Electric was right when he predicted in 1921 that "the electric age is upon us." The rest is a success story, we congratulate the company warmly and look forward to many more years of good cooperation.

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 North America efficiently. If you are using any kind of tablet or smart phone, you will find all our content on the website www.eepower.com. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com

My Green Power Tip for the Month:
Make sure washers, dryers and dishwashers are completely full. It is better to wait another day before switching on than to waste energy.

Kind regards

Events

EPE 2021
Online September 6 – 10
www.epe2021.com

PCNS 2021
Milan, Italy September 7 – 10
https://pcns.events

PCIM Asia 2021
Shenzhen, China September 9 – 11
www.pcimasia-expo.com

Industry Tech Days 2021
Online September 13 – 17
www.allaboutcircuits.com/tech-days

EV Tech Expo North America 2021
Novi, MI, USA September 14 - 16
www.evtechexpo.com

IEEE – IPFA 2021
Online September 14 – October 13
https://ipfa-ieee.org/2021

Bodo's WBG Expert Talk
Online September 29
www.bodospower.com/experttalk.aspx

ESREF 2021
Online October 4 – 8
https://esref2021.sciencesconf.org

The Smarter E 2021
Munich, Germany October 6 – 8
www.thesmartere.de

Optimize the design of EV chargers

CDSR Series

Extremely compact, the LEM CDSR leakage current sensor ensures your next EV charger will have the small size and low cost that customers want, while remaining fully compliant with relevant standards.

In addition, it provides highly flexible connectivity, offering both cable IC-CPD (mode 2) and AC wallbox (mode 3).

The CDSR also uses the latest open-loop fluxgate technology, offering high safety for EV users by measuring AC and DC leakage current below 1mA at frequencies up to 2kHz.

- **Single and three phase configuration**
- **32 Arms nominal current per phase**
- **0.5 mA accuracy at 6mA**
- **Test winding and default output signal**
- **Analog and digital communication (SPI)**
- **Complies with application standards IEC 61851, 62955, 62752, UL 2231**

www.lem.com

LEM

Life Energy Motion

Mobile Fast Charging with Gallium Nitride (GaN) Power ICs

Navitas Semiconductor announced that Xiaomi has launched their third GaNFast™ charger, a 65W dual-output fast charger. The '65W 1A1C' has a USB-C output up to 65W to power laptops and fast-charge smartphones via USB-PD 3.0, QC and PPS fast-charging protocols, with an extra USB-A output up to 18W to conveniently

– and simultaneously – charge another phone or accessory such as headphones. The GaN charger can power the Xiaomi Mi11 from 0% to 100% charge in only 45 minutes. Due to high-speed GaN power ICs, the charger achieves a small size of only 69 cc with folding AC-pins – a 30% reduction vs Xiaomi's previous silicon-based designs – and a world-leading featherweight 104 g for ultimate portability. "We believe that the success of any company comes from continuous technological innovation, corporate social responsibility and the achievement of sustainable development goals," said Mr. Xiang WANG, President and Partner of Xiaomi. "We look forward to a bright future for Navitas."

"Xiaomi's openness to new materials and technologies, and its continued commitment to gallium nitride (GaN), demonstrates Xiaomi's recognition of the advantages of GaN devices over traditional silicon devices," said Gene SHERIDAN, CEO of Navitas Semiconductors. "It is a long and successful partnership, introducing a series of world-class chargers, and celebrating mass production milestones, as when we presented Xiaomi with a special award for their receiving the 10,000,000th GaNFast power IC back in November 2020."

www.navitassemi.com

Transition to 200mm Silicon Carbide Wafers

STMicroelectronics announced it has manufactured the first 200mm (8-inch) Silicon-Carbide (SiC) bulk wafers for prototyping next-generation power devices from its facility in Norrköping, Sweden. The transition to 200mm SiC wafers marks an important milestone in the capacity build-up for ST's customer programs in automotive and industrial sectors and will consolidate ST's lead in the disruptive semiconductor technology that allows for smaller, lighter, and more efficient power electronics with a lower total cost of ownership. Among the first in the world, ST's initial 200mm SiC wafers are also very high quality, with minimal yield-impacting and crystal-dislocation defects. The low defectivity has been achieved by building on the excellent know-how and expertise in SiC ingot growth technology developed by STMicroelectronics Silicon Carbide A.B. (formerly Norstel A.B., which ST acquired in 2019). In addition to meeting the quality challenge, the transition to 200mm SiC substrates requires a step forward in manufacturing equipment and the overall support ecosystem performance. ST, in collaboration with technology partners covering the entire supply chain, is developing its own 200mm SiC manufacturing equipment and processes. ST currently manufactures its leading-edge, high-volume STPOWER SiC products on two 150mm wafer lines in its fabs in Catania (Italy) and Ang Mo Kio (Singapore) and performs assembly and test at its back-end sites in Shenzhen (China) and Bouskoura

(Morocco). This milestone comes as part of the Company's planned move to more advanced, cost-efficient 200mm SiC volume production. This transition is within the Company's ongoing plan to build a new SiC substrate plant and source over 40% of its SiC substrates internally by 2024.

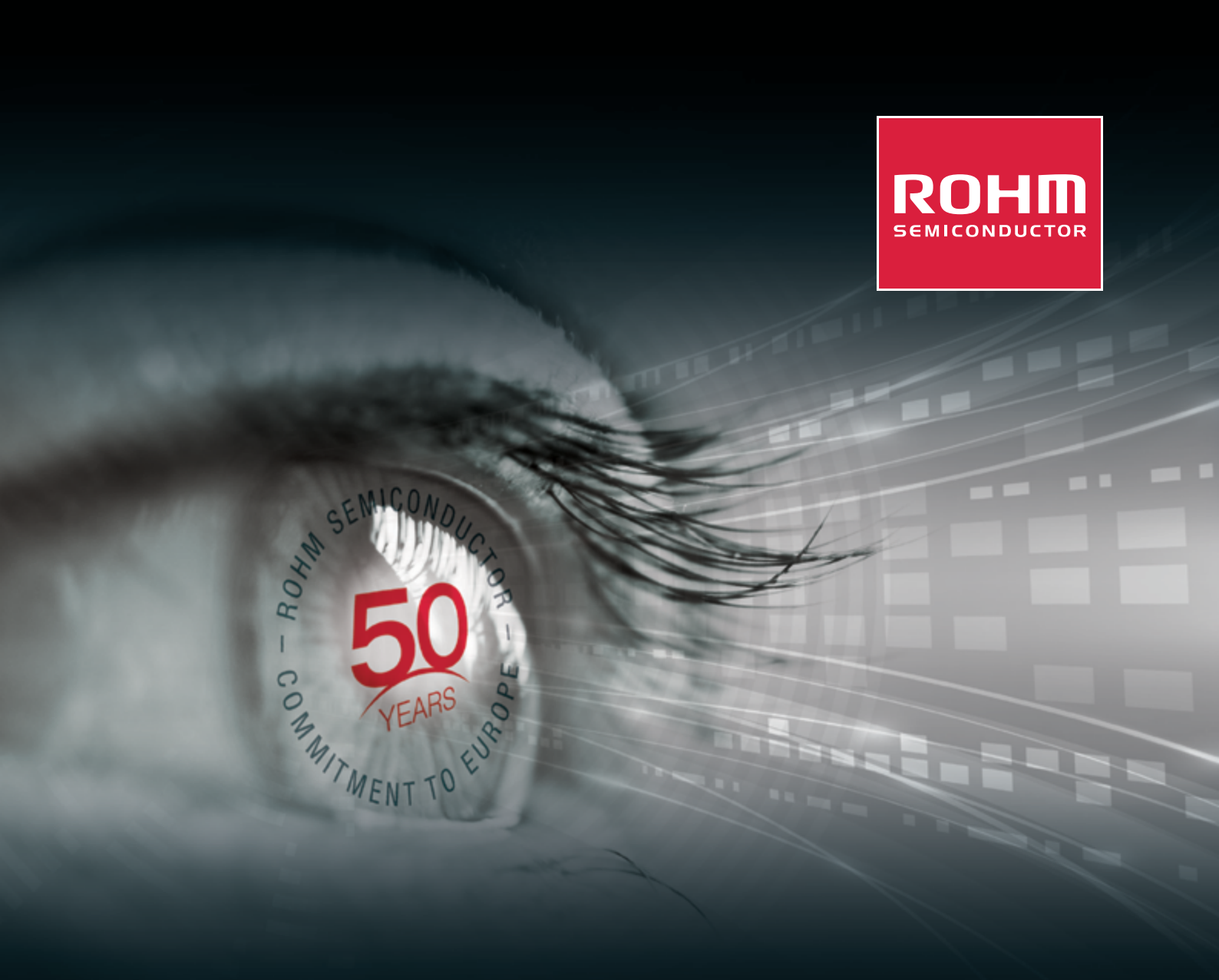
www.st.com

Wade Appelman Named President & COO

ACEINNA named Wade Appelman as the company's President & COO, responsible for developing and implementing strategy for the company's worldwide operations. "ACEINNA is part of two exciting market trends, autonomous driving and vehicle electrification. Used in autonomous vehicles to ensure both accuracy and safety, high precision Inertial Measurement Unit Sensors (IMU) complement perception sensors such as imaging, radar and LiDAR," says Mr. Appelman. "Current sensing is another strength for ACEINNA critical to power management and I'm excited to help this talented team continue its amazing growth and technology innovation in both of these segments."

According to Dr. Yang Zhao, founder and CEO of ACEINNA, "Wade is an organized and dynamic technology executive who will be able to successfully lead the ACEINNA engineering, marketing and business teams towards our goal of making next generation self- driving and eco-friendly vehicles a reality." Prior to joining ACEINNA, Mr. Appelman was VP and GM of the depth sensing division of ON Semiconductor where he led the team responsible for adoption of low light sensors in LiDAR and successfully secured early customers designs in automotive, medical, and industrial markets for the divisions sensing product portfolio.

www.aceinna.com



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www.rohm.com

Li-ion Battery Materials for Use in VW and Ford EVs

Toyocolor announced that it was tapped to supply the North American and European operations of SK Innovation, a South Korean lithium-ion (li-ion) battery manufacturer, with Toyocolor's Lioaccum™ series of conductive carbon nanotube (CNT) dispersions. Lioaccum dispersions are used as the conductive additive in li-ion cathodes to help expand li-ion battery capacity of electric vehicles (EVs), for increased driving distances and faster charging performance. They will help power SK Innovation's li-ion batteries installed in EVs manufactured by the Volkswagen Group and the Ford Motor Company. In recent years, the shift toward EVs is accelerating rapidly due to the global trend toward decarbonization, and many automakers have announced plans to sell only EVs by 2025 to mid-2030s. Li-ion batteries are the most common battery-type used in modern EVs due to their higher energy capacity. The incorporation of CNTs as the conductive additive is essential to increasing capacity but there have been a number of issues associated with CNT dispersion that have hindered its practical use. To resolve this issue, leveraging its unique dispersion technology, Toyocolor researchers in Japan successfully achieved high conductivity levels by replacing carbon black in the battery cathode with a small amount of Lioaccum CNT dispersions as the conductive additive. Reduced material usage not only gives battery manufacturers the additional cell space to insert active materials needed to boost battery capacity and performance, but it also considerably reduces manufacturing cost.

https://schd.toyoinkgroup.com

Distributors in Europe Awarded

TDK honored its best distribution partners in Europe by presenting them – for the eighth time – with the TDK European Distribution Award 2020. The gold award in the "High-Service Distributors" category went to Mouser Electronics. In the "International Volume Distributors" category, Rutronik Electronics was honored as in the previous year. The best local distributor is the Austrian company EPi Components. Only two other awards were given in the "Local Distributors" category this time: Silver went to Gateway Electronic Components in the UK and Bronze to AVIS KS in Slovakia.

"In the past year, during lockdown periods of the pandemic and especially in the aftermath, we have seen that distributor inventory is a major factor for satisfaction of end-customers," says Dietmar Jaeger, Head of TDK's Global Distributor Division. "That's why we raised our requirements and couldn't give out as many awards this year as we would have liked." At the end of 2020, there were already signs of a recovery in global business, followed by a massive upswing and extremely high demand for TDK products in 2021, says Jaeger. Mouser Electronics, in particular, was able to meet the highly increased demand very well and thus best fulfilled the award criteria.

www.tdk-electronics.tdk.com

Power Supply Engineering Scholarship Winner

Acopian Power Supplies announced that Yoelis Brito of Newark, New Jersey has been named the recipient of the annual Acopian Power Supply Engineering Scholarship. The scholarship program was established to help talented engineering students, enrolled full-time in an undergraduate United States college or university, pursue careers in power electronics or a related engineering discipline.

Ms. Brito is currently a junior at The College of New Jersey (TCNJ) and is pursuing her (BS) in Electrical Engineering. This summer, she took additional courses to further her education while tutoring middle school children in mathematics. Her specific areas of interest relate to renewable energy where she hopes to find a job in the energy sector. Ms. Brito plans to work in sustainability and renewable energy because she aspires to make clean air and energy accessible to underrepresented communities. "As a product of a major urban community like Newark, I want to give back to my community and others like it across the nation," she said. Ms. Brito will use the $1,000 Acopian Power Supply Scholarship towards tuition, books and other educational expenses at TCNJ next semester.

"Ms. Brito's stellar academic and extracurricular accomplishments, coupled with her focus on alternative clean energy sources, made her the obvious scholarship recipient," said Alex Karapetian, President of Acopian. "We are excited to see all the great things that are in Yoelis' future path."

www.acopian.com

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Inspire the Next

HPMSIM Hitachi

Online Power Simulation Tool

HPMSIM, Hitachi's new online power simulation tool is designed to help assist you in choosing the right Hitachi IGBT, Hybrid SiC and SiC MOSFET, suited to your needs.

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How to get started:

Contact us:

For further information on our products or services, please get in touch with one of our experts on: pdd@hitachi-eu.com

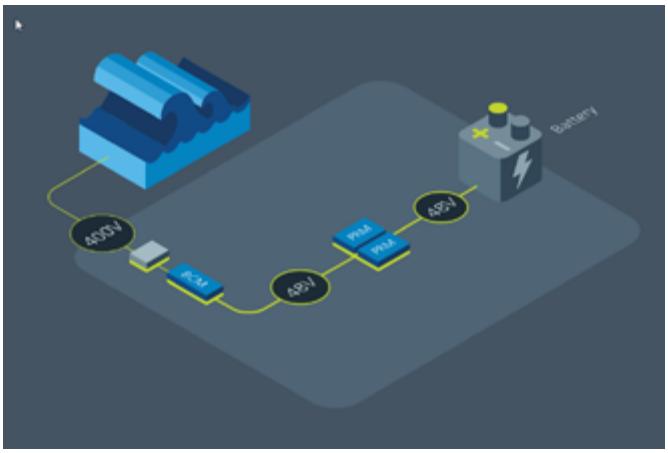
New Brand and Promise of Sustainable Future

ON Semiconductor revealed its new trade name “onsemi” and refreshed brand as a next step in the company’s evolution to establish itself as the leading provider of intelligent power and sensing technologies. With a continued focus on the automotive and industrial end-markets, onsemi has sharpened its strategy to drive disruptive innovation that contributes to a sustainable ecosystem of high-growth megatrends such as vehicle electrification, advanced safety, alternative energy and factory automation. Under the tagline, “Intelligent Technology. Better Future.”, onsemi plans to break through traditional thinking and market barriers to create innovative solutions that solve customers’ most difficult design challenges, and support their achievement of their own climate initiatives, propelling the sustainable energy revolution. onsemi’s value proposition includes a unique combination of deep systems knowledge, technology leadership, and industry-leading manufacturing and packaging proficiency. “We have spent the last several months focusing the strategy, and realigning our product portfolio and investments to deliver market-leading and differentiated technologies to our customers,” said Hassane El-Khoury, CEO and president at onsemi. “We are creating intelligent power and sensing technologies to enable our customers’ success, drive a better future for next generations and create value for our shareholders, always with an eye on sustainability to make the world a better place for everyone.”

www.onsemi.com

Ocean Wave Energy Harvesting

The ability to harness ocean wave energy is a rapidly evolving field that marine engineers are refining to provide reliable, cost-effective maritime energy generation and storage while enabling new forms of offshore data and communication services. Columbia Power Technologies (C-Power) is helping to expand the marine economy by providing reliable, cost-effective energy generation and storage, data and communication services for offshore assets. C-Power Autonomous Offshore Power Systems (AOPS) capture mechanical wave energy and convert it into usable power for a wide range of oceanic applications such as offshore oil and gas exploration and production, offshore carbon sequestration, oceanographic research, aquaculture and homeland defense. With the development of AOPS, C-Power opened the door to un-imagined applications by supplying an autonomous, environmentally friendly, ocean-borne power source capable of doubling as a communications conduit. SeaRAY enhances power efficiency and data communication. The latest AOPS platform, known as the SeaRAY, is key to the near-term focus of C-Power to produce power systems that generate 10W to 1MW from ocean waves. To achieve its goals at the lower end of the power spectrum, C-Power created a SeaRAY AOPS design with a high power-to-weight ratio using power conversion technology from Vicor Corporation. The small design footprint enhances mobility and commercial viability, making SeaRAY easier to deliver and set up, saving tens of thousands of dollars in daily operating costs.



“We really needed wide-range DC-DC, something that we could control and regulate as we’re converting pulsed ocean wave power into a semi-stable DC bus,” said Joe Prudell, a C-Power senior R&D electrical engineer. “This is extremely challenging. Being able to do that at various power levels using Vicor power modules really is an advantage.”

www.vicorpower.com

Cooperation for Ebike Drive Systems in the European Market

The BMZ Group and Panasonic Cycle Technology will join forces in the future in the European market. Panasonic Cycle Technology developed their first e-powered bike as early as 1979, launched current pedelec type of e-bike on the market in Japan in 1996 and has since been able to gain high market shares, especially in Japan, thanks to its high-performance e-bike components. Next to joint efforts for dedicated service and support, the cooperation will include the common equipping of OEMs with e-bike systems consisting of BMZ’s battery solutions combined with Panasonic Cycle Technology’s motor and display. Synergies can also be used effectively here, the BMZ Group can rely on an existing concept with international service points and partners. For many years, Panasonic Cycle Technology has been developing high-performance motors for different requirements, which are installed in well-known bicycle brands. From 60 Nm power, the GX Power to the GX Ultimate with 90 Nm, all power levels are covered - for city to mountain bikes. The appropriate range of compatible e-bike batteries from the BMZ Group, such as the recently introduced and most powerful integral e-bike battery of its time - BMZ V10 Intube with 725 Wh - were one more argument in favour of installing common systems in future.

www.bmz-group.com

Industrialized process for pre-pasted Thermal Interface Material (TIM)

FEATURES

- Optimized for Fuji modules
- Increased lifetime of IGBT
- Advanced IGBT power density

- Thermal – Benefits
  - Higher thermal conductivity
  - Uniform thermal resistance
  - Increased reliability and lifetime

- Process – Benefits
  - Outsourcing of a “dirty” process
  - Stable quality level
  - Computer controlled automated process
  - Increased System reliability
  - Printing according customer specification
  - TIM upon customers preference possible

VW ID.4 USA Tour

Demonstrating the power and convenience of an electric vehicle (EV), Volkswagen of America has teamed up with long-distance driving expert Rainer Zietlow for the VW ID.4 USA tour that recently kicked off at Volkswagen of America's headquarters in Herndon, VA. Infineon Technologies is on board of the VW ID.4 with over 50 semiconductors and enabling energy efficient electric drives and charging infrastructure. Moreover, the drive route of the tour, which will be crisscrossing the United States, will incorporate five Infineon facilities including Livonia, MI; San Jose, CA; Austin, TX; El Segundo, CA; and Washington D.C.

"Infineon supports climate protection through reduction of our own carbon emissions, along with products and technologies that enable renewable power generation, efficient storage, and sustainable mobility," said Lars Ullrich, Vice President of Automotive, Infineon Technologies Americas. "Our semiconductors are at the heart of vehicle electrification and the enabling charging infrastructure. By increasing range, efficiency and accessibility, we are helping the automotive industry to successfully achieve the fundamental transformation towards electromobility - to protect the environment without compromising drivers' flexibility and comfort." The ID.4 is Volkswagen's first all-electric SUV and the brand's first global EV. Infineon provides over 50 semiconductor components for the ID.4, including power semiconductors, microcontrollers and driver ICs.

www.infineon.com

Joining PowerAmerica Institute

Heraeus Electronics joins PowerAmerica Institute to advance the use of wide bandgap (WBG) semiconductors. The technological expertise of Heraeus Electronics and the industry connections of Power America Institute will accelerate the development of new materials and support the expansion of the Power Electronics industry.

The collaboration will result in bringing next generation silicon carbide and gallium nitride power electronics to markets faster, reducing cost and risk factors associated with new generation technologies. An organization that brings together the semiconductor manufacturers and the companies that use semiconductor power electronics in their products, PowerAmerica Institute is well placed as an information hub. With the backing of the U.S. Department of Energy and the engagement of top researchers, knowledge and processes can be provided to educate the American workforce and provide more innovative product designs.

"By working in collaboration with Heraeus Electronics, we can maximize device performance without the compromise of cost", says Executive Director Victor Veliadis from PowerAmerica Institute. Heraeus Electronics offers matched materials as well as latest equipment to support customer developments by assembling prototypes and test modules according to the highest standards.

David Malanga, Director of Marketing and Sales for Heraeus Electronics in the Americas, adds: "With our deep understanding of the power electronics market and PowerAmerica Institute's connections, we can assist in driving future developments, employee education, and market direction for a stronger industry tomorrow."

www.heraeus.com

ECCE 2021 Comes to Vancouver

The Energy Conversion Conference and Expo (ECCE) is making its West Coast rotation to Vancouver, Canada, October 10-14, 2021. The conference for the IEEE Industrial Application Society (IAS) and Power Electronics Society (PELS), has been running annually for 12 years, and is the world's largest podium for presenting the latest power electronics, electric machines, and drives research, their applications, and engineering training. With over 1,600 attendees (2019), multiple educational tutorials, technical sessions, industry panels, social events, and public Exhibit Hall, the conference is the ideal location to meet with existing customers. Typically, half in attendance are international, which gives the exposure needed to forge new customer relationships.

For those unable to travel to the event, the program will run in parallel using vFAIRS, a widely adopted virtual event platform, providing participants with the closest "in-person" experience possible. The exhibition takes place over the first two days, at the height of conference attendance. On day one, join industry leaders, entrepreneurs and top researchers as they address attendees during the Plenary Sessions, followed by the Expo and Welcome Reception, which will offer complimentary food, beverage, and plenty of booth traffic.

www.ieee-ecce.org/2021

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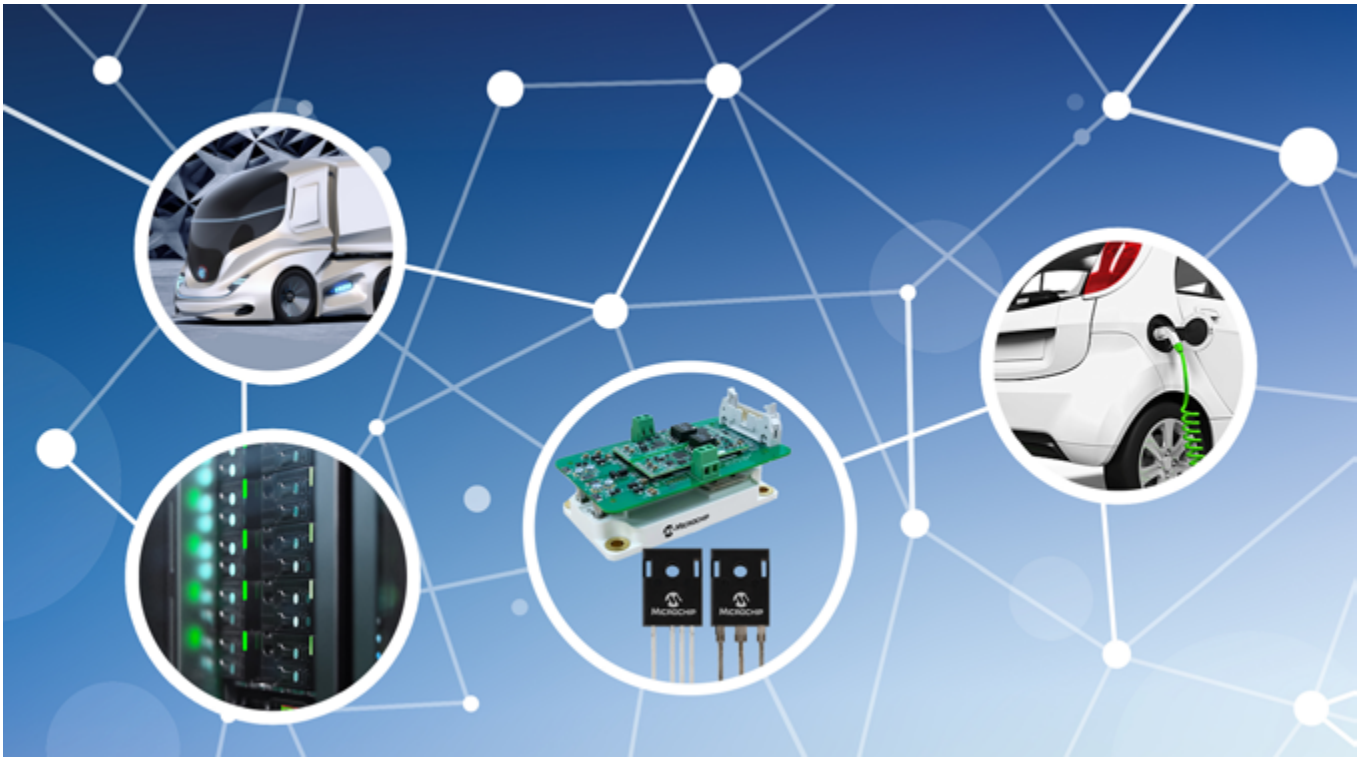
Silicon Carbide Power Devices Now Available at 1700V

Silicon carbide portfolio with 1700V MOSFET die, discrete and power module devices extend designers' options for efficiency, power density



Today's energy-efficient electric charging systems powering commercial vehicle propulsion, as well as auxiliary power systems, solar inverters, solid-state transformers and other transportation and industrial applications all rely on high-voltage switching power devices. To meet these requirements, Microchip Technology announced the expansion of its silicon carbide portfolio with a family of high-efficiency, high-reliability 1700V silicon carbide MOSFET die, discrete and power modules.

Microchip's 1700V silicon carbide technology is an alternative to silicon IGBTs. The earlier technology required designers to compromise performance and use complicated topologies due to restrictions on switching frequency by lossy silicon IGBTs. In addition, the size and weight of power electronic systems are bloated by transformers, which can only be reduced in size by increasing switching frequency.

The silicon carbide product family allows engineers to move beyond IGBTs, instead using two-level topologies with reduced part count, greater efficiency and simpler control schemes. Without switching limitations, power conversion units can be significantly reduced in size and weight, freeing up space for more charging stations, additional room for paying passengers and cargo, or extending the range and operating time of heavy vehicles, electric buses and other battery-powered commercial vehicles – all at reduced overall system cost.

"System developers in the transportation segment are continuously asked to fit more people and goods into vehicles that cannot be made larger," said Leon Gross, vice president of Microchip's discrete product business unit. "One of the best ways to help achieve this is through the enormous reductions in size, and weight of power conversion equipment that utilizes high-voltage silicon carbide power devices. These same advantages for transportation bring similar benefits to many other industry applications."

Features include gate oxide stability where Microchip observed no shift in threshold voltage even after an extended 100,000 pulses in repetitive unclamped inductive switching (R-UIS) tests. R-UIS tests also showed excellent avalanche ruggedness and parametric stability and with gate oxide stability, demonstrated reliable operation over the life of the system.

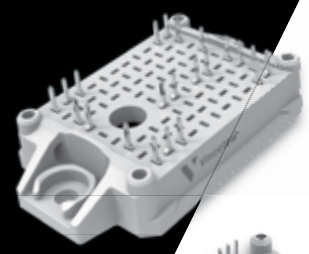
The degradation-free body diode can eliminate the need to use an external diode with the silicon carbide MOSFET. A short-circuit withstand capability comparable to IGBTs survives harmful electrical transients. A flatter $R_{DS(on)}$ curve over junction temperature from 0 to 175 degrees Celsius (C) enables the power system to operate at greater stability than other silicon carbide MOSFETs that exhibit more sensitivity to temperature.

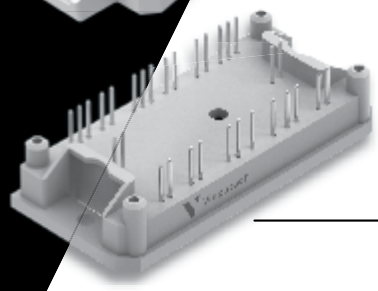
Microchip streamlines the adoption of its technology with a family of AgileSwitch® digital programmable gate drivers and wide range of discrete and power module packaging, available in standard and customizable formats. These gate drivers help speed silicon carbide development from benchtop to production.

www.microchip.com

TANDEM DIODES FOR FASTER SWITCHING

Vincotech

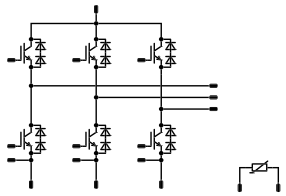




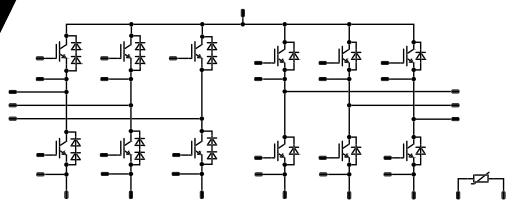
Solutions for Motion Control applications with MiniSKiiP® and *flow* lines.

Tandem diodes design approach for Power Modules implementation aligns performance, robustness and cost effective solutions. For Motion Control Market segment, Vincotech offers Tandem diodes solutions in SixPack, Twin SixPack and PIM topologies using several housing options.

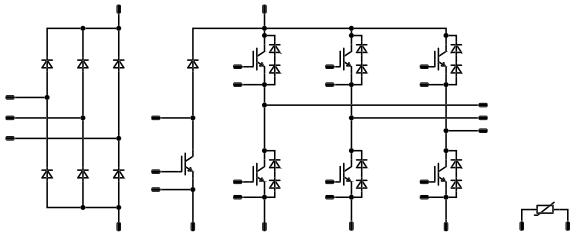
SixPack Topology



Twin SixPack Configuration



PIM: Converter+Inverter+Brake



Main benefits

- 650 V diodes in tandem configuration cut the switching losses even further
- Integrated thermal sensor makes it so much easier and cheaper to measure temperature
- Standardized footprint for easier and cheaper PCB design
- Kelvin emitter enhances current control and switching performance

Check out

Vincotech's fully optimized and tailor-made solutions for 1500 V PV systems with a broad range of power modules for the consumer, commercial and utility market.

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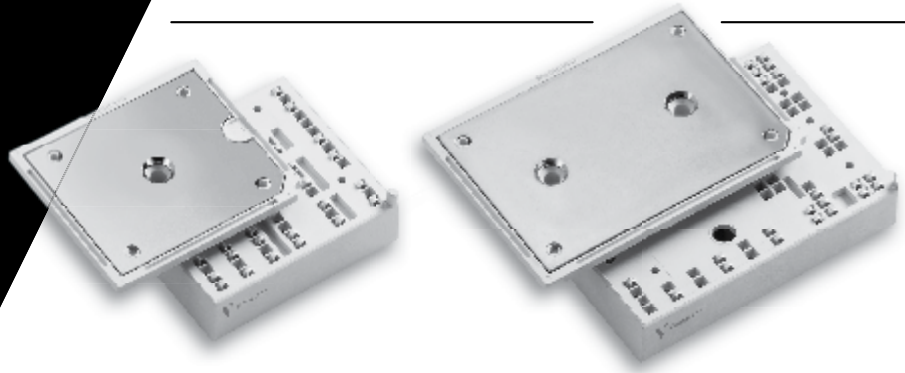

EMPOWERING **YOUR IDEAS**

Bidirectional DC Power Supplies and Regenerative DC Loads for Testing Fuel Cells

In response to demand for growing hydrogen fuel cell development and test, EA Elektro-Automatik offers a series of powerful bidirectional DC power supplies and regenerative DC loads ideal for fuel cell stack testing.´Fuel cell performance requires adherence to a variety of specifications, so test engineers must conduct a series of characterization, performance and durability tests. Fuel cells are characterized by determining their resistance. Fuel cell performance is usually indicated via polarization curves by measuring its voltage and current. A durability test is the test after a fuel cell stack reaches operating conditions, the stack is subjected to a continuous series of charge/discharge cycles to ensure that it will work safely and reliably in the field.

"In response to the demand for clean energy, the market for fuel cells is growing at a compound annual growth rate of 26.4% and is projected to reach $848 M by 2025. Uses for fuel cells include power generation for commercial vehicles such as buses and forklifts, backup power generation systems, and for other power sources. To ensure the design and manufacturing of quality fuel cells, EA Elektro-Automatik offers its EA-PSB 10000 2-quadrant power supplies and EA-ELR 10000 series electronic loads. Both the EA-PSB power supplies and the EA-ELR loads sink up to 30 kW and feed the energy back to the grid to enable testing of any size fuel cell stack," said Markus Schyboll, CEO of EA Elektro-Automatik (EA).

Both the PSB power supplies and the ELR electronic loads have built-in function generators that include arbitrary waveform generation, which simplifies characterization, performance, and durability testing of fuel cells. Unlike other loads that need a separate AC instrument, the ELR load, with its built-in waveform generator, can perform the perturbation test to determine fuel cell resistance. In addition, both the PSB supplies and the ELR loads, with their built-in waveform generators, can subject the fuel cell-under-test to dynamic load variations for performance and durability testing.

The PSB DC supply also has an internal X-Y generator that allows the supply to simulate the output of a fuel cell. At various voltages, the PSB supply can vary its output resistance to generate a current characteristic of the fuel cell at the programmed voltage. Thus, the PSB supply can emulate the three phases of a fuel cell's characteristic output. The PSB supply can add ripple and noise onto its output to determine how well a fuel-cell powered device can perform under a wide range of conditions.

Both the PSB series supplies and the ELR loads offer true autoranging performance. The PSB supplies have a constant power characteristic output that allows for a wider range of voltage and current output with one instrument. The supplies can have ranges from 0 – 60 V up to 0 – 2000 V. Current outputs can be up to 1000 A at 30 V with the 30 kW supply. Similarly, the ELR loads can sink up to 2000 V or 1000 A with the 30 kW load. Autoranging power supplies and loads enable users to obtain higher voltages and currents without having to oversize the supply or the load. Thus, one instrument provides a wider range of testing capacity and versatility for use in multiple test applications. The PSB supplies and ELR loads save test costs and test rack space compared with fixed range instruments.

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INCREASING POWER DENSITY FOR MOTOR DRIVES WITH SILICON CARBIDE

COMPACT DUAL INLINE PACKAGE

Footprint 58.7mm x 41.4mm

FEATURES

- Utilizes Silicon Carbon MOSFETs for superior performance
- High continuous output current – 30 A
- High supply voltage– 650 V maximum
- Fast switching frequency – 400 kHz
- Integrated with digitally controlled gate drive
- Under-voltage lock-out and active Miller clamping

TARGET APPLICATIONS

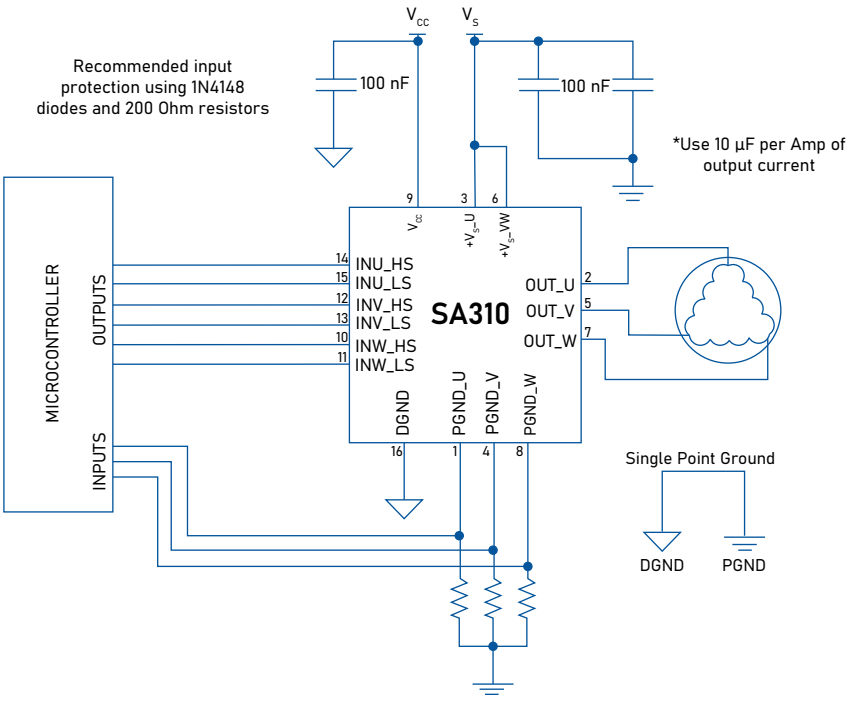
- BLDC Motor Drivers
- Variable Frequency Drives
- DC/AC Converters
- Power Inverters
- Test Equipment

SA310: 3-PHASE SILICON CARBIDE MODULE

The SA310 is a fully integrated three-phase driver designed primarily to drive Brushless DC (BLDC) and Permanent Magnet Synchronous (PMSM) motors or DC/AC converters. The module uses Silicon Carbide MOSFET technology to improve efficiency over other devices in its class. Three independent half-bridges provide up to 80A peak output current under direct microcontroller or DSC control. The SA310 is built on a thermally conductive substrate that is electrically isolated to provide the most versatility and ease in heatsinking.

The amplifier protection features include under-voltage lockout (UVLO) function and active Miller clamping to reduce switching noise and improve reliability. Also included in the module are Silicon Carbide Schottky Barrier free-wheeling diodes to protect the body diode of each MOSFET. No external output protection diodes are required. The SA310's integrated gate drivers provide transformer isolation between the inputs and high-voltage outputs.

TYPICAL APPLICATION



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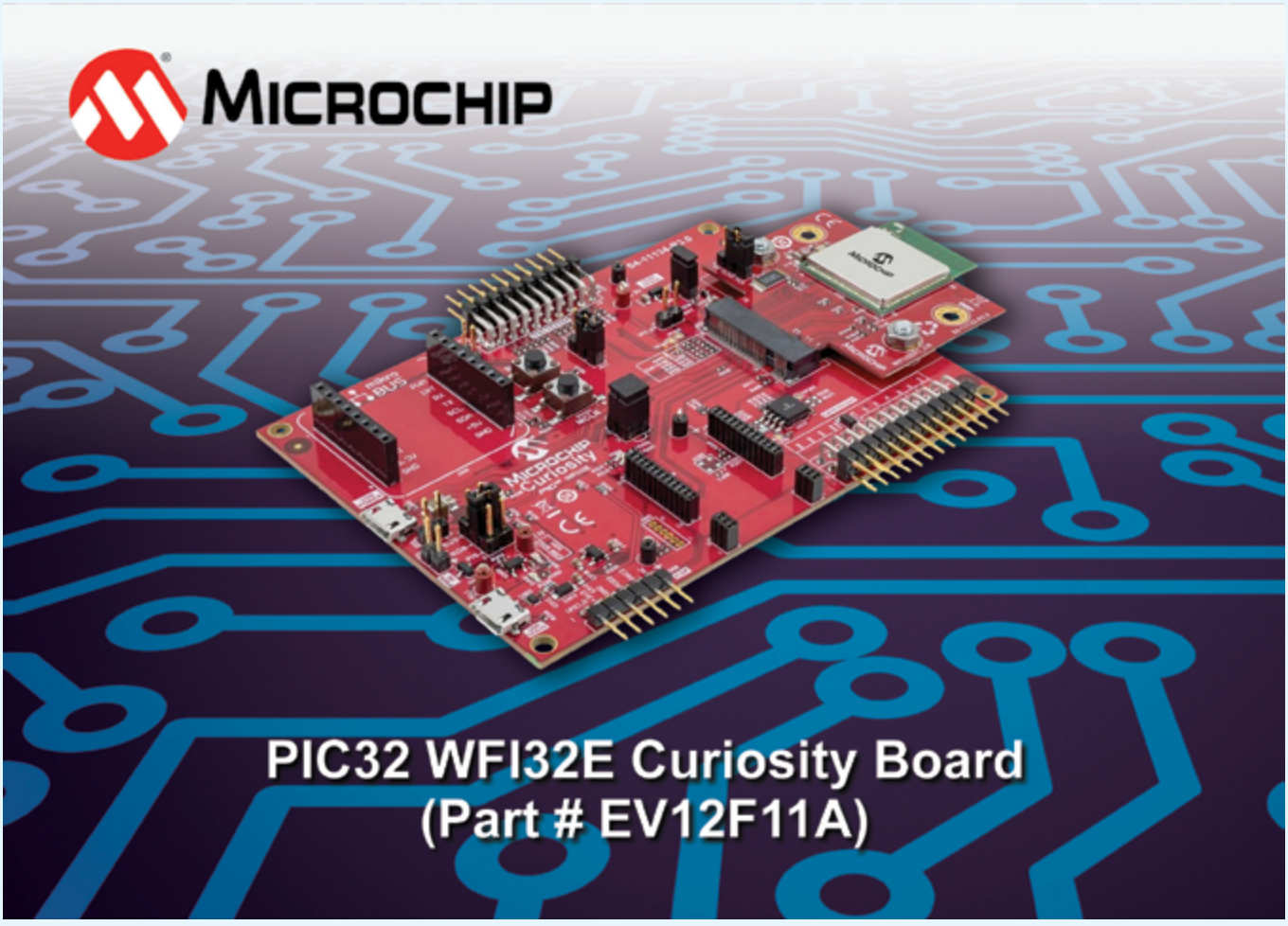

The PIC32 WFI32E Curiosity Board is an easy-to-use evaluation tool to evaluate the performance of WFI32E01PC Wi-Fi MCU module, which contains the PIC32MZW1 series Wi-Fi SoC. This 200MHz high performance MCU has industrial leading Wi-Fi connectivity and rich peripheral options. The PIC32MZW1 has 1MB embedded flash and 256KB SRAM, empowering embedded designers to rapidly build complex IoT software covering WLAN, TCP/IP stack, RTOS, Cloud connectivity, and application. Various types of peripherals, such as Ethernet, USB, ADC, CVD touch buttons, and CAN, make PIC32MZW1 a perfect system core to realize the most application features.

There are various types of on-board connecting header for users to build up their applications by connecting to various types of add-on boards such as Microchip's XPRO boards. Users can also expand its functionality through MikroElectronika mikroBUS™ Click™ adapter boards. The PIC32 WFI32E Curiosity Board has the PICkit On-board (PKOB) debugger based on a PIC24FJ256GB106 USB Microcontroller. Additionally, it supports external debuggers, such as MPLAB REAL ICE, MPLAB ICD 3 by connecting to the ICSPTM header.

For your chance to win a PIC32 WFI32E Curiosity Board or receive a 20% off voucher, including free shipping, visit https://page.microchip.com/Bodo-PIC32.html and enter your details in the online entry form.

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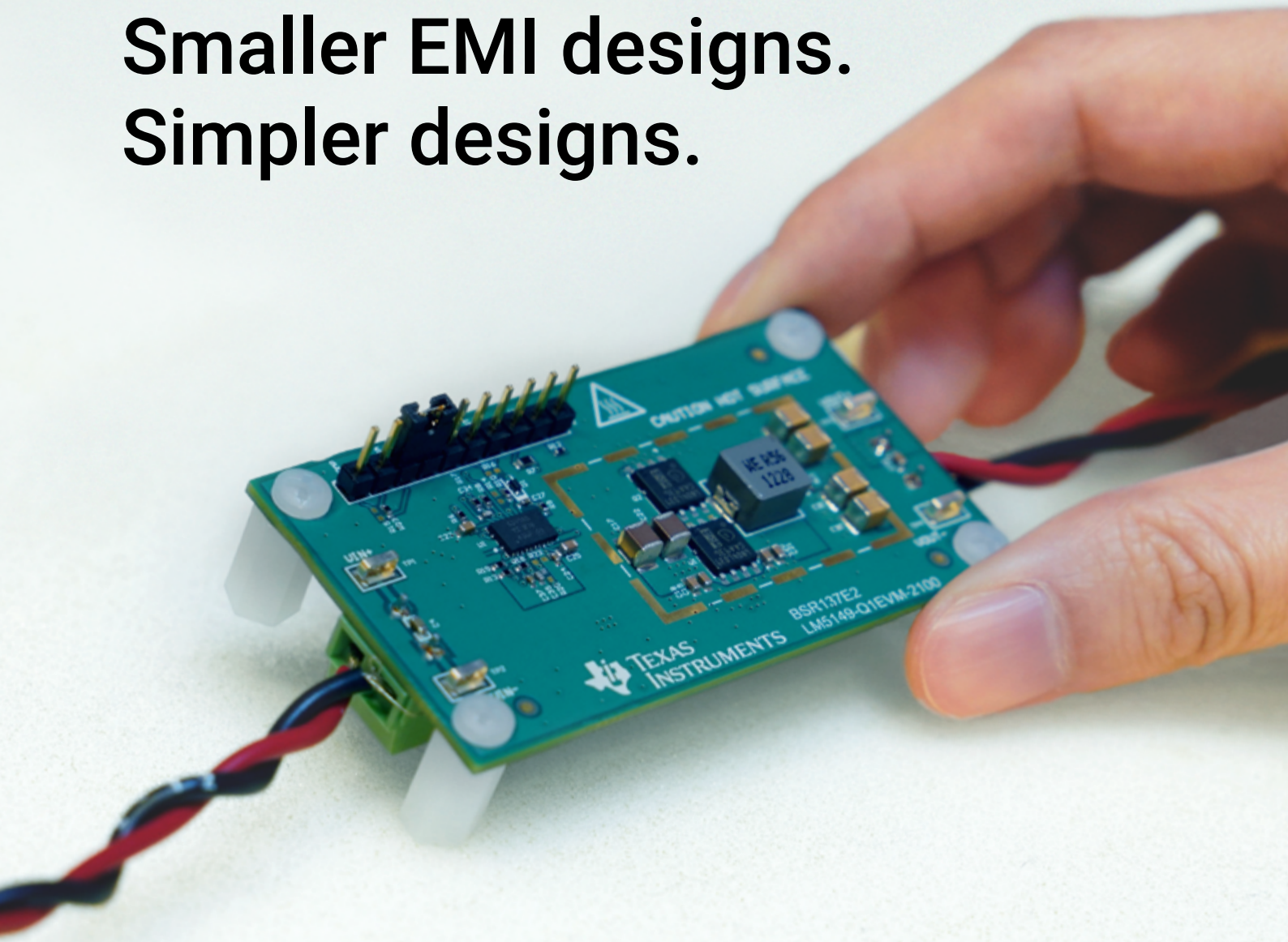

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TEXAS INSTRUMENTS

Why Motors Are Smaller, Faster and More Precise With GaN

With the growing adoption and increasing applications of GaN, Bodo Arlt has taken the opportunity to talk to EPC's CEO and Co-Founder Alex Lidow to discuss what he believes is the next big market for this evolving technology.

By Bodo Arlt, Publishing Editor, Bodo's Power Systems

EPC has contributed multiple articles to this magazine on the topic of GaN-based motor drives recently. What applications do you see getting the most benefit from motor drives using GaN technology?
The best fit for our GaN devices is for brushless DC motors where the input voltage is between 24 V and 150 V, typically 48 V and the emerging 96 V. Applications include servo drives, e-bikes and e-scooters, warehouse, autonomous robots, lean production line collaborative robots, medical robotics, and industrial drones.

e-scooters and e-bikes is a very fast-growing market but seems to be cost-sensitive. Where do you see the fit for GaN in this market?
The rapid emergence of e-scooters and e-bikes has created a surge in demand for compact, lightweight motor drives. The high frequency capability of GaN allows for the design of much smaller motor drives and this miniaturization enables better esthetic, lighter weight, and lower cost solutions for eMobility. Also, the higher efficiency provided by GaN is critical for longer battery life to achieve increased range between charges.

I don't typically think of motor drives as needing particularly high frequency. What is the benefit in motor drive designs to increasing the frequency?
For motor drive applications a GaN inverter can easily operate at 100 kHz PWM frequency thanks to its lower switching dissipation and smoother switching at the allowed dv/dt. An immediate result is that voltage and current ripples at the battery cables are drastically reduced, so there is no need for any LC input filter based on electrolytic capacitors. Ceramic capacitors can replace bulky, temperature sensitive, and lower reliability electrolytic capacitors, thus saving costs, increasing efficiency, reliability, and lifetime. For example, in a 400 W motor drive as would be used in a e-bike, a 330 uF electrolytic capacitor can be replaced with 22 uF of ceramic capacitors. In addition, the input filter inductor can be completely eliminated.

Is the GaN inverter going to be more efficient than an inverter based on MOSFETs? Is there any effect on the motor due to the use of GaN?
To answer this question, we need to consider the system made of motor-plus-inverter and not only the inverter alone. Let me explain better: a conventional 20 kHz MOSFET inverter can reach 98% efficiency as well as a GaN inverter can reach 98% when running at 100 kHz. But there is one big difference: the GaN inverter allows very small dead time (tens of ns). Dead time in motor drives is responsible for an even harmonic (the sixth) on the torque that produces only vibration and heat and does not contribute to motion. With a GaN inverter the even harmonic of the torque is completely removed and the motor itself becomes more efficient delivering more torque per ampere. So, the total system becomes more efficient.

It seems the advantages of compact, lightweight design also benefits many of the other applications you mentioned such as autonomous robots and industrial drones. Are there other advantages to consider?
Yes, there's quite a large advantage which resulted in some of our earliest motor drive success, and that is precision motion and positioning. Some of the earliest adoption of GaN-based motor drives has been for medical robotics. The weight and size of the motor are also important for these designs but what is perhaps even more crucial is precision. The ability to operate at higher frequencies increases control bandwidth for the motor. This increases the precision at which the motor can be controlled. In addition, the higher frequency reduces, or even eliminates, mechanical vibration which is crucial to being able to take advantage of the higher control precision. Precision can literally save lives in this application!

What about automotive motors?
There is an emerging use case for GaN in a myriad of small motors that are inside the vehicle. The value for GaN devices in 48 V automotive motors is that they can reduce the size and weight of the motors, reduce audible noise, get better torque, extend battery life, and provide higher efficiency. EPC has a growing line of AEC-Q101 qualified FETs for automotive applications and will be adding AEC-Q100 qualified GaN ICs to the product portfolio as well.

If my readers would like further technical information on EPC's GaN solutions for Motor Drive applications, where should they go?
The motor drive landing page on the EPC website is a great place to start because it has an entire repository of information on GaN in motor drives including applications notes and videos. The landing page is at: https://epc-co.com/epc/Applications/MotorDrive.aspx. In addition, our fantastic team of field applications engineers is always ready to help with everything from product selection to layout reviews and production assistance. The easiest way to reach them, if you don't already have a direct contact, is to submit an inquiry via our Ask a Motor Drive Expert feature.

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High-Voltage IGBT Modules for High-Power High-Reliability Applications

When it comes to high-power applications with highest reliability requirements, HV-IGBTs in the famous std-type package are still the favorable choice. This article explains the reasons and how this traditional package is raised to the next level by a variety of innovative technologies.

By Nils Soltau, Eugen Stumpf, Mitsubishi Electric Europe B.V., Ratingen, Germany
Junya Sakai, Hitoshi Uemura, Mitsubishi Electric Corporation, Fukuoka, Japan

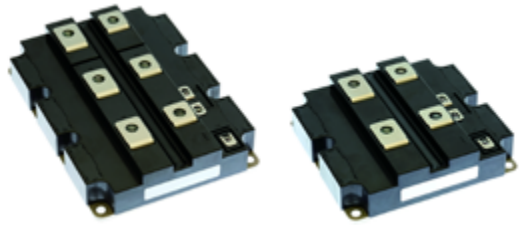
Introduction

In the second half of the 1990s, development and commercialization of IGBT power modules for high voltage ratings as 2500 V and 3300 V has started. Originally, these HV-IGBTs were designed as GTO replacement for high-power and high-reliability applications like for example railway traction inverters [1]. Additionally, the use in many other high-power applications has followed.

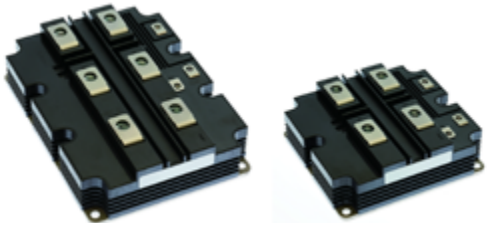
The device package, which has been used back then, already had the same outline like today's HV-IGBT power modules. It is the well-known std-type package with a rectangular footprint of 190 mm times 140 mm.

The advantage of the std-type package is the huge current capacity. Moreover, as single-switch device, it offers great flexibility for complex converter topologies. Therefore, MITSUBISHI ELECTRIC develops power modules in the std-type package further and includes latest chip and package technology.

The newest std-type power modules with state-of-the-art X-Series chip set are now available for voltage classes from 1700 V to 6500 V. Figure 1 shows the different std-type packages. This article reveals why and for which applications MITSUBISHI ELECTRIC has developed these power modules. Efficiency, power density and robustness of these power modules increased compared to previous generations. We will have a look at the key-enabling technologies for this improvement.



(a) Insulation voltage 6 kV



(b) Insulation voltage 10.2 kV

Figure 1: std-type package with latest X-Series chip technology with 190x140mm² and 130x140mm² footprint packages

Applications Dedicated to std-type HV-IGBTs

HVDC

Considering bulk-power electricity transmission, high-voltage DC (HVDC) systems based on IGBT power modules have become a mature technology. They allow more compact plant design and more flexible operation compared to the classical thyristor-based transmission systems [2]. In state-of-the-art HVDC systems, DC transmission currents reach 2 kA and beyond [3] [4].

STATCOM

The share of renewable energy sources in our electricity network is steadily increasing. At the same time, related to the goal for CO2 reduction, the share of coal generation is decreasing. The loss of inertia by large generators together with the fluctuating power generation from renewables make stabilization of the electricity network more difficult. STATCOMs (Static Synchronous Compensators) are able to stabilize the network by providing reactive power, active filtering capability, flicker reduction or frequency stabilization. MMC-based [5] STATCOMs are highly modular. Single converter branches can provide inductive or capacitive reactive power of ± 400 MVA for example [6].

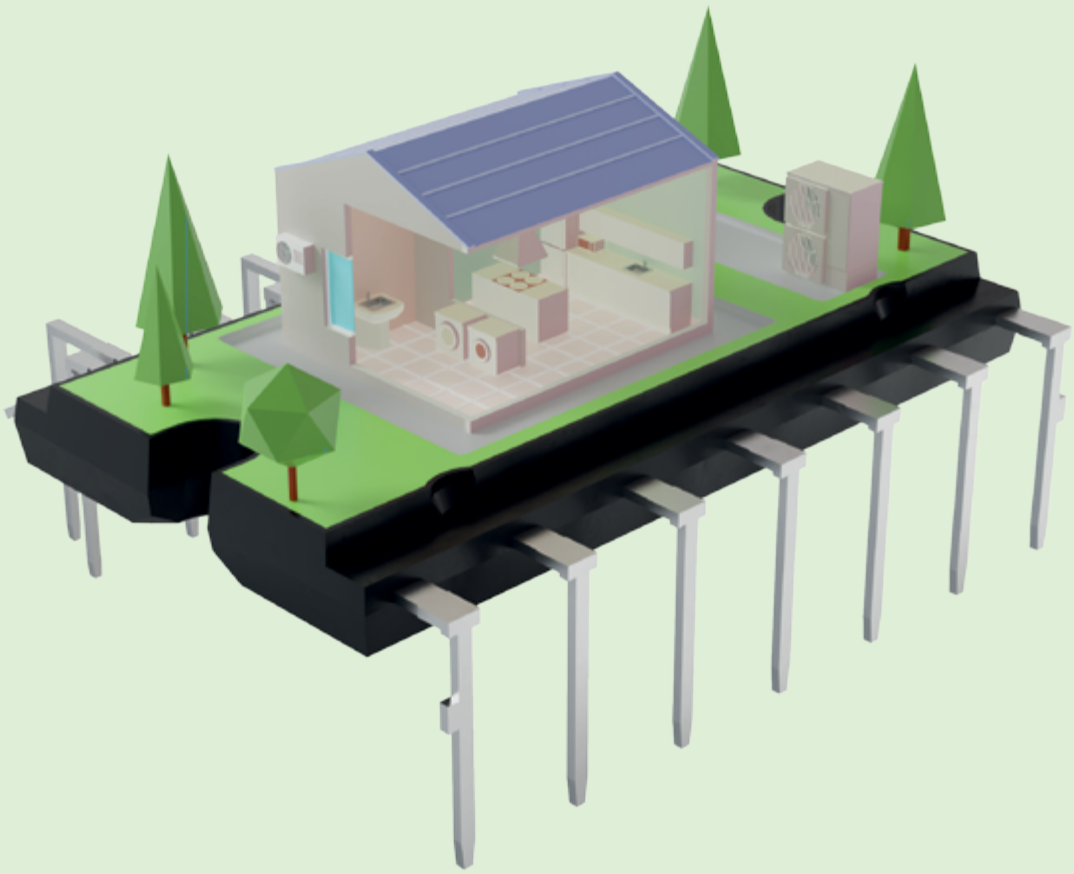
Medium-Voltage Drives

Medium-voltage (MV) drives allow the speed control of high-power motors and generators in the voltage range of 3.3 kV or higher. These drive systems are used for offshore wind generation, mills, conveyor belts, compressors or ship propulsion. Usually, these drives have high reliability requirements. Bidirectional power flow for recuperating electric energy is often mandatory. For such MV drives, multilevel converter topologies are frequently used, like 3-level NPC converter [6] or other 5- or 7-level topologies.

All above applications have in common that they require IGBT power modules with high current capability. Moreover, end-customers have highest expectations about converter reliability and robustness of semiconductor power modules within. Especially when considering 3-, 5-, or 7-level converter topologies, the busbar design becomes challenging. Hence, the semiconductor power modules should provide as much freedom as possible when designing the converter.

The three examples above show that std-type packages are still the first choice for many applications. The std-type packages enable large output currents as 2400 A in the 130x140 mm² package. Moreover, the package outline itself has proven its suitability in decades of field operation. The std-type package originally features "1-in-1" single-switch power modules. The single-switches allow maximal freedom in the converter design which is particularly important for multi-level topologies.

AUTOMOTIVE HOME APPLIANCES INDUSTRIAL POWER TRANSMISSION RENEWABLES RAILWAY



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Changes for the Better

Another use is the development or refurbishment of existing converter platforms. Outline of the new std-type power modules is compatible with previous power modules generations. Therefore, changing to a newer IGBT generation is easily possible. Newer IGBT generations allow higher output current, higher power cycling capability or robustness against humidity. Figure 2 illustrate the possibility to increase the output current by 50 % or reduce size to 2/3 with the new X-Series.

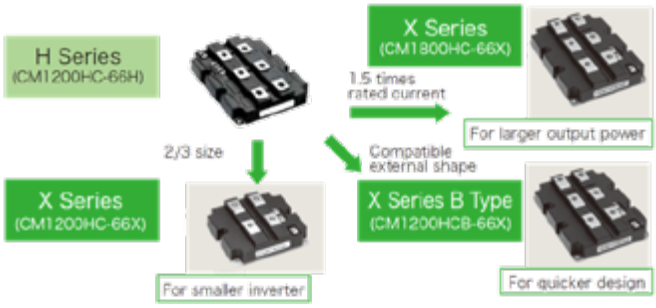

Figure 2: Output current and compactness improvement of new X-Series compared to previous H-Series

Technical Features of X-Series std-type Power Modules

CSTBT (III) and RFC diode

The current generation of high-voltage power modules has utilized all advantages of 7th generation chips using CSTBT (III) (Carrier Stored Trench-Gate Bipolar Transistor) structure of IGBT and RFC (Relaxed Field of Cathode) structure in the free-wheel-diode. Both chip technologies allow combination of reduced steady state loss, switching loss and robust switching performance. Both chip technologies shift the boarders of technology triangle considering robustness, low total power loss and wide SOA.

The CSTBT is a trade mark of MITSUBISHI ELECTRIC. The CSTBT technology is to be considered as improved technology of trench structure of IGBT. The trench architecture in power devices is introduced by MITSUBISHI ELECTRIC in 1994 allowing reduction of ON-state voltage and endurance property for latch up vs. planar IGBT [7]. The main gain by using of trench IGBTs is elimination of the parasitic JFET resistance. This technological step in combination with LPT (light punch through) technology allows significant drop of $V_{CE(sat)}$ value in IGBT.

The CSTBT forms the n-layer under p-base between trenches, the n-layer stores carriers; as result, the carrier distribution of the CSTBT becomes that of the diode. The density of minority chargers increases, allowing recombination, allowing further reduction of steady state loss [8]. Figure 3 represents the differences between conventional trench technology and CSTBT proposed by MITSUBISHI ELECTRIC. The semitransparent n-buried-layer increases the concentration of minority charges in n-layer.

The CSTBT (III) development is further improvement of CSTBT technology with focus on turn-off loss reduction and uniformity of characteristics like $V_{GE(th)}$ distribution [9]. This improvement allows further utilization of Si material before substitution by SiC power devices.

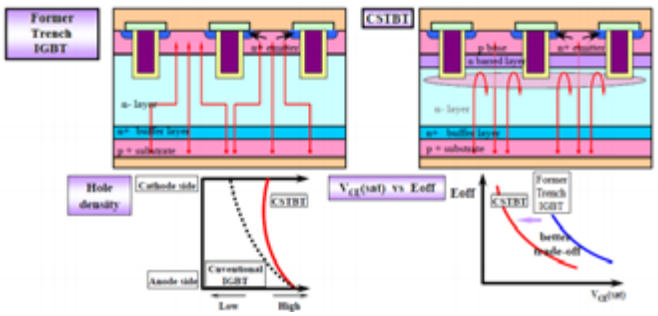

Figure 3: CSTBT in comparison to conventional IGBT

The other contribution for efficiency and reliability increase is considered by development and utilization of RFC technique in antiparallel free wheel diode. The dynamic ruggedness and recovery softness are two characteristics which are achieved by introduction of a "Light Punch-Through (LPT) II" and a "Controlling Carrier-Plasma Layer (CPL)" [10] [11] [12]. The Figure 4 shows realization of LPT II buffer on back side pattern which mainly construes to the softness of diode, to improvement of EMC behavior and finally to ruggedness of the total power module.

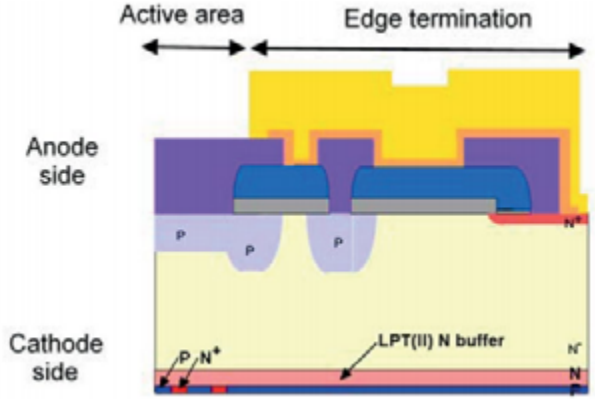

Figure 4: Structure of RFC diode

RBSOA Capability

One of the critical events for HVIGBT is turn-off event. Therefore, a wide turn-off safe operating area, so called RBSOA (Reverse Bias Safe Operating Area), is desired. Usually, the maximum specified turn-off current is twice rated current as mentioned in the datasheet. In order to secure low FIT rate in so called "useful life" of the bathtub curve of the power module, the actual turn-off capability must be higher than specified value. The following example demonstrates how big the margin between specification and actual capability is. In this example, turn-off event in one segment of a 6500 V power module with rated current of 330 A is used. Figure 5 represents such event showing turn-off current of 2000A under worst case conditions of V_{cc} = 4500 V; T_j = 150°C. The factor between RBSOA specification (330Ax2) and actual turn-off capability is 3. Similar RBSOA margin by using of 1000A/6500V power module CM1000HG-130XA is reported in [13], showing margin factor of 4.

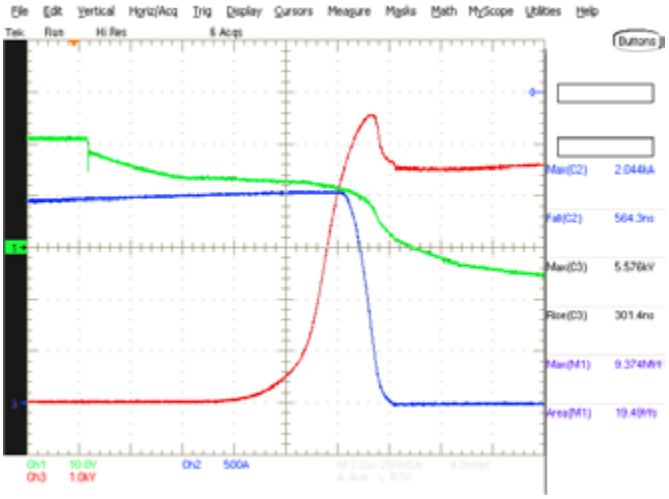

Figure 5: Turn-off switching waveform (green: V_{GE} 10V/div, blue: I_C 500A/div, red: V_{CE} 1000V/div, time: 2µs/div)

Short Circuit Robustness

To increase converter robustness and decrease downtime after a failure, IGBT power modules usually require short circuit withstand capability. However, not every short circuit has same impact on the power module. Different classifications are done. For example, short circuit type 1 is present when the short circuit occurs before

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the IGBT turns on. On the contrary, a short circuit type 2 appears when the IGBT has already been turned on and is conducting current [14].

Figure 6 shows the test setup for testing short circuit type 2. IGBT 1 is constantly turned off and only used for freewheeling. IGBT 2 is the actual device under test (DUT). IGBT 3, the "short-circuiter", emulates the short circuit together with the short circuit inductance L_{SC}, which is substantially lower than the load inductance L_{load}. To begin the test, the DUT is turned on to ramp up the current. When the desired testing current is reached, the short-circuiter is turned on causing a steep current rise. After a specified time, the DUT is turn-off. The current stored in the inductances L_{SC} and L_{load} freewheels through IGBT 1. When the currents reaches zero, the test ends.

Figure 7 demonstrates the withstand of a 6.5 kV power module. The test utilizes one of three segments of CM1000HG-130XA. Hence, one segment corresponds to a rated current of around 330 A. The short circuit appears when the IGBT segment already conducts 3-times rated current, means 1000 A. During the short circuit the current rises up to almost 4 kA when the IGBT desaturates and limits the current. After 10 µs, the DUT successfully turns off the short circuit and keeps alive. This test demonstrates once more the high ruggedness of the X-Series power modules.

Power Cycling Capability

Even though X-Series std-type power modules look similar like previous generations from the outside, they include many technical improvements in the inside. Many of these improvements target the increase of power cycling capability.

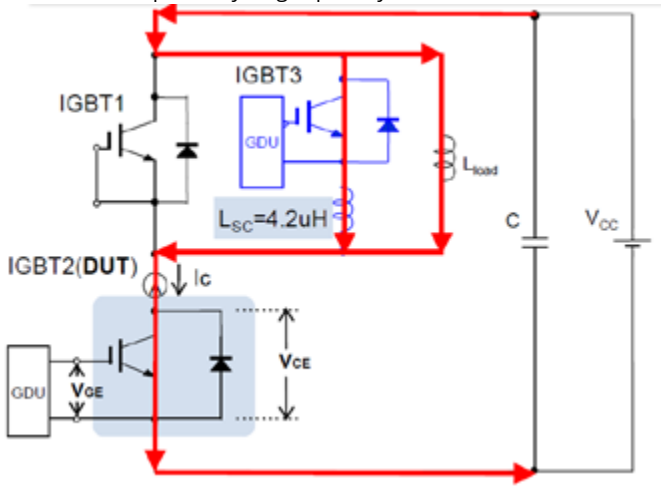


Figure 6: Short circuit type 2 test setup

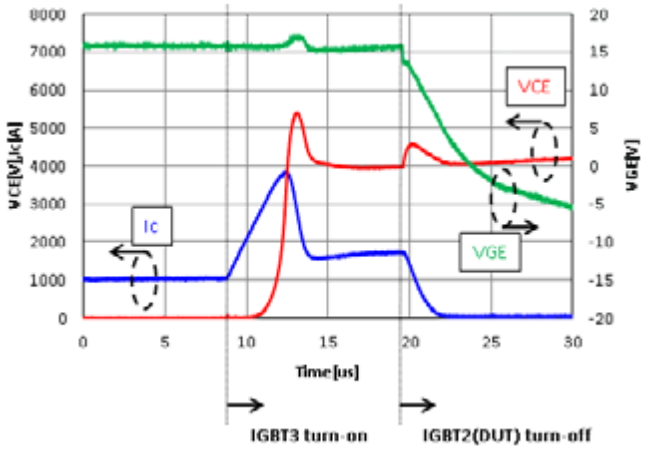


Figure 7: Withstand of short circuit type 2 using one of three segments of CM1000HG-130XA (conditions: V_{CC}=4200V, T_j=150°C, V_{GE}=15V, t_w=10µs, I_c (before short circuit)=1000A (3·I_{nom})

Compared to previous generations , the X-Series uses a high-temperature solder for the die bonding. Also the solder for attaching the substrate to the baseplate has been improved together with a change of the ceramic metallization. Finally, using improved gel material enabled further increase of power cycling capability. Power cycling tests as exemplarily given in Figure 8 have been conducted. It has been confirmed that the combination of the new package technologies has enabled a 2.7-times improved power-cycling capability compared to the previous generation [15].

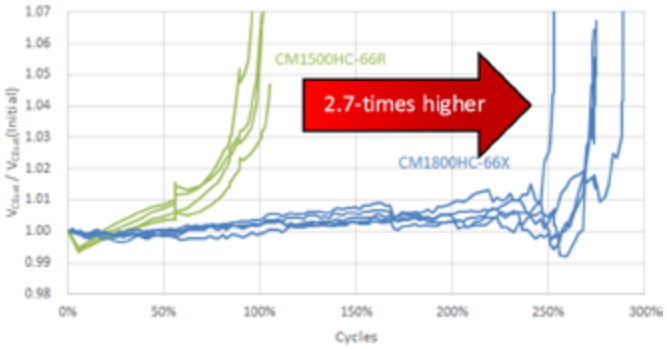


Figure 8: Power cycling confirmation test of 3.3 kV X-Series device and previous generation [15]

Humidity Robustness

In last decade, the impact of environmental factors like humidity, temperature and pollution on reliability of power devices has become a major topic for outdoor applications where such factors can't be controlled. In this chapter ruggedness of power device on humidity stress is described. The necessity of such ruggedness is described in [16] [17].

The silicone gel is the most popular encapsulation material in power devices. The presence of humidity in silicone gel and applying of relatively high voltages provoke building of dipoles, so called surface charges Q_{ss}. The amount of Q_{ss} has significant impact on efficiency of chip guard ring and finally on avalanche voltage. Figure 9 shows the relationship of surface charges and blocking voltage capability of 6.5 kV IGBT chip [18]. The reduction of voltage capability by humidity could lead to catastrophic and unpredicted failures which is to be avoided. The immunity against humidity could be reached by influencing of capsulation material, chip structure and passivation material [18]. The intrinsic immunity of power chip by designing of dedicated chips structure is the key step to minimize influence of humidity on reliability of power device. In 2015 MITSUBISHI ELECTRIC has proposed SCC technology (Surface Charge Control) [19]. Figure 10 shows the concept of SCC technology. It uses a semi insulation layer instead of an isolated layer under the passivation. This technology allows reduction of stray capacitance and plays an important role as carrier path. Under electrically biased conditions, carriers generated by the high electric field accumulate at the interface between the silicon surface and the semi-insulated layer as well as the conventional layer. However, the carriers are swept away through the optimized semi-insulated layer simultaneously as shown in Figure 10. There is the temperature dependences of the leakage current density. At room temperature, the SCC type has slightly higher leakage current density than the type without the SCC due to an additional leakage current through the semi-insulated layer. On the other hand, in the high temperature region the SCC type has the superior characteristics because the semi-insulated layer redistributes the electric field optimally in the edge termination area [19]. The verification of robustness degree could be done by test proposed in [18] (cf. Figure 11). This test provoke dew condensation which is the highest humidity stress within a power module. A new automatic condensation test approach was proposed by Mitsubishi Electric to perform the cycling condensation test more efficient using the humidity chamber [20]. This auto-

matic test is helpful to derive the acceleration factors between the field conditions and the hard qualification tests. Furthermore, the lifetime model was proposed in [21] in order understand the influence of humidity and temperature variation at certain humidity on degradation of power module.

Nowadays the reliability test combined three stress factors temperature, humidity and electrical field so called H3TRB is a standard high acceleration reliability test at MITSUBISHI ELECTRIC before releasing of HV power modules. Comparing the X-series with conventional design at 85°C/85%RH an improvement by more than 100 times was confirmed by testing. From these H3TRB test results an unprecedented robustness against 8000 condensation events under IEC 60721-3-5 5K2 reference conditions can be derived for the X-series [22].

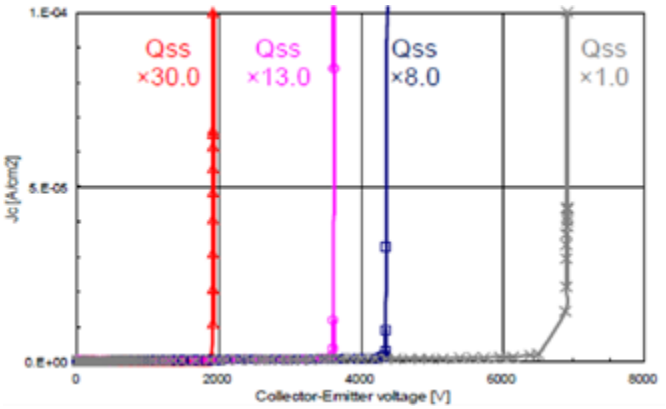


Figure 9: Relationship between surface charge Qss and blocking capability

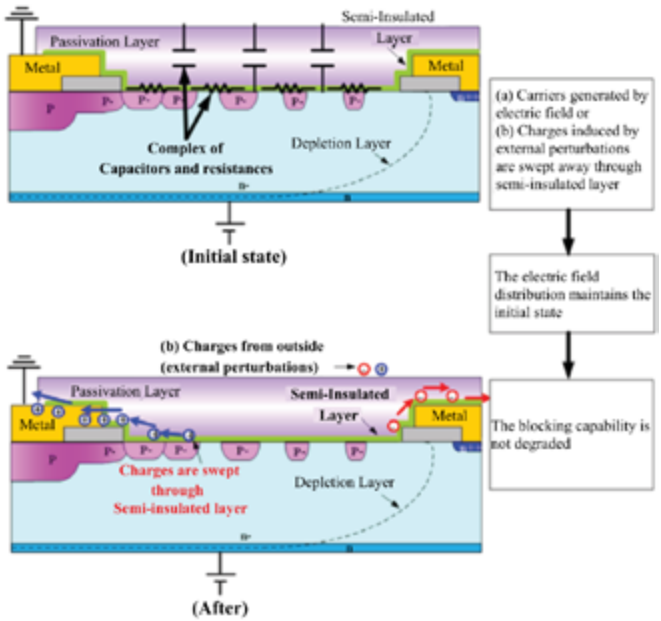


Figure 10: Concept of Surface Charge Control (SCC)

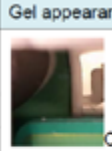
STEP	Item	Ta	RH	Time	Gel appearance
STEP0	I_{CES} measurement @ V_{CE}=5200V (DC)	25°C	50%	3 min	 Clear
STEP1	Storage	85°C	85%	36 hr	
STEP2	Cooling	25°C	50%	4 hr	
STEP3	Storage	25°C	50%	2 hr	 Foggy
STEP4	I_{CES} measurement @ V_{CE}=5200V (DC)	25°C	50%	3 min	

Figure 11: Condensation test procedure

Line-Up

The overview of X-Series power modules is given in Figure 12. The X-Series contains devices with blocking voltage ratings 1.7kV, 3.3kV, 4.5kV and 6.5kV. The focus in development priority is set on power modules with highest current ratings utilizing the package with the biggest footprint 140x190 mm². But also power devices in so called middle package 130x140mm² is developed. Now, at least power modules in two different packages with same current rating are available. This development is done based on thermal design consideration. Power devices according to Figure 12 have finished development and successfully passed all reliability tests. The test reports are available on request. All used packaging material are in line with European Railway Standard for Safety EN45545.

Product lineup

std type	1.7kV	3.3kV	4.5kV	6.5kV
	1600A* 2400A	1200A	900A 1000A	600A*
	2400A	1200A 1800A	900A* 1350A 1500A	600A* 900A 1000A

*Figure 12: Line up of X-Series HVIGBT power modules *Product under development*

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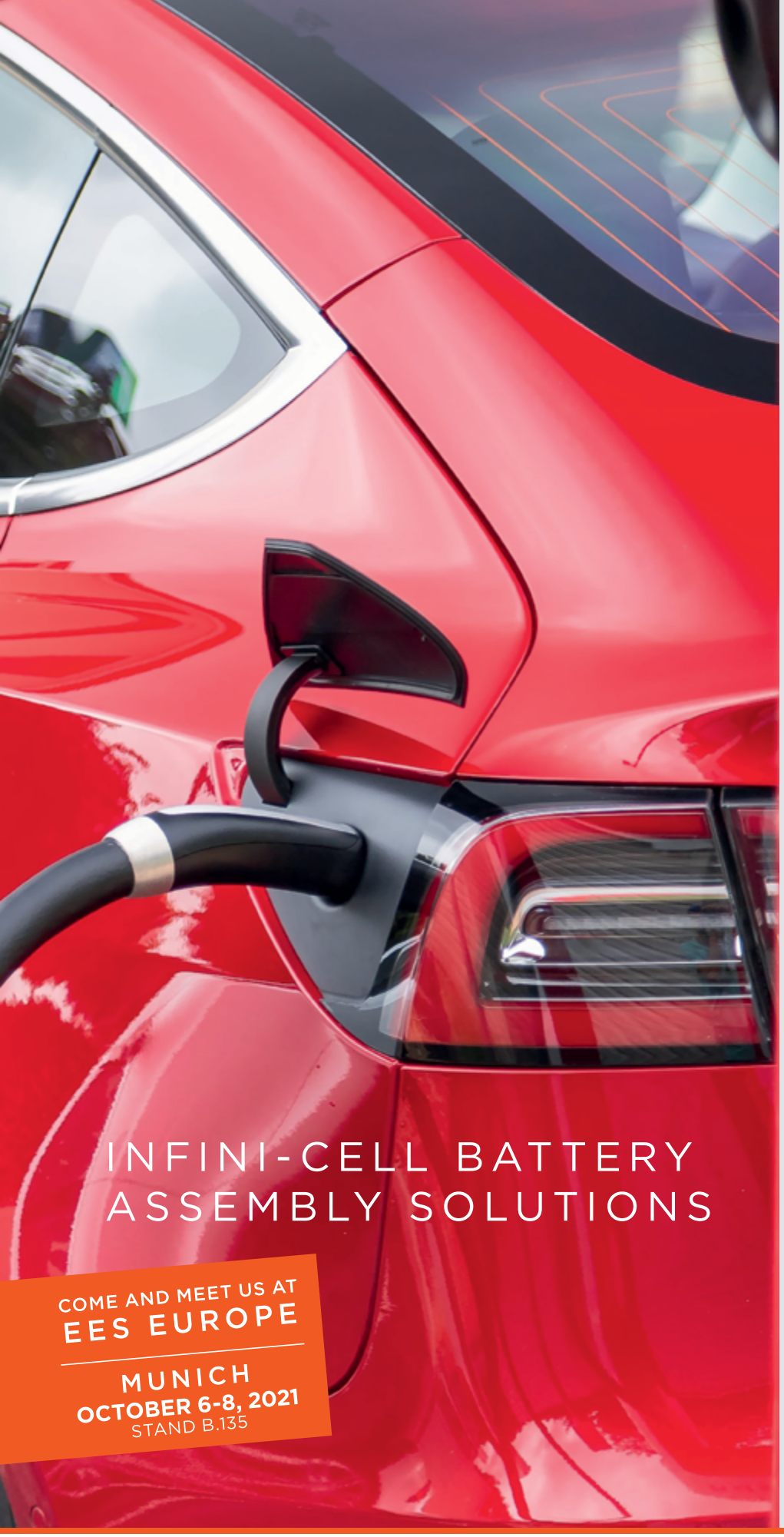

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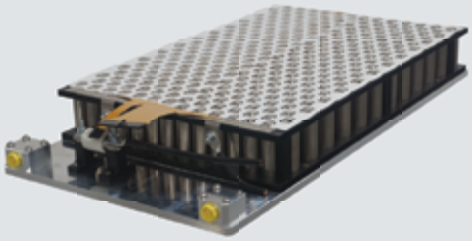

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GaN FETs Become the Technology of Choice for Audiophiles

Gallium nitride (GaN) FETs are becoming widely preferred in many products, from low power, low-cost applications such as smart device chargers all the way up to high power automotive applications. Mostly, designers are impressed by the increased efficiency and power density that GaN delivers, which results in devices that have greater power capabilities than their silicon counterparts.

By Ilian Bonov, GaN International Product Marketing Engineer, Nexperia

However, high-end audio amplifiers are also now increasingly turning to GaN technology as the smooth switching characteristics of GaN FETs result in less audible noise being injected into the amplifier. Recently, big name manufacturers of audio equipment including Technics (Panasonic) have all announced new audio equipment that contains GaN technology. GaN FETs can switch faster than their counterparts with higher efficiency, therefore equipment size can be minimized. Recent high-end audio products, for example, are now switching at 400kHz, whereas previous generation amplifiers switched at 100kHz.

But for audiophiles, the ultimate goal is a pure sound. This means that any audible noise which may be fed into the amplifier should be kept to as close to zero as possible. Usually, higher switching frequency results in higher levels of EMI and higher levels of audible noise – exactly the opposite of what audio companies are trying to achieve. Yet the characteristic switching behaviour of GaN FETs is different to silicon devices. Figure 1 compares the switching waveform for a typical silicon MOSFET (blue line) used in previous generation high-end audio equipment and that of a GaN FET device (red line) that Nexperia manufactures and sells into the same application today. We can see that although the performance of the MOSFET is well suited to the task, there is a high degree of ringing at turn-off and that the peak voltage of 505V is much higher than for the GaN device. The GaN part is much smoother, with a peak of only 420V.

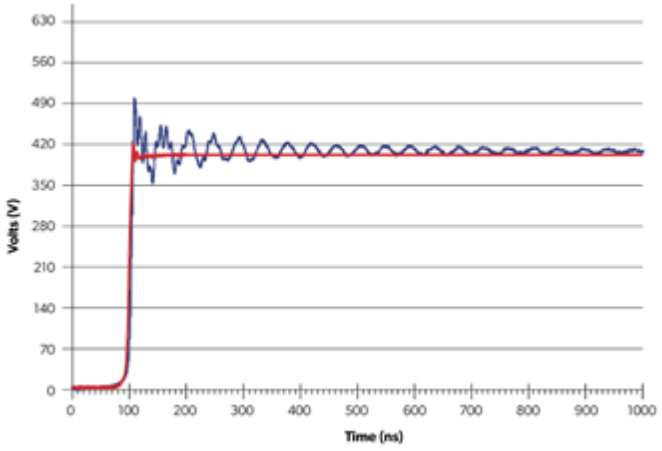

Figure 1: Switching Waveform for standard industry MOSFET (blue trace) and for a Nexperia 650V, 35mΩ GaN FET (red trace)

It should be noted that the silicon and the GaN devices are not exactly comparable, as they are different technologies, however, it is well established that the smooth switching that can be achieved with GaN FET devices results in significantly reduced noise – electrical and audible. A recent article in this publication, 'GaN Transistor Eliminates EMC at Source' by independent consultant engineer, Nigel Springett of Büro Springett (Bodo's Power Systems, January 2021) presents measured data showing a significant reduction in EMI – 10dB at 170kHz – achieved primarily by replacing a silicon MOSFET with a Nexperia GAN FET in a 3kW power supply design. While the noise spectrum of that design is very different to the audible frequency, the principal is the same.

Why is GaN switching 'smoother' with less ringing than silicon? In Nexperia's case, the answer lies in the design of the device. GaN HEMTs operate as a depletion mode FET with a naturally 'on' state. Most engineers prefer to work with naturally 'off' devices in switching applications due to safety and acceptability considerations. Currently there are two ways to deliver naturally "off" operation – single-chip enhancement mode (e-mode) or two-chip cascode mode devices. The gate structure of e-mode p-GaN HEMTs makes them very sensitive to gate drive voltage and they suffer from very low threshold voltages. They can also be difficult to drive. For these reasons, Nexperia prefers the stacked die cascode structure which pairs a low-voltage, low-$R_{DS(on)}$ MOSFET in series to the naturally 'on' GaN HEMT device (Figure 2). This configuration provides the robust and reliable insulated (dielectric) gate structure of a silicon gate, coupled with the improved voltage blocking characteristics of a high voltage GaN HEMT, effectively combining the benefits of the naturally 'on' operational state of a GaN HEMT with the safety and operational benefits of a naturally 'off' device. Even better is that the cascode device can be driven by standard cost-effective gate driver with simple 0-10 or 12 V drive voltage.

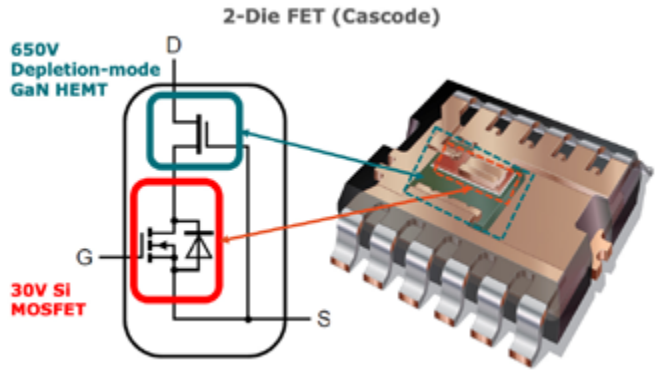

Figure 2: Nexperia's cascode GaN FET configuration is robust and easy to drive

For the purposes of our discussion on noise – both audible for the high-performance audio amplifiers and EMI for the power supply example – the cascode structure offers additional benefits. Nexperia closely matches the capacitances of the low voltage silicon MOSFET and the GaN HEMT, with the silicon device acting like a filter, resulting in the smooth waveform. This capacitance matching is discussed in detail in a Nexperia paper entitled 'Reliability and Performance Related to Internal Avalanche of GaN Cascode Devices' by Yifeng Wu of Transphorm and Yan Lai from Nexperia.

Switching power supplies have excellent instantaneous power supply capabilities and can achieve powerful sound, which are both attributes that suit high end audio applications. However, traditionally they have been viewed negatively because they generate noise due to switching operations. Higher switching speeds were also a problem for the same reason. Now, GaN switches with their smoother switching are enabling audio equipment manufacturers to rethink. Figure 3 is a representation of real data provided by one leading manufacturer which is now using GaN switches, and has increased the switching speed of its latest products to 400kHz – previous silicon-based amplifiers were limited to 100kHz.

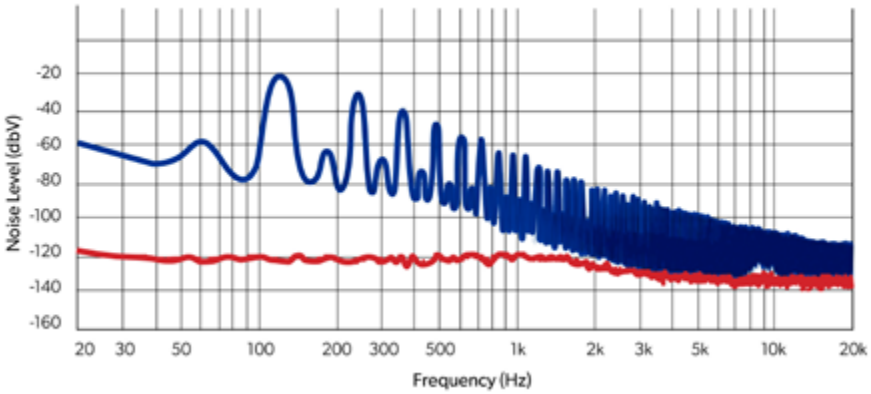

Figure 3: A comparison of audible noise for previous generation silicon powered audio equipment (blue) versus the new GaN powered products (red).

The noise produced by the GaN power supplies in the new amplifiers (orange line) is considerably less than that of the older generation products (blue line) across the entire audible spectrum from 20Hz to 20kHz. The company employs a wide-band, low-noise reference voltage generation circuit and a control circuit in the new design. This ensures stable gain and achieves ultra-low noise characteristics that are flat down to low frequencies.

Summary

Nexperia's industrialization of GaN has been extremely rapid. In the three years that Nexperia has been actively selling GaN devices, the company has moved from an initial launch position having 650V transistors with an $R_{DS(on)}$ of 50mΩ, to current devices which are rated at 35mΩ, and very shortly, 12mΩ parts will be available. Also, Nexperia – a leader on packaging technology - will shortly be offering GAN devices in CCPAK1212, a high-performance SMD package designed for GaN. Such devices bring obvious benefits of efficiency and power, but their smooth switching performance – optimized for efficiency – also means that they are an ideal solution for low noise applications too.

Readers can watch the GaN FET technology in action presentation and speak to experts at Nexperia's online Power Live Event: 21 – 23 September www.nexperia.com/power-live

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A Line of Products for Electric Vehicles

Everybody is talking about electric vehicles nowadays. The huge potential for this industry also means stringent requirements for the electronic components used in the vehicles. Manufacturers are therefore well advised to procure as many products as possible from a single source – the best way to ensure optimal compatibility and integration.

By Simon Landrivon, Marketing Communications Projects Manager, Europe
MERSEN ELECTRICAL POWER

As a global supplier of passive electronic components, Mersen offers numerous product lines that are ideal for the special requirements of the electric vehicle (EV) market: DC fuses, laminated busbars, cooling solutions and, last but not least, film capacitors and electrolytic capacitors.

Products from Mersen are installed at numerous locations in an electric vehicle: Laminated busbars, for example, are needed in the battery modules, battery packs inverters and charging stations. Mersen already has more than 65 years of experience in the development, production and testing of components in this product area. A global research and development department, extensive in-house production capacities with IATF certification, and a large supplier network ensure fulfillment of even the most complex customer requirements.

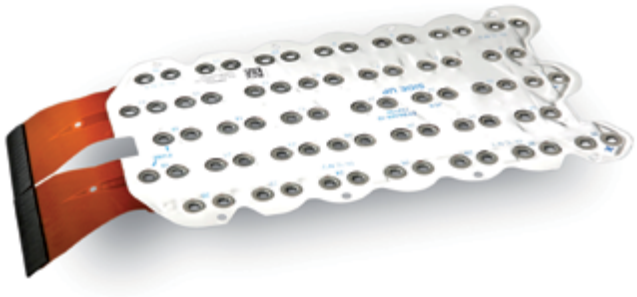

Figure 1: Laminated busbars as a modular component are ideal for low inductance and high temperatures. Image © Mersen

Laminated busbars – as a modular component, ideal for low inductance and high temperatures

In cooperation with F & K DELVOTEC, Mersen developed the standardized battery cell connection platform "Infini∞cell" especially for use in electric vehicles. The modular solution comprises an ultra-thin single-layer overlapping laminated busbar with intelligent voltage and temperature monitoring, which is designed for easy installation at affordable cost and features good resistance to shocks and vibrations, as well as improved current-carrying and thermal capacity. A proprietary laser welding process makes the mounting process four times faster than conventional wire or ribbon bonding.

In addition, the laminated busbars of the MHi-T105, MHi-T130 and MHi-T180 series are suitable for use in electric vehicles and charging stations. The optimal material properties of these high-temperature solutions enable use at temperatures up to 180 °C, which makes them ideal for the handling of silicon carbide (SiC) electronic components with low inductance needs.

Low-inductance capacitor banks with a high capacity

Since 2018, the capacitor manufacturer FTCAP has been part of the Mersen Group – and since then the group has placed a special focus on the development of solutions with integrated capacitors and laminated busbars. A good example is the FischerLink 2.0 capacitor bank: It consists of foil capacitors that are laser welded to a laminated high-temperature busbar of the MHi-T series with low inductance. Due to its well thought-out design the FischerLink 2.0 achieves 20 percent higher capacitance than comparable capacitor banks of the same height. The FischerLink 2.0 also features extremely low inductance of <9 nH.

Figure 3: FischerLink 2.0 capacitor banks represent an innovation in the area of capacitors. Image © Mersen

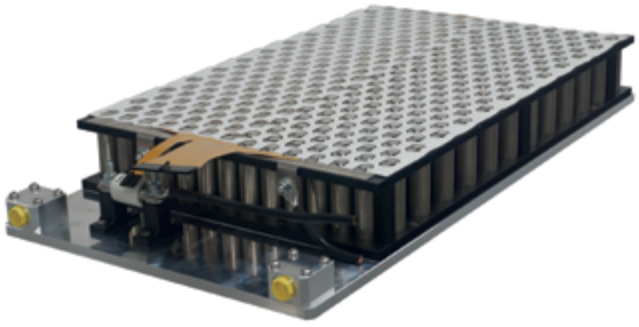

Figure 2: Mersen developed the standardized Infini∞cell battery platform in cooperation with F & K DELVOTEC for use in electric vehicles and as a battery bank. Image © Mersen

Figure 4: Mersen's EVpack fuses for battery packs fulfill the special requirements of hybrid and electric vehicles, as well as battery banks. Image © Mersen

In electric vehicles, capacitors are generally used for generating the power for the electric motors and for improving EMC. Another important application is high-voltage DC link capacitors, in which there is a mechanical connection between the capacitor and the IGBT in a modular design. Above all, these capacitors must feature high resistance to temperatures and a high current-carrying capacity. Mersen has already developed numerous innovative projects, such as a capacitor that is specially designed to fit in the space around the wheel hub in a wheel hub motor. The company is working on both a new film capacitor as well as aluminum electrolytic capacitors for this industry.

Components for DC protection up to 1,000 VDC

Mersen's EVpack fuses for battery packs and M fuses for battery modules fulfill the special requirements of hybrid and electric vehicles, as well as battery packs. With extensive protection from 100 to 1,000 VDC and up to 800 A, they ensure a minimum breaking capacity adapted to perfectly interact with DC switching gear.

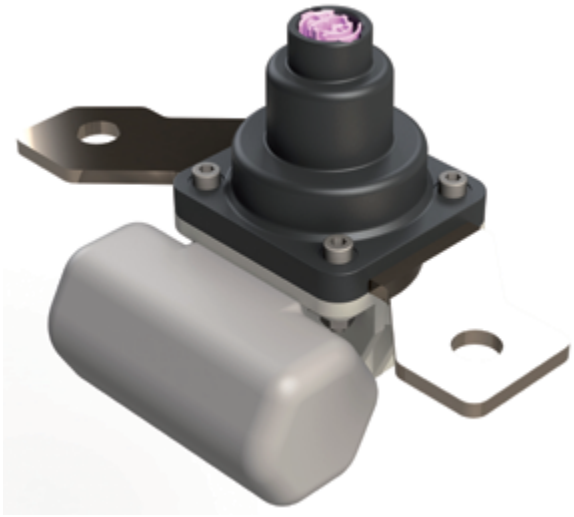

Figure 5: The hybrid pyro fuses of the Xp series were specially developed to protect critical direct current applications in electric vehicles. Image © Mersen

Figure 6: Mersen offers flexible cooling solutions – the picture shows a 7mm thick AL vaccuum brazed liquid cold plate for battery cooling. Image © Mersen

A product highlight is the MEV50A series. It ensures a low minimum breaking capacity (4xIn or 2 kA), high breaking capacity of 30 kA for all battery types, and optimal energy efficiency with low power losses. In addition, the solution features excellent cycle capability and conforms to ISO 8820 and international electrical standards. EV fuses are available in five compact sizes, and the design can be individually adapted.

The hybrid pyro fuses of the Xp series were specially developed to protect critical direct current applications in electric vehicles. The compact, solid solutions are based on a cost-effective technology. They minimize power losses, provide very fast acting protection of less than 1ms, and operate with both high and low fault currents. The latter is a unique selling proposition, since the expanded protection in the range of smaller currents allows complete cooperation between the pyro fuse and the electric contactor. The reason: From a purely theoretical point of view, these components should operate together within the EV battery protection concept, regardless of the current and voltage ratios. In reality, however, there is often a gray zone – but not with pyro fuses from Mersen.

Liquid cooling solutions for the latest IGBT and SiC generations

Mersen offers solutions on the basis of three cooling technologies: Air-cooled, phase switching and liquid heat sinks cover a broad range of applications. The modular solution IsoMAXX, for example, is a liquid heat sink. It improves thermal management in the latest generation of IGBT and SiC power modules and is designed for a lower pressure drop than regular heat-sink plates. The compact design allows flexible adaptation to the number of modules on the plate.

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How Lightweight 5G is Made Possible by GaN

With the launch of 5G, this next generation cellular network promises a trilogy of capabilities that will change how we approach wireless applications. Offering massive connectivity, tremendous throughput, and ultra-low latency, many applications will, at last, be able to ditch the wire.

By Giuseppe Bernacchia, Senior Principal Application Engineer and Moshe Domb, Director Application Engineering at Infineon Technologies

While businesses and consumers await rollout in their regions to benefit from 5G, network operators must carefully assess how to install the required hardware. Today's equipment often uses rented sites and properties with strict limits set on floor area, volume, and allowable weight. Furthermore, 5G makes use of additional equipment compared to 4G, such as active antenna systems (AAS) and micro base transceiver stations (BTS), to implement the coverage needed for massive connectivity (Figure 1). Available power at such sites can be limited too, restricting what can be installed. Since rental costs make up around one-third of the operating expense (OPEX) outlay, 5G systems need to do more than the 4G systems they replace while being the same or lighter in weight and smaller in volume.

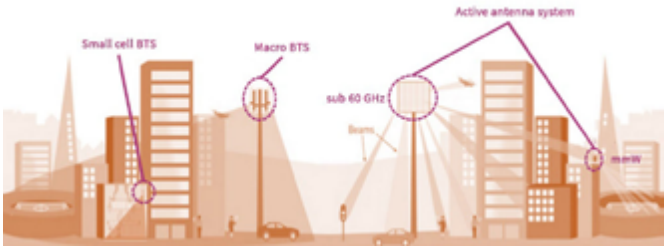


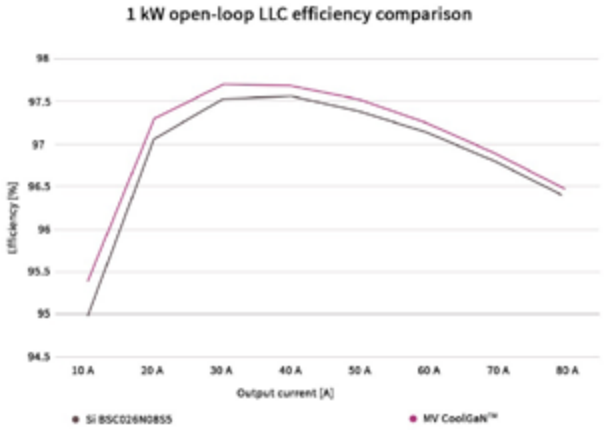
Figure 1: Massive connectivity requires small cell BTS and active antenna systems, all of which have demanding power requirements.

Power switching from silicon to GaN

Gallium nitride (GaN) wide-bandgap transistors are already contributing to the radio-side of 5G, but they are increasingly being considered for the power supplies too. Its superior performance when compared to silicon MOSFETs translates to improved efficiency, leading to reduced heat dissipation, smaller, more compact designs, and improved robustness. Telecom operators benefit by consuming less energy and needing fewer on-site visits to service and repair equipment.

Relatively temperature-independent $R_{DS(ON)}$ coupled with almost no reverse recovery charge (Q_{rr}) mean that GaN high-electron-mobility transistors (HEMT) are suited to both power factor correction (PFC) and DC-DC converter stages. Thanks to the higher switching frequencies supported, smaller passives can also be used, delivering designs that are both compact and lighter in weight than silicon-based alternatives. A move to natural convection, instead of forced-air cooling, can often be considered too.

Power converters based upon silicon MOSFETs, such as the 80 V OptiMOS™ 5 series, are a staple of 1 kW 48 V to 12 V DC-DC ¼ brick designs, delivering peak efficiencies of 97.58 %. By moving such a design to CoolGaN™, the same 1 kW LLC solution achieved a 5 % reduction in heat and peak efficiency of 97.70 % (Figure 2). The efficiency improvement achieved at light loads can be attributed to the move to GaN. Conduction losses are the primarily contributor at full load, so the move to GaN has little impact on efficiency at the highest current consumption.



Output current	Efficiency 1 kW LLC with Si MOSFET (BSC026N08S5)	Efficiency 1 kW LLC with MV CoolGaN™
10 A	94.97	95.38
20 A	97.07	97.28
30 A	97.54	97.69
40 A	97.58	97.70
50 A	97.41	97.53
60 A	97.16	97.25
70 A	96.81	96.90
80 A	96.40	96.46

Figure 2: Efficiency comparison of a 1 kW fixed-frequency 48 V to 12 V ¼ brick DC-DC LLC when using silicon MOSFETs and CoolGaN™.

Replacing silicon MOSFETs with CoolGaN™ in a 3.6 kW, 385 V to 52 V DC-DC LLC delivers even more significant improvements, even when the PFC is already GaN-based. By moving the two synchronous rectifier stages to GaN, heat dissipation was reduced by some 15 %. Despite both devices exhibiting similar $R_{DS(ON)}$ values, the supply attained a peak efficiency of 97.83 % in this 160 W/inch3 design (Figure 3). Subtracting the impact of the housekeeping supply and cooling fan, the peak efficiency almost touches 98.5 %.

Gate drivers and packaging

The move away from silicon requires more than just replacing the MOSFETs. CoolGaN™ requires a different gate drive circuit that can be implemented using an RC-coupled circuit. However, this can suffer from the impact of varying gate duty cycles and, under some circumstances, a lack of negative drive. Infineon offers an EiceDRIVER™ series dedicated to GaN HEMT that delivers the continuous gate current needed to maintain the "on" state, as well as a duty-cycle-independent "off" voltage.

I_{load}	Efficiency 3.6 kW LLC with Si MOSFET (BSC026N08S5)	Efficiency 3.6 kW LLC with MV CoolGaN™
7 A	92.9	93.9
14 A	95.85	96.4
25 A	97.1	97.47
34 A	97.43	97.74
48 A	97.55	97.83
55 A	97.54	97.8
68 A	96.37	97.7

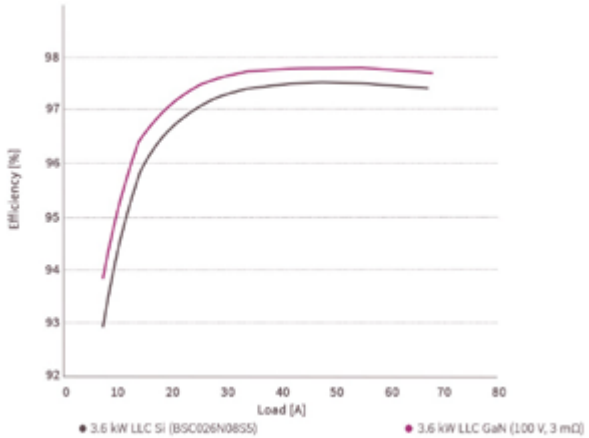


Figure 3: Efficiency comparison of CoolGaN™ in a 3.6 kW DC-DC LLC versus silicon MOSFETs.

New power supply housings and innovation in heat extraction are also needed to reduce equipment weight and provide alternative installation approaches, such as in street lighting, that are aesthetically pleasing. CoolGaN™ supports this thanks to its low inductance, low-profile PG-VSON surface mount packaging (Figure 4). Measuring just 5 × 3 × 1.075 mm, not only does it help with passive heat dissipation approaches in narrow, low-profile, and rack-mounted designs, it also helps to keep traces short and their inductance low.

Figure 4: The PG-VSON surface mount package of the medium voltage CoolGaN™ device, with its low inductance leakage, is ideal for high-frequency switching applications.*

GaNs' broader impact on 5G

Due to its performance at high frequencies, GaN is often linked with the implementation of 5G RF transceivers. However, due to the pressures on equipment volume and weight caused by the cost of site rental and physical restrictions, it is also exceptionally relevant for base station power supplies. Infineon's portfolio of CoolGaN™ HEMT transistors, ably supported by matching EiceDRIVER™s, ensure these design goals for 5G can also be met while also improving efficiency and reliability.

www.infineon.com/gan

* samples of the medium voltage CoolGaN™ device in PG-VSON SMD package are already available.

How to Empower Automotive DC Fast-Charging with Advanced Current Sensing

Although range anxiety is disappearing from the short list of objections to EV adoption, it has been replaced by recharging speed angst. For the demanding consumer marketplace, fast DC charging systems are emerging as the preferable way to go.

By Michael DiGangi, Executive VP, ACEINNA

While the adoption curve for electric vehicles (EVs) is constantly changing for the better, the automotive industry is dealing with the remaining driving-range anxiety and battery-life fear.

Through improved EV electronics such as power management and motor control, along with increased energy storage densities, the automotive industry has gone far to alleviate range and capacity concerns. There are still reasonable concerns behind EV charging times. This is why it is critical that the EV industry fields advanced fast battery-charging systems and make them available to the public.

Faster charging will increase EV adoption, as it directly addresses perceived user aggravations. It is also financially lucrative, as the EV charging market is growing rapidly, with installations expected to surpass 9 million units by 2025. In 2019 the EV charger market was approximately $4 billion, and should reach $25.5 billion by 2027 (https://www.alliedmarketresearch.com/). The Electric Vehicle Charging Station market worldwide is projected to grow to 30,758,000 units by 2027. There are several methodologies available when it comes to charging EVs. Highway and city charging stations are currently being deployed, but the ability to charge at home is a major market trend. Most individual passenger cars remain parked overnight, making home charging easier and often cheaper than charging elsewhere. However, even home charging situations can demand short daytime recharging, if only for other family member vehicles and visitors.

Charging types

The most common wall-plug chargers are known as Level 1 and Level 2 systems. Since EV batteries are charged with a DC current, a conversion stage is needed. Using an onboard AC charger is more affordable in some deployments, because in-vehicle power conversion stages replace any needed in-house charging systems. However, in-car conversion circuitry limits power capacity and charging time (see figure 1).

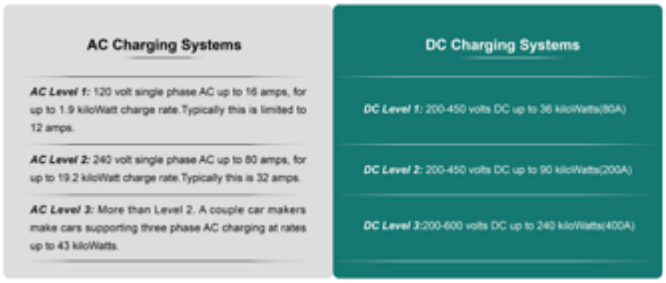


Figure 1: Various levels of AC and DC Electric vehicle Charging Systems.

Level 3 DC fast charging is available in higher voltages and can charge some plug-in electric vehicles with up to 800 volts, allowing for very rapid charging. This solution is best for residential and business buildings as well as facilities due to cost. For most household deployments, high-power Level 2 systems, currently operating at levels of up to 50 Amps, are turning out to be the best mainstream solution.

In-home DC fast-charging systems are becoming a significant part of the growing electrical mobility infrastructure. When developing consumer-oriented capital goods, longevity and reliability compete with cost-effectiveness in the buying decision. Cost-effectively improving the efficiency, safety, and performance of the power conversion system increases consumer acceptance. The four aspects of a power conversion system involve measuring the current, ensuring tight power-factor correction, frequency management, and addressing thermal issues. Each leverages one another to impact the overall performance of the system.

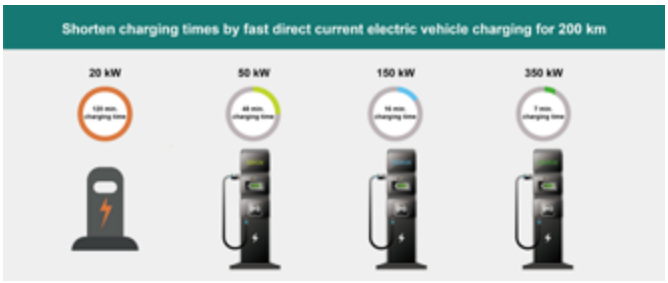


Figure 2: Fast DC Car Charging Systems greatly decreases the amount of time required to charge an electric vehicle and get it back on the road.

Current measurement

Beyond determining power output, current measurement can also help manage thermal performance. Poor thermal management is destructive and costly, and when properly done can significantly increase performance, safety, and cost-effectiveness. Current measurement provides, among other things, early fault detection and real-time performance information. Many power systems require an indication of an out-of-range current condition, or an overcurrent condition, or other loss of performance, to predict and address potential thermal issues. Dangers to power electronics' performance, and thereby system thermal issues, range from ground faults and short-circuits to operating at extreme power levels and at loading conditions beyond the system's capability to support. Current sensors in charging systems are deployed in each converter module in a charging system, as part of the feedback control-loop function regulating the performance, efficiency, and thermal linearity of the power systems in inverters.

When it comes to current-sensing in power systems, an integrated sensing solution offers significant footprint savings over board-assembled solutions using an op-amp and comparator. The size of a non-integrated implementation will vary depending on the actual components chosen, but it will be larger than a single-package solution. If we use a traditional component package size for devices of this type, around 2~3 mm, this leads to solution footprints dozens of millimeters in size.

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Overcurrent detection

By definition, current measurement is a key aspect of over-and undercurrent protection against damage in electronic systems. At the speeds, power levels, and always-on aspect of modern systems, fuses are no longer adequate in any manner for advanced power products except to prevent catastrophic failure. Using a fuse for protection doesn't give you any information on the actual performance of the power system beyond cutting the power in an overcurrent situation. Using a current sensor, overcurrent detection response can be optimized for a given application. Circuit protection and safety of the overall system is paramount, and current-sensing solutions like ACEINNA's are well suited for overcurrent detection, due to their very fast response and large current measurement range. Being isolated, they can be used on both the high and low sides of the circuit.

Integration of aspects such as isolation, along with the core Anisotropic Magneto-Resistive (AMR) technology, create sensors that are precise and contactless. This manner of current sensing optimizes performance and enables temperature correction, reducing the complexity of the customer design compared to a shunt plus isolated amplifier solution. Additionally, by using a device such as the ACEINNA current sensor on the high side, the ground fault of the phase current could be detected (possibly due to wrong wiring, aging etc.), and the overall system could be protected. Power quality is essential for efficient operation, and the power factor is a big part of it. Power factor measures the efficiency of incoming power used, and is a ratio of active to apparent power. If you have a bad power factor, less than 95% for example, it results in more current needed to do the same work. Power factor correction (PFC) improves that ratio and the power quality. PFC reduces grid stress, increases device energy efficiency, and reduces electricity costs, while reducing instability and risk of system failure.

Producing reactive energy in opposition to the energy absorbed by loads such as battery chargers, close to the load, improves the power factor, with the ideal compensation applied at the point of load, at the needed level in real time. Using a current sensor on PFC equipment on the low voltage side improves the power available. When it comes to harmonic distortion, PFC is necessary in the AC/DC inverter front end, and most of the time, isolation between the primary and secondary side of the AC/DC front end module is required, ACEINNA's current sensors not only simplify the overall system design, but reduce the cost of implementation.

Switching frequency

With the increasing demand for higher performance, CPUs, DSPs, and other such devices are growing more power-hungry. Increasing the regulator frequency reduces the size and board footprint requirements of the power circuit involved while increasing power density. However, as frequency increases, so do switching losses, mostly due to high-side losses during turn on, as well as body-diode conduction losses. This forces limits on the switching frequency of conventional converters and regulators.

Current measurement in advanced fast-switching circuits is required to track the currents in real-time for the highest efficiency possible. Intelligent current measurement is also required in AI and machine learning to create a control algorithm for better performance. ACEINNA's high accuracy and high bandwidth current solutions increase the efficiency of the system while simplifying the current control design, due to its high phase margin.

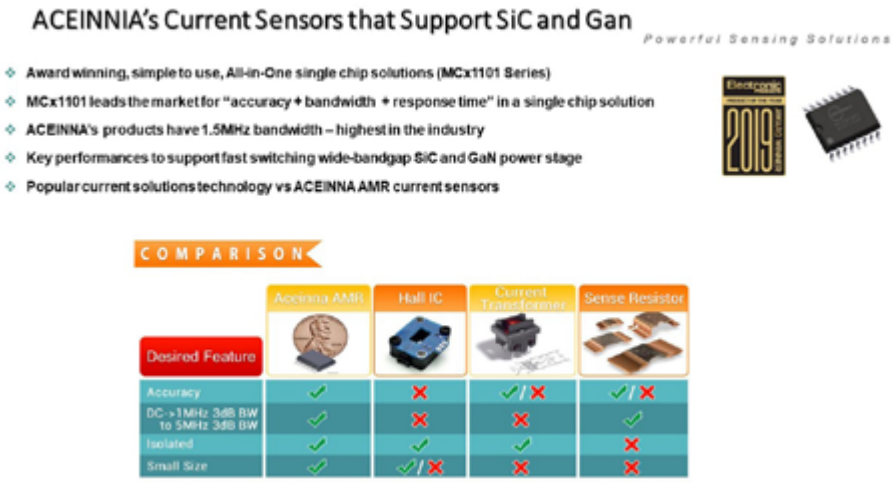

Figure 4: ACEINNIAs Current Sensors that Support SiC and GaN.

Driving forward

The market for fast recharging systems to accelerate EV adoption and market viability, requires advanced, efficient, and cost-effective charging solutions. Fast DC charging is one of the more preferable forms of EV replenishment, and by using advanced current sensing to optimize such systems, will ensure product success in the rapidly growing EV charging marketplace.

www.aceinna.com/current-sensors

Figure 3: In addition to electric vehicles, tiny current sensors are used in a wide variety of applications.

About the Author

Mr. Michael DiGangi has been appointed Executive Vice President and is responsible for ACEINNA's worldwide sales efforts. He brings with him over 26 years of Power and Analog IC semiconductor sales, business development and marketing experience spanning a number of larger corporations and start up's.

Prior to joining ACEINNA, Mr. DiGangi was VP of Sales and Marketing for two startup SiC Power Semiconductor makers. Previously, he was Vice President of Worldwide Sales and Marketing at Allegro Micro Systems. Mr. DiGangi also was at International Rectifier, now Infineon, during the formidable growth of the company, with responsibilities as Vice President of Sales and number of senior sales and marketing management roles. He has a BS. and an M.B.A from Wilmington University.

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Trench Schottky Rectifiers Reduce Trade-Offs and Deliver Increased Performance

Schottky diodes feature a low forward voltage drop and high switching speed suiting them to a wide variety of applications, such as a boost diode in power conversion circuits. However, there have been trade-offs concerning forward voltage drop, the leakage current, and the reverse blocking voltage.

By Dr.-Ing. Reza Behtash, Applications Marketing Manager, Nexperia

Today, Trench Schottkys address this challenge and provide greater capabilities than their original planar counterparts, reducing switching losses, and delivering a wider SOA and lower Q_{rr}.

Schottky trade-offs

The ideal rectifier would have a low forward voltage drop, a high reverse blocking voltage, zero leakage current and a low parasitic capacitance, facilitating a high switching speed. When considering the forward voltage drop there are two main elements: the voltage drop across the junction – PN junction in case of PN rectifiers and metal-semiconductor junction in case of Schottky rectifiers; and the voltage drop across the drift region. While the forward voltage drop across a PN junction is intrinsically determined by the built-in voltage and hence, mainly by the specified semiconductor material, the forward voltage drop across the metal-semiconductor interface in a Schottky barrier rectifier can be modified by the choice of the Schottky metal, with the Schottky barrier being the result of the difference between the metal work (MW) function and the electron affinity of the semiconductor.

By using Schottky metals with a low MW function, the voltage drop across the metal semiconductor interface can be minimized. However, there is a trade-off between the forward voltage drop across the junction and the leakage current of the Schottky rectifier, as the level of the leakage current is also determined by the Schottky barrier and the electrical field across the metal-semiconductor interface. Also, the advantage of the low voltage drop across the junction can disappear when the thickness of the drift region is increased to achieve a high reverse blocking voltage. This is why the reverse blocking voltage of Schottky rectifiers is traditionally limited to less than 200 V.

Trench technology

The challenge, therefore, is how to preserve the low voltage drop across the metal semiconductor interface given the demand for a low leakage current and a high reverse blocking voltage? Here, Trench rectifiers prove very useful. The concept behind the Trench Schottky rectifier is termed 'RESURF' (reduced surface field). The RESURF effect is illustrated in Figure 1. In a planar Schottky rectifier the equipotential lines are concentrated close the top electrode, resulting in a high electrical field near the surface. This results in a strong increase of the leakage current with increasing reverse voltage, and an early breakdown when the critical electrical field is exceeded near the surface.

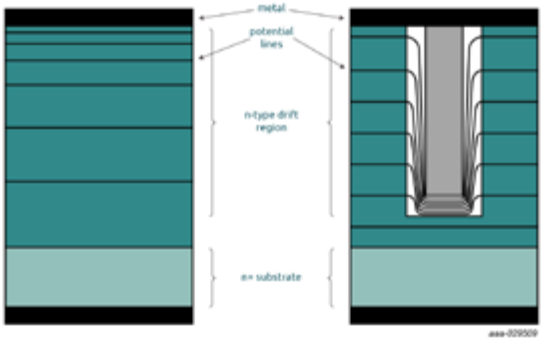


Figure 1: Equipotential lines in a planar Schottky rectifier (left) and in a Trench Schottky rectifier (right) in reverse direction.

By etching trenches into the silicon and filling them with poly-silicon – electrically separated from the drift region by a thin dielectric – the trenches act like a field plate in the semiconductor, depleting the drift region in reverse direction and resulting in a flattened electrical field profile along the drift region. Therefore, the trench structure achieves a lower leakage current by reducing the electrical field near the surface and producing a higher breakdown voltage compared to a planar device with the same epitaxial structure.

At Nexperia, a portfolio of Trench Schottky rectifiers has been developed and launched with a voltage range of 45-100 V (PMEG*T family). These devices achieve a well-balanced trade-off between the forward voltage drop (V_f) and the leakage current (I_R). As an example, the V_f / I_R trade-off for 60 V products is shown in Figure 2. In this figure, the leakage current at maximum reverse voltage is plotted against the forward voltage drop at maximum forward current at 125°C. For comparison, Trench and planar Schottky rectifiers from two other manufacturers are shown in this graph. For a given forward voltage drop, the Nexperia device exhibits the lowest leakage current.

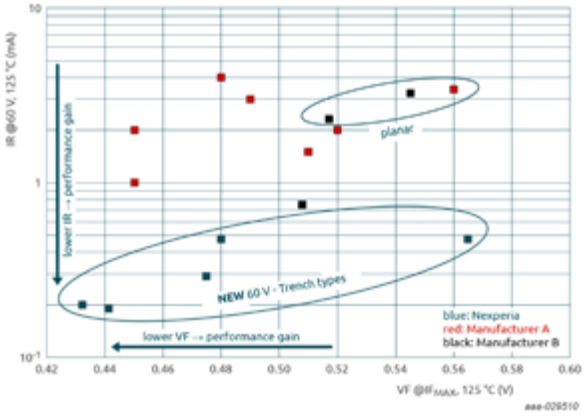


Figure 2: V_f / I_R trade-off at maximum reverse voltage and maximum forward current at 125°C.

Wide safe operating area (SOA)

The lower leakage current of Trench Schottky rectifiers compared to their equivalent planar counterparts with comparable forward voltage drop shows the Trench devices have a wider safe operating area (SOA). SOA plots the maximum reverse voltage that can be applied against the junction temperature. As well as the intrinsic SOA advantages offered by Trench rectifiers compared to planar Schottkys, Nexperia Trench products have additionally been designed

with special attention to creating a wide SOA. Figure 3 shows the SOA at a thermal system resistance (Rth(j-a)) of 90 K/W of a Trench Schottky (PMEG100T080ELPE - orange line) versus a similarly-rated Trench Schottky device from another supplier (blue). At 125°C junction temperature the maximum allowable reverse voltage of the Nexperia Trench device is almost 40 V higher than the competitor's Trench product.

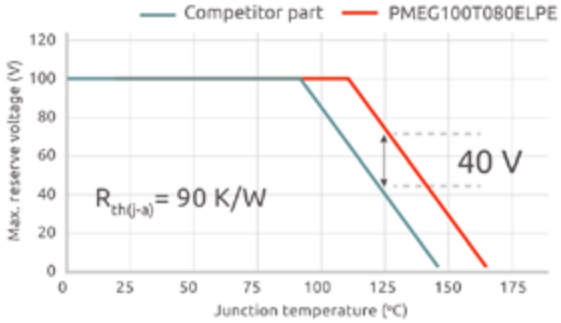


Figure 3: Comparison of safe operating area of Nexperia's PMEG-100T080ELPE Trench Schottky versus a Trench Schottky part from a competitor.

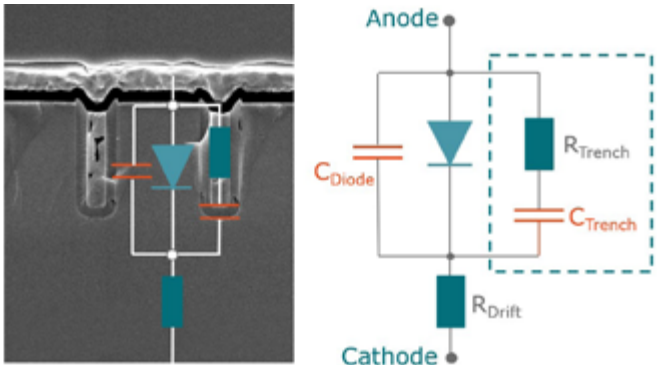
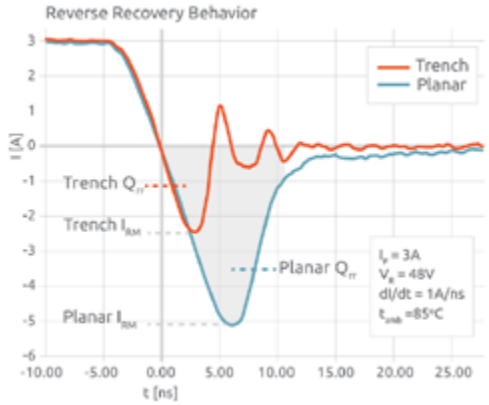


Figure 4: Cross section and equivalent circuit diagram of a Trench Schottky rectifier, highlighting the circuit elements.

Therefore, in applications where higher ambient temperatures will be experienced such as automotive, Trench Schottky rectifiers are a suitable choice since they are more robust against thermal runaway (the instability that occurs when the increase of the dissipated power caused by the leakage current of the rectifier is faster than the heat dissipation through the thermal resistance of the system).

shown in Figure 4. Besides the usual parasitic capacitance of the Schottky diode, C_{DIODE}, there is a second parasitic capacitance caused by the electrode and the thin dielectric in the Trench structures, C_{TRENCH}. This means that per unit area the total parasitic capacitance of a Trench Schottky rectifier is higher than its planar counterpart.

However, C_{TRENCH} does not affect the diode switching characteristics or EMI; in fact, Trench rectifiers have less stored charge, Q_{rr}, and show an excellent switching performance when compared to planar Schottkys despite this overall larger parasitic capacitance.



	Q_{rr} (T=25°C)	Q_{rr} (T=85°C)	I_{RM} (T=25°C)	I_{RM} (T=25°C)
Trench Schottky	*8.6 nC*	*8.5 nC*	*2.8 A*	*2.7 A*
Planar Schottky	*26.3 nC*	*33.5 nC*	*5.2 A*	*5.2 A*

Figure 5: Reverse recovery behaviour of Trench and planar Schottkys.

Reverse Recovery Behaviour and Q_{RR}

The switching behaviour of a device is characterized by reverse recovery measurements. Such measurements are carried out by biasing the rectifier in a forward direction, then switching the device into a reverse condition. Due to the stored charge in the device (represented by the parasitic capacitance, C_{Diode}, in the equivalent

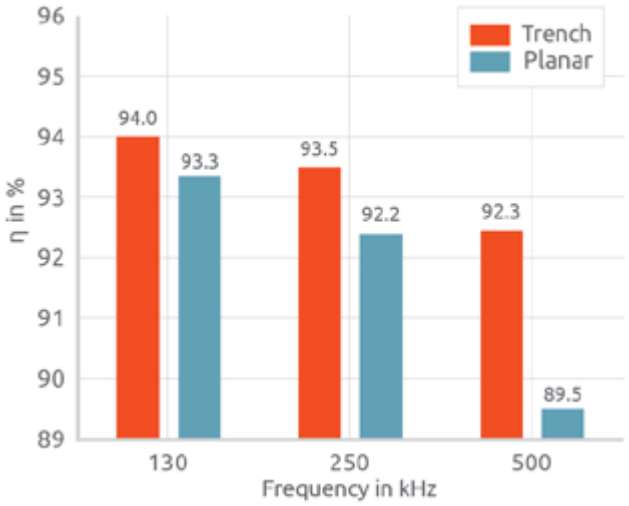


Figure 6: Trench Schottky rectifiers deliver significant converter efficiency benefits, especially at higher frequencies where their switching losses are less than planar devices.

circuit, Figure 4) which must be first removed before the diode blocks, a so-called reverse recovery current of the rectifier occurs. The ramp reverse recovery measurement for a Trench Schottky rectifier and its planar counterpart with comparable die size and package is shown in Figure 5.

In this measurement, the current has been ramped down with a di/dit rate of 1 A/ns. The area under the zero line represents the Q_{rr} of the rectifier. The blue line shows the lower Q_{rr} of the Trench device.

The graph also shows the lower reverse recovery current and the shorter reverse recovery time of the Trench rectifier compared to its planar counterpart (despite its higher parasitic capacitance, as discussed earlier). The temperature stability of Q_{rr} for Trench rectifiers is particularly notable, since applications very rarely operate at 25°C. As shown in Figure 5, the Q_{rr} of the Trench rectifier barely changes at an elevated 85°C ambient temperature while the Q_{rr} of a planar Schottky increases significantly.

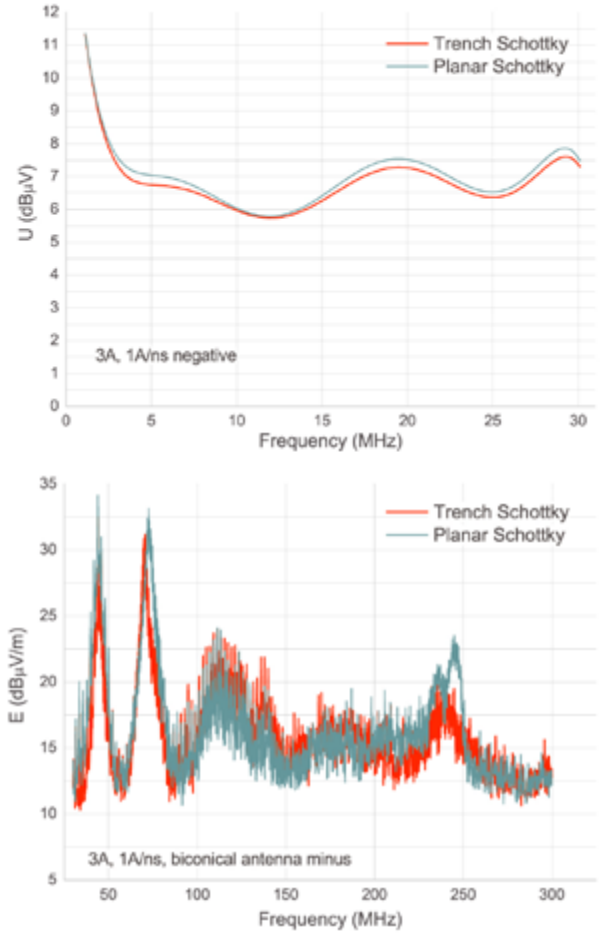


Figure 7: Impact on electromagnetic emission: radiated emission (left); conducted emission (right). A 48 V /12 V buck converter is used as the test vehicle; 3 A CFP3 rectifiers.

The impact of the lower Q_{rr} of the Trench Schottky on the efficiency of a 48V/12V switch-mode converter is shown in Figure 6. The low Q_{rr} of the Trench Schottky rectifiers results in significant converter efficiency gains, especially at high frequency where switching losses are greater.

Any ringing that occurs in the Trench rectifier during switching does not impact electromagnetic emission levels, as confirmed by conducted and radiated emission measurements shown in Figure 7.

Conclusion

In summary, Trench rectifiers are a suitable choice if a better trade-off between forward voltage drop and the leakage current is required. Trench rectifiers should also be selected in high power density applications where the ambient temperature is elevated since they are more robust against thermal runaway effects. For applications with switching speeds above 100 kHz, the reduced switching losses of the Trench devices are particularly significant.

Readers can watch the Trench Schottky technology in action presentation and speak to experts at Nexperia's online Power Live Event: 21 – 23 September www.nexperia.com/power-live

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DPG10-1500B/E	1 to 1500A	2750J
DPG10-3000B/E	3 to 3000A	2750J
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Answer: All that is needed is a clean additional positive voltage to hook up to the feedback resistor of a dc-to-dc converter. Supply voltages for electronic components have been decreasing steadily over the last few years. The reason for this is the decreasing size of the geometrical structures in digital circuits such as microcontrollers, CPUs, DSPs, and others.

By Frederik Dostal, Field Applications Engineer, Analog Devices

There are also applications in the measurement field that require low supply voltages. For many years, linear regulators and switching regulators had a feedback voltage of approximately 1.2 V. This voltage was generated with a band gap circuit in a dc-to-dc converter IC, which determined the lowest voltage that could be set with an external resistive divider. By now, most modern voltage regulator ICs can generate output voltages of 0.8 V, 0.6 V, or even 0.5 V. The internal voltage reference is designed in such a way that lower voltages are possible. Figure 1 shows such a switching regulator, the LTC3822, which generates a feedback voltage of 0.6 V with a 0.6 V voltage reference.

However, if a supply voltage of less than 0.6 V is required, the circuit in Figure 1 cannot be used without further adjustments.

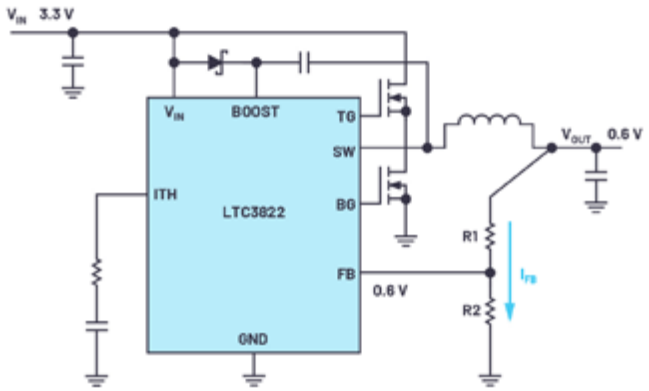


Figure 1: An LTC3822 dc-to-dc converter for generating low output voltages of 0.6 V or higher.

With a trick, you can make a switching or linear regulator also generate lower voltages than the feedback voltage. This can be achieved by using circuits like the one shown in Figure 2. It requires an additional positive supply voltage to which the resistive divider is connected for adjustment of the output voltage. This voltage can come from a low dropout (LDO) regulator or a voltage reference. The resistive divider thus forms a voltage divider in which the current flow IFB flows in a direction opposite to the normal case in Figure 1. In Figure 2, the current flows from the external reference voltage through the resistive divider to the output voltage.

Equation 1 shows the relationship between the feedback voltage of the IC (VFB), the desired output voltage (VOUT), the additional positive dc bias voltage (VOFFSET), and the resistors of the resistive divider R1 and R2.

$$\frac{V_{FB} - V_{OUT}}{V_{OFFSET} - V_{OUT}} = \frac{R1}{R1 + R2} \quad (1)$$

The recommended values for the resistive divider are a total value of R1 plus R2 of between 100 kΩ and 500 kΩ. This keeps the bias current low enough in regard to power efficiency but high enough to prevent from excessive noise coupling into the sensitive feedback path.

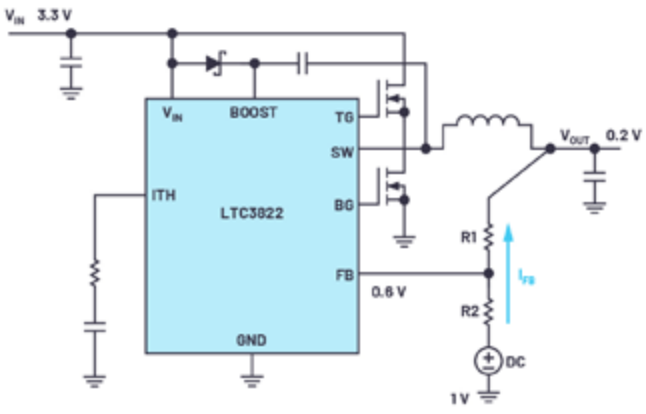


Figure 2: Circuit of Figure 1 modified to generate output voltages of less than 0.6 V.

This concept generally works well for generating voltages below the specified minimum voltage of a switching regulator or linear regulator. However, a few things should be considered. The additional voltage reference should be up and running before the dc-to-dc

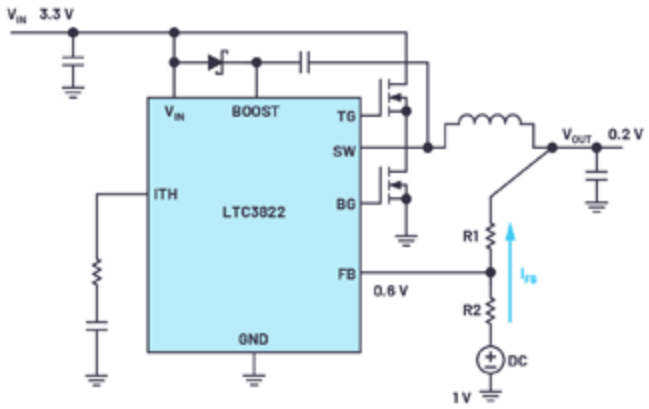


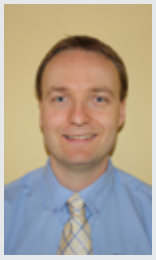
Figure 3: A simulation tool such as LTspice® from Analog Devices can be used for initial testing of the circuit.

converter is switched on. If this auxiliary voltage is at 0 V or has a high impedance, the dc-to-dc converter might generate an excessively high voltage and damage the load circuit.

In the worst-case scenario, in which the switching regulator is not yet switched on but the auxiliary voltage has already been applied, the current IFB through the resistive divider will charge the output capacitor to voltages above the set voltage. This can happen when the load has a very high impedance. It may be necessary to install a minimum load to avoid this.

The accuracy of the auxiliary voltage at the resistive divider (1 V in Figure 2) contributes directly to the accuracy of the generated supply voltage. Thus, an especially clean voltage with low ripple should be used. Additionally, not every voltage converter is suitable for this type of operation. For example, the measuring range of the current sense amplifier in a dc-to-dc converter might only provide for an operating range at higher voltages. It should also be noted that generating very low voltages at quite high input voltages requires a low duty cycle. Here, it might be helpful to choose a switching regulator IC with a short minimum on-time and to operate it at a low switching frequency.

About the Author



Frederik Dostal studied microelectronics at the University of Erlangen in Germany. Starting work in the power management business in 2001, he has been active in various applications positions including four years in Phoenix, Arizona, where he worked on switch-mode power supplies. He joined Analog Devices in 2009 and works as a field applications engineer for power management at Analog Devices in München.

For operating a linear regulator or switching regulator with lower output voltages than intended by the IC manufacturer, an initial check using a simulation tool such as LTspice from Analog Devices is useful. Figure 3 shows an LTC3822 circuit with an additional voltage source as a bias for the feedback path. In this circuit, an output voltage of 200 mV is generated. According to the data sheet, the LTC3822 is suitable for generating minimum output voltages of 0.6 V. In a circuit, the auxiliary voltage, voltage source V2 in Figure 3, could be implemented with an LDO regulator or a voltage reference. With the trick described here and thorough testing of the circuit, even lower output voltages can be generated.

www.analog.com

Integrating High Voltage Modules into Critical, Long-Term Applications

High voltage design-in process presents numerous challenges in various applications. These challenges have presented themselves through observations in the field and conversations with design engineers over the years.

By Hafiz Khalid, Director of Product Marketing, XP Power

Some of these challenges are listed below:

- Defining the high voltage module requirements
- Accuracy of high voltage power converter
- Design of the circuitry around high voltage in the application
- Ease of handling and integration in the end application

Defining the high voltage module requirements

Defining requirements is critical in the design process. Below is the list of a few things that should be considered when looking for high voltage modules.

- Input and output conditions: Understanding the input available to the high voltage module and loading conditions in the application is the first step towards getting the right solution. The input voltage along with its accuracy is important and helps define the required line regulation and protection requirements from the module. The load in most of the applications that one comes across is a hybrid of resistive and capacitive elements. So, understanding the load and loading conditions is critical in defining the voltage and current requirement for the high voltage supply.
- Voltage and current requirement: Based on what the high voltage needs to do, voltage and current along with polarity need to be defined. This mostly depends on the load specifications. For example, a Photomultiplier Tube may require 1200VDC with micro-Amps of current.
- Control and monitor signals: As most of the application in today's world are controlled by digital circuitry, understanding the signals that you have available in your application to control and monitor the high voltage module is critical for easier integration.
- Environmental conditions: Depending on the application, there may be specific environmental conditions like operating temperature, humidity etc. that need to be considered. Pay attention to where the application is going and where in the application the high voltage module resides.
- Size constraints: This corresponds to the space availability for the high voltage supply and overall application. In the small desktop and handheld applications size becomes very critical. Even in applications that require more space like semiconductor fabrication, inspection tools, and analytical instruments the focus has been to make them as small as possible to put more functionality into the same space or make space available for more new generation instruments.
- Agency approvals: This becomes critical where the end application is going into an industry segment that has certain regulatory approval requirement. For Example, UL/IEC/EN 61010 for the analytical instrument market.

Accuracy of high voltage power converter

Accuracy of the high voltage power converter is affected by other variables which may include variation in the input voltage, loading conditions, operating temperature, and other environmental factors. Below is the list of the specifications that should be considered while defining the high voltage accuracy requirement for the module.

- Output voltage tolerance: Variation from the specified voltage
- Setpoint accuracy: Ability of the supply to achieve the set point using the control voltage.
- Line and load regulation: Ability of the supply to hold the output voltage within the regulation specification based on the variation in the input voltage and the load.
- Ripple and Noise: The residual AC signal on top of the DC high voltage supply.
- Linearity of the control. Transfer function of the output voltage with respect to the control voltage
- Temperature coefficient: The change in output voltage with respect to the change in temperature per degree centigrade
- Stability over time: Ability of the high voltage supply to hold the high voltage within certain specification over a specified period while keeping other parameters constant. This becomes very critical in the applications like mass spectrometry where the instrument is kept functioning for 8 hours and expected to deliver same results if the same sample is going through. This becomes a problem if the high voltage supply is not stable enough to ensure that.

Designing the circuitry around high voltage in the application

Designing a high voltage circuit board needs extra attention to the details which are not relevant when designing a low voltage or digital circuit board. During the design in process, you may need components around the high voltage supply which becomes challenging especially on the high voltage side. There are certain specifications that become more important when working with high voltage and those are listed below along with the details that need to be taken care of during the high voltage board design.

- Proper creepage and clearance distances from low voltage circuitry
- No ground planes in the high voltage area
- Avoiding sharp edges on the pads on the circuit board
- No silk screens in the vicinity of high voltage
- No plated holes in the high voltage area
- Slots in the board if needed to provide isolation.
- Conformal coating and other insulating materials, if needed
- Key specifications and considerations of the high voltage components
- Voltage and power ratings
- Component derating
- Voltage and temperature coefficients
- Thermal performance

Ease of handling and integration in the end application

Ease of handling and ease of integration are electrical and mechanical aspects of module integration which also need to be considered. Integrating a high voltage becomes easier if the following things are already incorporated in the module that is being designed in.

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  - Control overvoltage protection protects the unit and the application from getting programmed for higher voltage than it is designed for.
- Output Protections
  - Arc protection saves the unit from arcing events in the application.
  - Overcurrent protection and short circuit protection provide safety for the module and application in case the unit is overloaded beyond the point it can optimally deliver or it sees a short circuit in the application.
- Thermal Protections
  - Thermal Shut- Down protects the module in case it undergoes a temperature range which is beyond its specified operating temperature range. Based on how this is designed, usually it recovers after the over temperature condition has been removed.

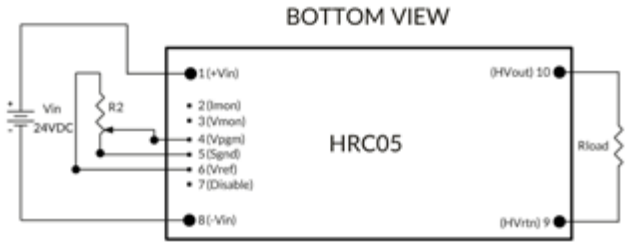

Figure 1: Diagram of the device

Control Signals

These are the signals used to control and monitor the high voltage module. The digital compatibility of the control and monitor signals is important as that defines what circuitry you will need to control the high voltage. If the signals are DAC compatible, then controlling the high voltage becomes much easier given that the module has that feature available. Measuring high voltage and load current is a challenge because of the special equipment needed as your DMM and scope probes are limited to certain voltage which usually does not go beyond 1000VDC. If the module has the digital compatible monitor signals that makes life much easier for the designer. Some of the signals and their features which comes in handy in module integration are listed below.

- Voltage Programming
- Enable/Disable Input
- Output voltage monitoring
- Load current monitoring.
- Digital compatibility of the control and monitor signals
- Repeatability of the performance

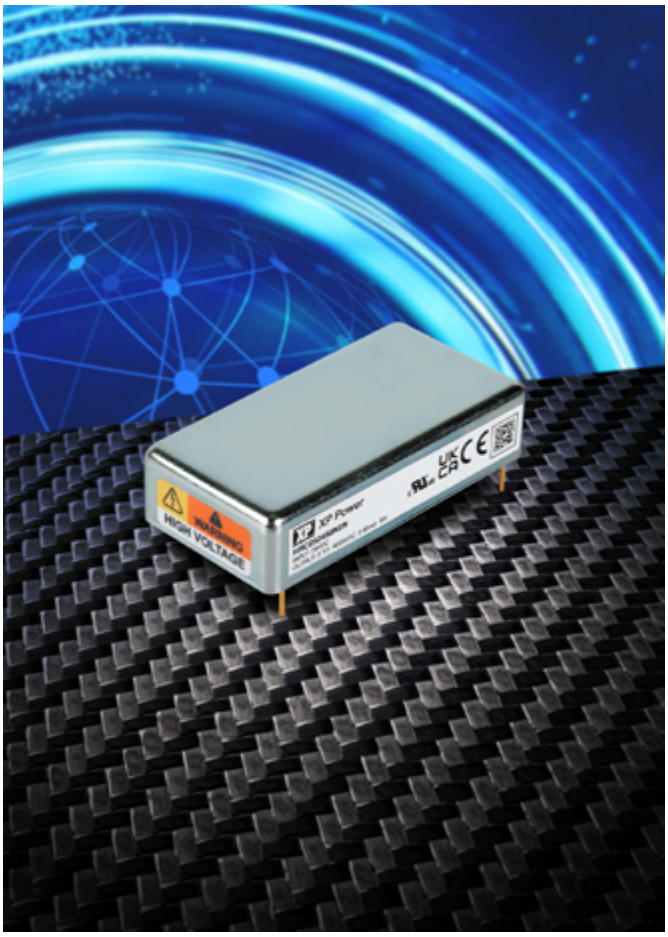

Figure 2: XP Power's HRC05 DC/DC Converter

Physical Module Integration

This corresponds to the space and physical integration of the module in the application circuitry. Following are the things that should be considered.

- Input and output connections
- Size constraints
- Mechanical Layout
  - PCB mounting
  - Chassis mounting
- Environmental considerations
- Heatsinking capability, if needed

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- Increased output power or longer lifetime
- Minimization of cavity between module and heat sink

www.infineon.com/new-sic-modules

Lineup of Chargers and Transmitters for Drones and Autonomous Mobile Robots

WiBotic introduced several chargers and transmitters for drones and autonomous mobile robots, including a passively cooled onboard charger and two transmitters that use the latest gallium nitride (GaN) technology from GaN Systems for maximum efficiency.

The OC-262 is a passively cooled onboard charger that was developed as a ruggedized system for the Department of Defense, but is now being released for wider use in response to customer demand. Passive cooling is particularly beneficial in punishing environments where water, dust, dirt and corrosion are significant concerns, and the OC-262 offers considerable benefits to customers operating in the oil and gas, mining, construction, marine exploration and agriculture industries.

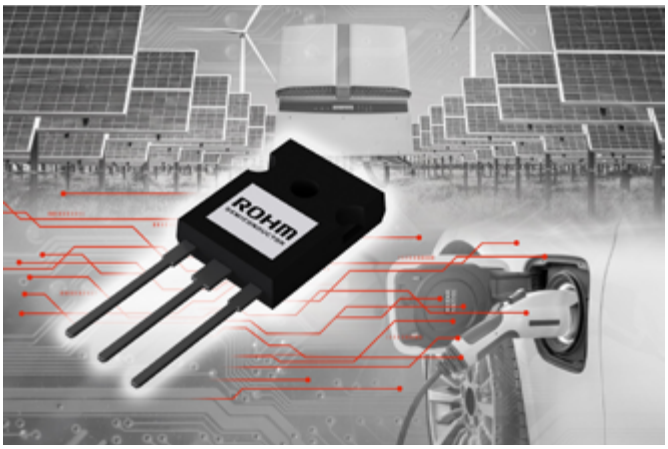
Providing up to 300W of power, the OC-262 has no moving parts, supports all common robot battery chemistries, and pairs with a weatherproof receiver antenna for a complete outdoor solution.

A compact transmitter, the TR-150 uses the latest high-efficiency GaN transistors from WiBotic partner GaN Systems. It is designed primarily for use with the new OC-150 onboard charger but supports all WiBotic OCs when deployed in diverse robot fleets. Delivering up to 150W of power, its GaN-driven power amplifier has an exemplary 95% efficiency – leading to end-to-end wireless power system efficiencies of 85% or more.

www.wibotic.com

Hybrid IGBTs with Built-In SiC Diode

ROHM developed Hybrid IGBTs with integrated 650V SiC Schottky barrier diode, the RGWxx65C series (RGW60TS65CHR, RGW80TS65CHR, RGW00TS65CHR). The devices are qualified under the AEC-Q101 automotive reliability standard. They are ideal for automotive and industrial applications that handle large power, such as photovoltaic power conditioners, onboard chargers, and DC/DC converters used in electric and electrified vehicles (xEV). The RGWxx65C series utilizes ROHM's low-loss SiC Schottky barrier diodes in the IGBT's feedback block as a freewheeling diode that has almost no recovery energy and thus minimal diode switching loss. Additionally, since the recovery current does not have to be handled by the IGBT in turn-on mode, the IGBT turn-on loss is reduced significantly. Both effects together result in up to 67% lower loss over conventional IGBTs and 24% lower loss compared with Super Junction MOSFETs (SJ MOSFETs) when used in vehicle chargers. This effect provides good cost performance while contributing to lower power consumption in industrial and automotive applications. A variety of design support materials are also available on ROHM's website, including SPICE models and application notes on drive circuit design necessary for integration and evaluation, supporting quick market introduction. ROHM is committed to continuing to contribute to minimizing environmental impact through system low power consumption and miniaturization by developing low-loss power devices that meet different needs and offering design tools as a solution.



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Heat Sinks for Power Modules

High cooling capacity with minimal pressure drop are convincing features of the new IsoMAXX cold plates from Mersen. The cold plates meet the high demands of modern power electronics and have been specially developed for the latest SiC, GaN or IGBT power modules.

Modern converters, transport systems, electric vehicles and alternative energy generators benefit from the increasingly efficient wide bandgap electronics, which are optimised for operation at higher switching frequencies and temperatures and feature a much more compact design. Conventional heat sinks cannot meet these high cooling requirements. That is why Mersen developed IsoMAXX – a revolutionary vacuum brazed cold plate with unique features: The average thermal resistance (Rth) is 6 °C/kW. And at ~600 mbar, the pressure drop is substantially lower than that of all previous models. IsoMAXX cold plates ensure an optimal temperature range for power electronics, in which all single chips and modules on the cold plate remain at the same temperature. IsoMAXX helps development engineers to design solutions with increased efficiency and a minimal footprint: No minimum clearance is required between modules, which allows versatile integration regardless of the number of modules needed for the particular application.

www.ep-de.mersen.com

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Comprising GaN Power FET with Monolithically Integrated Driver

Tagore Technology announces the introduction of the TP44200NM 650V Gallium Nitride Power FET with integrated driver IC in a compact 22 pin, 5mm x 7mm QFN package. The device offers low RDS(ON) of 180mOhm and fast switching to deliver a highly efficient, low-cost power solution in a small footprint for a variety of applications requiring high power density including USB-PD charger, server and telecom AC-DC power supplies, power factor correction (PFC) converter. The TP44200NM Power IC has 650V E-mode GaN Power FET, driver, UVLO and high dv/dt immunity with and without supply - all monolithically integrated on GaN-on-Si substrate. The device has low propagation delay for high frequency application and slew rate control through external resistor.

www.tagoretech.com

Fast Recovery Epitaxial Diodes

Taiwan Semiconductor announces the availability of the PU1xMx / PU2xMx families of fast recovery epitaxial diodes. These high-reliability (AEC-Q101 qualified) FREDs offer optimized switching speed vs. reverse recovery time. Their soft reverse recovery results in lower noise switching while achieving low losses and increased efficiency. The Micro SMA package heat spreader contacts provide excellent heat transfer. "TSC's FRED devices offer an unparalleled combination of small footprint, fast switching speed, low parasitic capacitance and low leakage," said Vice President, TSC Products, Sam Wang. "In terms of price, performance and package, our FREDs set a new benchmark for the industry." Applications include automotive alternator charging regulators in 12-, 24 to 28- and 48-Volt systems; POE power, protection and blocking circuitry; general purpose switching power, snubber circuits, antiparallel diodes in high frequency switching circuits; freewheeling diode in converters, chargers and motor control circuits.

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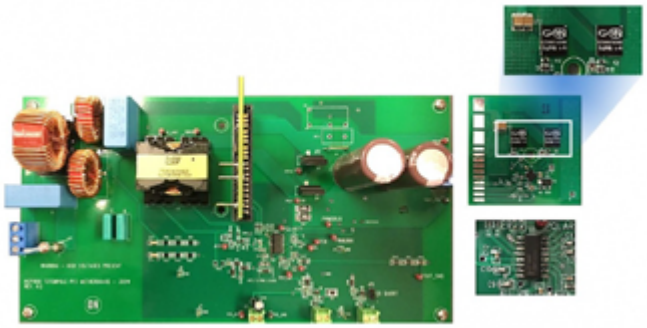
Gallium Nitride Power Device for Demanding Space Applications

EPC Space announces the introduction of EPC7014UB, a 60 V radiation-hardened gallium nitride transistor. Utilizing GaN technology, the EPC7014UB outperforms RH silicon-based devices as it offers higher breakdown strength, faster switching speed, and lower on-resistance, than other RH power devices. Lower resistance and gate charge enable faster power supply switching frequencies resulting in higher power densities, higher efficiencies, and more compact and lighter weight circuitry for critical spaceborne missions. Applications benefiting from the performance of these products include power supplies for satellites and space mission equipment, light detection and ranging (lidar) for robotics and autonomous navigation and rendezvous docking, motor drives for robotics, instrumentation and reaction wheels, and ion thrusters for satellite orientation and positioning, as well as interplanetary propulsion of low-mass robotic vehicles. Additionally, the EPC7014UB can be used as a gate driver interface between CMOS or TTL control circuits and power devices in a radiation hardened environment. The EPC7014UB, is a 60 V, 580 mΩ, 4 APulsed, rad-hard eGaN FET in an industry standard UB package. The EPC7014UB has a total dose rating greater than 1 Mrad and SEE immunity for LET of 85 MeV/(mg/cm2). These devices are also offered in a chip-scale package from EPC. "GaN technology enables a new generation of power conversion and motor drives in space operating at higher frequencies, higher efficiencies, lower cost, and greater power densities than achievable with rad hard silicon" said Bel Lazar, CEO of EPC Space. "We are excited about this technology's ability to provide mission-critical components for the space and other high-reliability markets".

www.epc.space

Bridgeless Totem Pole PFC Evaluation Board Chip PMIC Solution

GaN Systems and onsemi released a 300W BTP-PFC Bridgeless Totem Pole Power Factor Correction (PFC) evaluation board. The board includes onsemi's NCP1680, a dedicated critical conduction mode (CrM) bridgeless totem pole PFC controller, and GaN Systems' 650V GS66508B GaN transistors. The NCP1680 controller and GS66508B transistors combine to deliver an innovative cost-effective and high-performing solution in a small footprint. The solution enables power engineers to evaluate GaN and capitalize on its benefits in improving power system performance. GaN Systems' GS66508B is a 650V, 30A transistor that provides low-loss, high switching frequency, zero reverse recovery, and very low junction-to-case thermal resistance. The evaluation board allows rapid development of advanced totem pole PFC designs and ideal in various power supply applications for the data center, telecom, industrial, and consumer industries.



On the controller side, this Bridgeless Totem Pole PFC solution leverages the NCP1680, which offers unique features for operation under light load conditions, digital voltage loop compensation, and near unity power factor in all operating modes. Altogether, the solution achieves near 99% efficiency, simplifies design, and reduces bill-of-material count and cost.

"Leaders like onsemi recognize the importance of GaN and are optimizing controllers and creating complementary tools like the new 300W PFC evaluation board we introduced today. These solutions strengthen the GaN industry ecosystem in the goal to make better performing and more cost-effective power electronics," said Jim Witham, CEO at GaN Systems.

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